SCHEME AND SYLLABUS

of

NEP-2020

for

4-Years UG Programme in Chemistry

(To be implemented from Session 2023-2024)

DEPARTMENT OF CHEMISTRY

SCHOOL OF PHYSICAL SCIENCES

GURU GHASIDAS VISHWAVIDYALAYA, BILASPUR, CHHATTISGARH

DEPARTMENT OF CHEMISTRY

GURU GHASIDAS VISHWAVIDYALAYA, BILASPUR, CHHATTISGARH

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

Program Outcomes (PO):

PO1: Core Competency: The chemistry graduates are expected to know the fundamental concepts of chemistry and applied chemistry. These fundamental concepts would reflect the latest understanding of the field, and therefore, are dynamic in nature and require frequent and time-bound revisions.

PO2: Communication Skills: Chemistry graduates are expected to possess a minimum standard of communication skills expected of science graduates in the country. They are expected to read and understand documents with in-depth analyses and logical arguments. Graduates are expected to be well-versed in speaking and communicating their ideas/findings/concepts to a wider audience.

PO3: Critical Thinking and Analytical Reasoning: Chemistry graduates are expected to know the basics of cognitive biases, mental models, logical fallacies, scientific methodology, and constructing cogent scientific arguments. Additionally, they are expected to learn how to create persuasive arguments and identify logical errors, contradictions, circular reasoning, etc.

PO4: Psychological Skills: Graduates are expected to possess basic psychological skills required to face the world at large, as well as the skills to deal with individuals and students of various sociocultural, economic, and educational levels. Psychological skills may include feedback loops, self-compassion, self-reflection, goal-setting, interpersonal relationships, and emotional management.

PO5: Problem-Solving: Graduates are expected to be equipped with problem-solving philosophical approaches that are pertinent across the disciplines.

PO6: Research Skills: Graduates are expected to be keenly observant about what is going on in the natural surroundings to awaken their curiosity. Graduates are expected to design a scientific experiment through statistical hypothesis testing and other *a priori* reasoning, including logical deduction.

PO7: Teamwork and Leadership Readiness: Graduates are expected to be team players, with productive cooperation involving members from diverse sociocultural backgrounds. Alongside this, graduates are likely to be familiar with the decision-making process and have basic managerial skills to become better leaders. Skills may include defining objective vision and mission, how to become a charismatic, inspiring leader, and so on.

PO8: Digital Literacy and Lifelong Learning: Graduates are expected to be digitally literate to enroll and increase their core competency via e-learning resources such as MOOCs and other digital tools for lifelong learning. Graduates should be able to spot data fabrication and fake news by applying rational skepticism and analytical reasoning.

PO9: **Moral and Ethical Awareness:** Graduates are expected to be responsible citizens of India and be aware of the country's and the world's moral and ethical baseline. They are expected to define their core ethical virtues well enough to distinguish what is considered illegal and criminal in the Indian Constitution. Emphasis is given to academic and research ethics, including fair benefit sharing, plagiarism, scientific misconduct, and so on.

Program Specific Outcomes (PSO)

PSO1: Students will be able to explain fundamental knowledge of chemistry.

PSO2: To opt for higher education, disciplinary & multidisciplinary research, and to be a lifelong learner.

PSO3: Students will be able to identify chemical formulas and solve numerical problems**.**

PSO4: To provide professional services to industry, research organizations, and institutes.

PSO5: Students will be able to understand good laboratory practices and safety.

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

(to be implemented from 2023-2024)

SEMESTER-I

Sem.	Courses	Course Code	Name of the Courses	Level	Credits	Credits (L+T+P)	Int. Marks	Ext. Marks	Total	Nature of Course
I	Major	CYUAMJT1	Basic Concepts of Chemistry-I	2	3	(3+0+0)	30	70	100	Compulsory
		CYUAMJL1	Basic Concepts of Chemistry-I (Lab)		1	(0+0+1)	30	70	100	Compulsory
	Minor		Opted from the pool of courses offered by Vishwavidyalaya	2	4					Elective
	MDC		Opted from the pool of courses offered by Vishwavidyalaya	1	3					Elective
	AEC		Opted from the pool of courses offered by Vishwavidyalaya	1	2	(2+0+0)	30	70	100	Elective
	SEC		Opted from the pool of courses offered by Vishwavidyalaya	1	3					Elective
	VAC-I		Opted from the pool of courses offered by Vishwavidyalaya	1	2	(2+0+0)	30	70	100	Elective
	VAC-II		Opted from the pool of courses offered by Vishwavidyalaya	1	2	(2+0+0)	30	70	100	Elective
Total Credits					**20**					

MDC: Multidisciplinary Course
AEC: Ability Enhancement Course
SEC: Skills Enhancement Course
VAC: Value Added Course

L: Lectures
T: Tutorials
P: Practicals

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

(to be implemented from 2023-2024)

SEMESTER-II

Sem.	Courses	Course Code	Name of the Courses	Level	Credits	Credits (L+T+P)	Int. Marks	Ext. Marks	Total	Nature of Course
II	Major	CYUBMJT1	Basic Concepts of Chemistry-II	2	3	(3+0+0)	30	70	100	Compulsory
		CYUBMJL1	Basic Concepts of Chemistry-II (Lab)		1	(0+0+1)	30	70	100	Compulsory
	Minor Or VOC		Opted from the pool of courses offered by Vishwavidyalaya	2	4					Elective
	MDC		Opted from the pool of courses offered by Vishwavidyalaya	1	3					Elective
	AEC		Opted from the pool of courses offered by Vishwavidyalaya	1	2	(2+0+0)	30	70	100	Elective
	SEC		Opted from the pool of courses offered by Vishwavidyalaya	1	3					Elective
	VAC-I		Opted from the pool of courses offered by Vishwavidyalaya	1	2	(2+0+0)	30	70	100	Elective
	VAC-II		Opted from the pool of courses offered by Vishwavidyalaya	1	2	(2+0+0)	30	70	100	Elective
Total Credits					**20**					

MDC: Multidisciplinary Course
AEC: Ability Enhancement Course
SEC: Skills Enhancement Course
VAC: Value Added Course
VOC: Vocational Course

L: Lectures
T: Tutorials
P: Practicals

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

(to be implemented from 2023-2024)

SEMESTER-III

Sem.	Courses	Course Code	Name of the Courses	Level	Credits	Credits (L+T+P)	Int. Marks	Ext. Marks	Total	Nature of Course*
III	Major-I	CYUCMJT1	Basic Concepts of Chemistry-III	3	3	(3+0+0)	30	70	100	Compulsory
		CYUCMJL1	Basic Concepts of Chemistry-III (Lab)		1	(0+0+1)	30	70	100	Compulsory
	Major-II	CYUCMJT2	Basic Concepts of Chemistry-IV	3	3	(3+0+0)	30	70	100	Compulsory
		CYUCMJL2	Basic Concepts of Chemistry-IV (Lab)		1	(0+0+1)	30	70	100	Compulsory
	Minor Or VOC		Opted from the pool of courses offered by Vishwavidyalaya	3	4					Elective
	MDC		Opted from the pool of courses offered by Vishwavidyalaya	1	3					Elective
	AEC		Opted from the pool of courses offered by Vishwavidyalaya	1	2	(2+0+0)	30	70	100	Elective
	SEC		Opted from the pool of courses offered by Vishwavidyalaya	1	3					Elective
Total Credits					**20**					

***The course (compulsory/elective) may be substituted with another online course in the same category.**

MDC: Multidisciplinary Course
AEC: Ability Enhancement Course
SEC: Skills Enhancement Course
VOC: Vocational Course

L: Lectures
T: Tutorials
P: Practicals

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

(to be implemented from 2023-2024)

SEMESTER-IV

Sem.	Courses	Course Code	Name of the Courses	Level	Credits	Credits (L+T+P)	Int. Marks	Ext. Marks	Total	Nature of Course*
IV	Major-I	CYUDMJT1	Inorganic Chemistry-I	3	4	(4+0+0)	30	70	100	Compulsory
		CYUDMJL1	Inorganic Chemistry-I (Lab)		1	(0+0+1)	30	70	100	Compulsory
	Major-II	CYUDMJT2	Organic Chemistry-I	3	4	(4+0+0)	30	70	100	Compulsory
		CYUDMJL2	Organic Chemistry-I (Lab)		1	(0+0+1)	30	70	100	Compulsory
	Major-III	CYUDMJT3	Physical Chemistry-I	3	3	(3+0+0)	30	70	100	Compulsory
		CYUDMJL3	Physical Chemistry-I (Lab)		1	(0+0+1)	30	70	100	Compulsory
	Minor Or VOC		Opted from the pool of courses offered by Vishwavidyalaya	3	4					Elective
	AEC		Opted from the pool of courses offered by Vishwavidyalaya	1	2	(2+0+0)	30	70	100	Elective
				Total Credits	**20**					

***The course (compulsory/elective) may be substituted with another online course in the same category.**

AEC: Ability Enhancement Course

VOC: Vocational Course

L: Lectures

T: Tutorials

P: Practicals

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

(to be implemented from 2023-2024)

SEMESTER-V

Sem.	Courses	Course Code	Name of the Courses	Level	Credits	Credits (L+T+P)	Int. Marks	Ext. Marks	Total	Nature of Course*
V	Major-I	CYUEMJT1	Inorganic Chemistry-II	4	4	(4+0+0)	30	70	100	Compulsory
		CYUEMJL1	Inorganic Chemistry-II (Lab)		1	(0+0+1)	30	70	100	Compulsory
	Major-II	CYUEMJT2	Organic Chemistry-II	4	4	(4+0+0)	30	70	100	Compulsory
		CYUEMJL2	Organic Chemistry-II (Lab)		1	(0+0+1)	30	70	100	Compulsory
	Major-III	CYUEMJT3	Physical Chemistry-II	4	4	(4+0+0)	30	70	100	Compulsory
		CYUEMJL3	Physical Chemistry-II (Lab)		1	(0+0+1)	30	70	100	Compulsory
	Minor Or VOC		Opted from the pool of courses offered by Vishwavidyalaya	4	4					Elective
	Internship	INTUE01	Internship		2	(0+0+2)	30	70	100	Compulsory
				Total Credits	**21**					

***The course (compulsory/elective) may be substituted with another online course in the same category.**

L: Lectures **T:** Tutorials **P:** Practicals

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

(to be implemented from 2023-2024)

SEMESTER-VI

Sem.	Courses	Course Code	Name of the Courses	Level	Credits	Credits (L+T+P)	Int. Marks	Ext. Marks	Total	Nature of Course*
VI	Major-I	CYUFMJT1	Advanced Inorganic Chemistry-I	4	4	(4+0+0)	30	70	100	Compulsory
		CYUFMJL1	Advanced Inorganic Chemistry-I (Lab)		1	(0+0+1)	30	70	100	Compulsory
	Major-II	CYUFMJT2	Advanced Organic Chemistry	4	4	(4+0+0)	30	70	100	Compulsory
		CYUFMJL2	Advanced Organic Chemistry (Lab)		1	(0+0+1)	30	70	100	Compulsory
	Major-III	CYUFMJT3	Advanced Physical Chemistry	4	4	(4+0+0)	30	70	100	Compulsory
		CYUFMJL3	Advanced Physical Chemistry (Lab)		1	(0+0+1)	30	70	100	Compulsory
	Minor Or VOC		Opted from the pool of courses offered by Vishwavidyalaya	4	4					Elective
Total Credits					**19**					

***The course (compulsory/elective) may be substituted with another online course in the same category.**

L: Lectures **T:** Tutorials **P:** Practicals

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

(to be implemented from 2023-2024)

SEMESTER-VII (Honors with Research)

Sem.	Courses	Course Code	Name of the Courses	Level	Credits	Credits (L+T+P)	Int. Marks	Ext. Marks	Total	Nature of Course*
VII (Honors with Research)	Major-I	CYUGMJT1	Advanced Inorganic Chemistry-II	5	4	(4+0+0)	30	70	100	Compulsory
		CYUGMJL1	Advanced Inorganic Chemistry-II (Lab)		1	(0+0+1)	30	70	100	Compulsory
	Major-II	CYUGMJT2	Fundamentals of Molecular Spectroscopy	5	5	(4+1+0)	30	70	100	Compulsory
	Major-III	CYUGMJT3	Analytical Chemistry	5	4	(4+0+0)	30	70	100	Compulsory
		CYUGMJL3	Analytical Chemistry (Lab)		1	(0+0+1)	30	70	100	Compulsory
	Minor		Opted from the pool of courses offered by Vishwavidyalaya	5	4					Elective
				Total Credits	**19**					

***The course (compulsory/elective) may be substituted with another online course in the same category.**

L: Lectures **T:** Tutorials **P:** Practicals

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

(to be implemented from 2023-2024)

SEMESTER-VIII (Honors with Research)

Sem.	Courses	Course Code	Name of the Courses	Level	Credits	Credits (L+T+P)	Int. Marks	Ext. Marks	Total	Nature of Course*
VIII (Hon. with Research)	Major	CYUHMJT#	Opted from the pool of courses offered by the Department of Chemistry	5	5					**Compulsory (Chemistry Departmental Optional)**
	Minor		Opted from the pool of courses offered by Vishwavidyalaya	5	4					Elective
	Research Project/ Dissertation	RSPCYUH1	Students will complete a research project under the supervision of an assigned supervisor.		12	(0+0+12)	30	70	100	Compulsory
				Total Credits	**21**					

#Number will be given by pool of courses offered by the Department.
***The availability of the course coordinator and student enrollment will determine whether or not the suggested optional courses will be offered.**
The course (compulsory/elective) may be substituted with another online course in the same category.

L: Lectures **T:** Tutorials **P:** Practicals

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

(to be implemented from 2023-2024)

SEMESTER-VII (Honors)

Sem.	Courses	Course Code	Name of the Courses	Level	Credits	Credits (L+T+P)	Int. Marks	Ext. Marks	Total	Nature of Course*
VII (Hon.)	Major-I	CYUGMJT1	Advanced Inorganic Chemistry-II	5	4	(4+0+0)	30	70	100	Compulsory
		CYUGMJL1	Advanced Inorganic Chemistry-II (Lab)		1	(0+0+1)	30	70	100	Compulsory
	Major-II	CYUGMJT2	Fundamentals of Molecular Spectroscopy	5	5	(4+1+0)	30	70	100	Compulsory
	Major-III	CYUGMJT3	Analytical Chemistry	5	4	(4+0+0)	30	70	100	Compulsory
		CYUGMJL3	Analytical Chemistry (Lab)		1	(0+0+1)	30	70	100	Compulsory
	Minor		Opted from the pool of courses offered by Vishwavidyalaya	5	4					Elective
	Seminar	SEMCYUG1	Students will prepare a ppt presentation for the seminar according to their chosen topic.		1		30	70	100	Compulsory
Total Credits					**20**					

***The course (compulsory/elective) may be substituted with another online course in the same category.**

L: Lectures **T:** Tutorials **P:** Practicals

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

(to be implemented from 2023-2024)

SEMESTER-VIII (Honors)

Sem.	Courses	Course Code	Name of the Courses	Level	Credits	Credits (L+T+P)	Int. Marks	Ext. Marks	Total	Nature of Course*
VIII (Hon.)	Major-I	CYUHMJT1	Advanced Spectroscopy for Structural Determination	5	5	(4+1+0)	30	70	100	Compulsory
	Major-II	CYUHMJT#	Opted from the pool of courses offered by the Department of Chemistry	5	5					**Compulsory (Chemistry Departmental Optional)**
	Minor-I		Opted from the pool of courses offered by Vishwavidyalaya	5	4					Elective
	Minor-II		Opted from the pool of courses offered by Vishwavidyalaya	5	4					Elective
	Seminar	SEMCYUH1	Students will prepare a ppt presentation for the seminar according to their chosen topic.		2	(0+0+2)	30	70	100	Compulsory
				Total Credits	**20**					

#Number will be given by pool of courses offered by the Department.
***The availability of the course coordinator and student enrollment will determine whether or not the suggested optional courses will be offered.**
The course (compulsory/elective) may be substituted with another online course in the same category.

L: Lectures **T:** Tutorials **P:** Practicals

Courses Structure Under NEP-2020

4-Years B.Sc.-Chemistry

Chemistry Major Courses

Sem.	Courses	Course Code	Name of the Courses	Credits (L+T+P)
I	Major	CYUAMJT1	Basic Concepts of Chemistry-I	(3+0+0)
		CYUAMJL1	Basic Concepts of Chemistry-I (Lab)	(0+0+1)
II	Major	CYUBMJT1	Basic Concepts of Chemistry-II	(3+0+0)
		CYUBMJL1	Basic Concepts of Chemistry-II (Lab)	(0+0+1)
III	Major-I	CYUCMJT1	Basic Concepts of Chemistry-III	(3+0+0)
		CYUCMJL1	Basic Concepts of Chemistry-III (Lab)	(0+0+1)
	Major-II	CYUCMJT2	Basic Concepts of Chemistry-IV	(3+0+0)
		CYUCMJL2	Basic Concepts of Chemistry-IV (Lab)	(0+0+1)
IV	Major-I	CYUDMJT1	Inorganic Chemistry-I	(4+0+0)
		CYUDMJL1	Inorganic Chemistry-I (Lab)	(0+0+1)
	Major-II	CYUDMJT2	Organic Chemistry-I	(4+0+0)
		CYUDMJL2	Organic Chemistry-I (Lab)	(0+0+1)
	Major-III	CYUDMJT3	Physical Chemistry-I	(3+0+0)
		CYUDMJL3	Physical Chemistry-I (Lab)	(0+0+1)
V	Major-I	CYUEMJT1	Inorganic Chemistry-II	(4+0+0)
		CYUEMJL1	Inorganic Chemistry-II (Lab)	(0+0+1)
	Major-II	CYUEMJT2	Organic Chemistry-II	(4+0+0)
		CYUEMJL2	Organic Chemistry-II (Lab)	(0+0+1)
	Major-III	CYUEMJT3	Physical Chemistry-II	(4+0+0)
		CYUEMJL3	Physical Chemistry-II (Lab)	(0+0+1)
VI	Major-I	CYUFMJT1	Advanced Inorganic Chemistry-I	(4+0+0)
		CYUFMJL1	Advanced Inorganic Chemistry-I (Lab)	(0+0+1)
	Major-II	CYUFMJT2	Advanced Organic Chemistry	(4+0+0)
		CYUFMJL2	Advanced Organic Chemistry (Lab)	(0+0+1)
	Major-III	CYUFMJT3	Advanced Physical Chemistry	(4+0+0)
		CYUFMJL3	Advanced Physical Chemistry (Lab)	(0+0+1)
VII	Major-I	CYUGMJT1	Advanced Inorganic Chemistry-II	(4+0+0)
		CYUGMJL1	Advanced Inorganic Chemistry-II (Lab)	(0+0+1)
	Major-II	CYUGMJT2	Fundamentals of Molecular Spectroscopy	(4+1+0)
	Major-III	CYUGMJT3	Analytical Chemistry	(4+0+0)
		CYUGMJL3	Analytical Chemistry (Lab)	(0+0+1)
VIII	Major	CYUHMJT1	Advanced Spectroscopy for Structural Determination	(4+1+0)

Course Structure Under NEP-2020 4-Years B.Sc.-Chemistry Chemistry Major Courses (Optional)				
Sem.	**Courses**	**Course Code**	**Name of the Courses**	**Credits (L+T+P)**
VIII	Major	CYUHMJT2	Introduction to Nanomaterials and Nanotechnology	(4+0+0)
		CYUHMJL2	Introduction to Nanomaterials and Nanotechnology (Lab)	(0+0+1)
	Major	CYUHMJT3	Modern Physical Methods in Chemistry Research	(4+1+0)
	Major	CYUHMJT4	Principles of X-ray Diffraction and Electron Microscope	(4+1+0)
	Major	CYUHMJT5	Supramolecular Chemistry	(4+1+0)
	Major	CYUHMJT6	Self-Assembly and Supramolecular Architectures	(4+0+0)
		CYUHMJL6	Self-Assembly and Supramolecular Architectures (Lab)	(0+0+1)
	Major	CYUHMJT7	Photo-Organic chemistry	(4+0+0)
		CYUHMJL7	Photo-Organic Chemistry (Lab)	(0+0+1)
	Major	CYUHMJT8	Homogeneous and Heterogeneous Catalysis: Lab to Industry	(4+0+0)
		CYUHMJL8	Homogeneous and Heterogeneous Catalysis: Lab to Industry (Lab)	(0+0+1)
	Major	CYUHMJT9	Polymer Science and Technology	(4+0+0)
		CYUHMJL9	Polymer Science and Technology (Lab)	(0+0+1)
	Major	CYUHMJL10	Heterocyclic Chemistry	(4+1+0)
	Major	CYUHMJL11	Inorganic Materials Chemistry	(4+1+0)

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

Chemistry Minor Courses

Sem.	Courses	Course Code	Name of the Courses	Credits (L+T+P)
I	Minor	CYUAMNT1	Fundamental Chemistry-I	(3+0+0)
		CYUAMNL1	Fundamental Chemistry-I (Lab)	(0+0+1)
II	Minor	CYUBMNT1	Fundamental Chemistry-II	(3+0+0)
		CYUBMNL1	Fundamental Chemistry-II (Lab)	(0+0+1)
III	Minor	CYUCMNT1	Fundamental Chemistry-III	(3+0+0)
		CYUCMNL1	Fundamental Chemistry-III (Lab)	(0+0+1)
IV	Minor	CYUDMNT1	Fundamental Chemistry-IV	(3+0+0)
		CYUDMNL1	Fundamental Chemistry-IV (Lab)	(0+0+1)
V	Minor	CYUEMNT1	Fundamental Chemistry-V	(3+0+0)
		CYUEMNL1	Fundamental Chemistry-V (Lab)	(0+0+1)
VI	Minor	CYUFMNT1	Fundamentals of Spectroscopy	(3+0+0)
		CYUFMNL1	Fundamentals of Spectroscopy (Lab)	(0+0+1)
VII	Minor	CYUGMNT1	Nanomaterials: Synthesis, Characterization, and Applications	(3+0+0)
		CYUGMNL1	Nanomaterials: Synthesis, Characterization, and Applications (Lab)	(0+0+1)
VIII	Minor-I	CYUHMNT1	Instrumental Methods of Analysis	(3+1+0)
	Minor-II	CYUHMNT2	Introduction of Bioorganic Chemistry	(3+0+0)
		CYUHMNL2	Introduction of Bioorganic Chemistry (Lab)	(0+0+1)

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

Multidisciplinary Courses (MDC)

Sem.	Courses	Course Code	Name of the Courses	Credits (L+T+P)
I/II/III	MDC		Conceptual Understanding of Physical Science-I	(2+1+0)
I/II/III	MDC	MDCCY01	Chemistry in Everyday Life	(2+1+0)
I/II/III	MDC	MDCCY02	Good Laboratory Practices	(3+0+0)
I/II/III	MDC	MDCCY03	Chemistry of Food Nutrition and Preservation	(2+1+0)

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

Skills Enhancement Course (SEC)

Sem.	Courses	Course Code	Name of the Courses	Credits (L+T+P)
I/II/III	SEC	SECCY01	Science Communication and Popularization	(2+1+0)
I/II/III	SEC	SECCY02	Fermentation Science and Technology	(3+0+0)
I/II/III	SEC	SECCY03	Environmental Impact Analysis	(2+1+0)

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

Value Added Course (VAC)

Sem.	Courses	Course Code	Name of the Courses	Credits (L+T+P)
I/II	VAC	VACCY01	Efficient Technologies for Food Processing and Shelf-Life Extension	(2+0+0)
I/II	VAC	VACCY02	Polymer Chemistry	(2+0+0)
I/II	VAC	VACCY03	Ancient Indian Chemistry in Modern Perspective	(2+0+0)

Course Structure Under NEP-2020 4-Years B.Sc.-Chemistry Vocational Course (VOC)				
Sem.	**Courses**	**Course Code**	**Name of the Courses**	**Credits (L+T+P)**
II/III/IV/V/VI	VOC	VOCCYT01	Green Water Technology	(1+0+0)
		VOCCYL01	Green Water Technology (Lab)	(0+0+3)
II/III/IV/V/VI	VOC	VOCCYT02	Cement Chemistry	(1+0+0)
		VOCCYL02	Cement Chemistry Practical	(0+0+3)
II/III/IV/V/VI	VOC	VOCCYT03	Drug Discovery and Pharmaceutical Chemistry	(1+0+0)
		VOCCYL03	Drug Discovery and Pharmaceutical Chemistry (Lab)	(0+0+3)

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

Online Courses

Sem.	Courses	Course Code	Name of the Courses	Level	Credits	Credits (L+T+P)	Int. Marks	Ext. Marks	Total
III Jul-25	**Online (SWAYAM)**	CYUCMJT3M	MOOC_Introductory Organic Chemistry II - Course	3	2	(2+0+0)	30	70	100
	Offline	CYUCMJL3	Introductory Organic Chemistry II (Lab) (Offline)	3	2	(0+1+1)	30	70	100
V Jul-25	**Online (SWAYAM)**	CYUEMJT1M	MOOC_Advanced Transition Metal Chemistry - Course	4	3	(3+0+0)	30	70	100
	Offline	CYUEMJL01	Advanced Transition Metal Chemistry (Lab)	4	2	(0+1+1)	30	70	100

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

Chemistry Major Courses

Semester	Nature of Course	Course Code	Name of the course	Credits
I	Major (Level 2)	CYUAMJT1	Basic Concepts in Chemistry-I	Theory 3 (45 Lectures)
		CYUAMJL1	Basic Concepts in Chemistry-I (Lab)	Practical: 1 (30 Hours)

CYUAMJT1: Basic Concepts in Chemistry-I

Level 2, Credit 3 (45 Lectures)

Course Outcomes:

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

1. Understand the atomic structure of an atom, quantum numbers, etc.
2. Know the ionic, covalent, and metallic bonds.
3. Understand aliphatic and aromatic compounds and their nomenclatures
4. Understand reaction intermediates and their characteristics.
5. Know the gaseous state of matter, deviation from ideal behaviours, and distribution laws of molecular velocities of gases.
6. Understand the basic knowledge of liquid and solid states of matter.

Inorganic Chemistry

Unit – I: Atomic Structure

Bohr's theory, its limitations and atomic spectrum of hydrogen atom. Wave mechanics: de' Broglie equation, Heisenberg's Uncertainty Principle and its significance, Schrödinger's wave equation, significance of ψ and ψ^2. Quantum numbers and their significance. Normalized and orthogonal wave functions. Sign of wave functions. Radial and angular wave functions for hydrogen atom. Radial and angular distribution curves. Shapes of s, p, d, and f orbitals. Contour boundary and probability diagrams. Variation of orbital energy with atomic number.

(6 Lectures)

Unit – II: Chemical Bonding

(i) Ionic bond: General characteristics, radius ratio rule and its limitations. Born-Landé equation with derivation, expression for lattice energy. Born-Haber cycle and its application.

(ii) Covalent bond: Valence Bond theory, (Heitler-London approach). Hybridization containing s, p and s, p, d atomic orbitals, shapes of hybrid orbitals, Bents rule, Molecular orbital theory. Molecular orbital diagrams of simple homonuclear and heteronuclear diatomic molecules, e.g., N_2, O_2, C_2, B_2, F_2, CO, NO, and their ions; HCl, BeF_2, CO_2. Covalent character in ionic compounds, polarizing power and polarizability. Fajan rules, polarization. Ionic character in covalent compounds: Bond moment and dipole moment. Ionic character from dipole moment and electronegativities.

(iii) Metallic Bond: Qualitative idea of free electron model, Semiconductors, Insulators.

(9 Lectures)

Organic Chemistry

Unit – III: Basics of Organic Chemistry

Organic Compounds: Classification, and Nomenclature, Hybridization, Shapes of molecules, Influence of hybridization on bond properties. Electronic Displacements: Inductive, electromeric, resonance and mesomeric effects, hyperconjugation and their applications; Dipole moment; Organic acids and bases; their relative strength. Aromaticity: Huckel's rule, aromatic character of arenes, cyclic carbocations/carbanions and heterocyclic compounds with suitable examples.

(7 Lectures)

Unit – IV: Reactive Organic Species and Reaction Intermediates

Homolytic and Heterolytic fission with suitable examples. Curly arrow rules, formal charges; Electrophiles and Nucleophiles; Nucleophlicity and basicity; types, shape and relative stabilities of reaction intermediates (Carbocations, Carbanions, Free radicals and Carbenes). Organic reactions and their mechanism: Addition, Elimination and Substitution reactions.

(8 Lectures)

Physical Chemistry

Unit – V: Gaseous State

Postulates of Kinetic Theory of Gases and derivation of the kinetic gas equation.

Behavior of real gases: Deviations from ideal gas behavior, compressibility factor. Causes of deviation from ideal behavior: van der Waals equation of state, its derivation and application in explaining real gas behavior, van der Waals equation expressed in virial form, and calculation of Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, the relation between critical constants and van der Waals constants, and law of corresponding states.

Maxwell-Boltzmann's distribution laws of molecular velocity and molecular energies (graphic representation – derivation not required) and its use in evaluating molecular velocities, law of equipartition of energy, degrees of freedom and molecular basis of heat capacities.

Collision frequency, collision diameter, and mean free path; viscosity of gases; calculation of collision diameter from coefficient of viscosity; variation of viscosity with temperature and pressure.

(8 Lectures)

Unit – VI: Liquid and Solid States

Qualitative treatment of the structure of the liquid state, Radial distribution function, physical properties of liquids, vapor pressure, surface tension, and coefficient of viscosity and their determination. Temperature variation of the viscosity of liquids and comparison with that of gases. Qualitative discussion of the structure of water.

Nature of the solid state, definition of space lattice, unit cell; laws of crystallography – (i) law of constancy of interfacial angles, (ii) law of rational indices (Miller indices) and, (iii) law of symmetry, elementary ideas of symmetry, symmetry elements and symmetry operations. Qualitative idea of point and space groups, seven crystal systems, and fourteen Bravais lattices; X-ray diffraction, Bragg's law.

(7 Lectures)

Recommended Books/References:

- Lee, J. D. *Concise Inorganic Chemistry*, ELBS,1991.
- Atkins, P. W and Shriver D. N. *Atkins' Inorganic Chemistry*, 5th Ed. Oxford University Press (2010).
- Morrison, R. N. & Boyd, R. N. *Organic Chemistry*, 6th Edn., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Pine S. H. *Organic Chemistry*, Fifth Edition, McGraw Hill, (2007)
- J. Clayden, N. Greeves, S. Warren, *Organic Chemistry*, 2nd Ed., (2012), Oxford University Press.
- P. Sykes, *A Guide Book to Mechanism in Organic Chemistry*, 6th Edition (1997), Orient Longman, New Delhi.
- Atkins, P. W. & Paula, J. de *Atkin's Physical Chemistry* 8th Ed., Oxford University Press (2006).
- B. R. Puri, L. R. Sharma, M. S. Pathania, *Principles of Physical Chemistry*, Vishal Publishing Co., 2018.

CYUAMJL1: Basic Concepts in Chemistry-I (Lab)

Credit 1 (30 Hours)

Inorganic Chemistry

1. Acid-Base Titrations

- **(a)** Titration of very weak acid-boric acid
- **(b)** Estimation of carbonate and hydroxide present together in a mixture.
- **(c)** Estimation of carbonate and bicarbonate present together in a mixture.

2. Redox Titrations

- **(a)** Estimation of Fe(II) and oxalic acid using standardized $KMnO_4$ solution.
- **(b)** Estimation of oxalic acid and sodium oxalate in a given mixture.

Physical Chemistry

1. Surface tension measurements:

- **(a)** Determine the surface tension by (i) drop number (ii) drop weight method.
- **(b)** Study the variation of surface tension of detergent solutions with concentration.
- **(c)** Surface tension composition curve for a binary liquid mixture.

2. Viscosity measurement using Ostwald's viscometer:

- **(a)** Determination of viscosity of aqueous solutions of (i) polymer (ii) ethanol and (iii) sugar at room temperature.
- **(b)** Study the variation of viscosity of sucrose solution with the concentration of solute.
- **(c)** Viscosity composition curve for a binary liquid mixture.

Note: ***Any other experiment will be carried out in the class if permitted.***

Recommended Books:

- J. Elias, *A Collection of Interesting General Chemistry Experiments*, Revised Ed., University Press, **2007**.
- C. W. Garland, J. W. Nibler and D. P. Shoemaker, *Experiments in Physical Chemistry*, 8th Ed., McGraw-Hill, **2003**.
- A. M. Halern and G. C. McBane, *Experimental Physical Chemistry: A Laboratory Textbook*, 3rd Ed., W. H. Freeman and Company, **2006**.
- P. C. Kamboj, *University Practical Chemistry*, 1st Ed., Vishal Publishing, **2013**.
- Mendham, J., A. I. Vogel's *Quantitative Chemical Analysis*, Sixth Edition Pearson, 2009.
- Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis*, University Press (2000).
- Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry,* R. Chand & Co.: New Delhi (2011).
- Athawale V. D. and Mathur P. *Experimental Physical Chemistry*, New Age International (2001)

Course Outcomes and their mapping with Programme Outcomes

PO CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		3	1	1		1	3	2	3	1	3
CO2	3	1	2		3	1	1		1	3	2	3	1	3
CO3	3	1	2		3	1	1		1	3	2	3	1	3
CO4	3	1	2		3	1	1		1	3	2	3	1	3
CO5	3	1	2		3	1	1		1	3	2	3	1	3
CO6	3	1	2		3	1	1		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
II	Major (Level 2)	CYUBMJT1	Basic Concepts in Chemistry-II	Theory 3 (45 Lectures)
		CYUBMJL1	Basic Concepts in Chemistry-II (Lab)	Practical: 1 (30 Hours)

CYUBMJT1: Basic Concepts in Chemistry-II

Level 2, Credit 3 (45 Lectures)

Course Outcomes:

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

1. Understand the first law of thermodynamics and its applications.
2. Know the chemical equilibrium, pH of solution, buffer solution and application.
3. Understand aliphatic hydrocarbons alkanes, alkenes, alkynes.
4. Understand reaction intermediates and their characteristics.
5. Know the chemistry of s, p, and d block elements.
6. Understand the role of metals in biological systems.

Physical Chemistry

Unit – I: First Law of Thermodynamics

Introduction of different terms and processes in thermodynamics: State and path functions and their mathematical differentials treatment, partial derivatives, Euler's reciprocity, and cyclic rule.

First Law: Concept of heat, *q*, work, *w*, internal energy, *U*, and sign convention for heat and work; Statement of first law; Enthalpy, *H*; heat capacities (C_v and C_p) and their relationships. Reversible and irreversible processes, maximum work. Calculations of *q*, *w*, *U*, and *H* for reversible, irreversible, and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions. Ideal gas law for adiabatic reversible expansion; comparison of adiabatic and isothermal reversible expansion. Joule-Thomson effect. Standard state and Thermochemistry (Hess's Laws and Kirchhoff's equation).

(8 Lectures)

Unit – II: Chemical Equilibrium

Law of mass action; K_p, K_c, and K_x; Effect of temperature on K; Le-Chatelier principle; Ionic equilibria in solutions; pH and buffer solutions; Derivation of Henderson-Hasselbalch equation, buffer capacity, buffer range, buffer action and applications of buffers in analytical chemistry, Salt hydrolysis, hydrolysis constant, degree of hydrolysis and pH for different salts; Solubility and solubility product; Acid-base titration curves; Theory of acid-base indicators; selection of indicators and their limitations.

(7 Lectures)

Organic Chemistry

Unit – I: Chemistry of Aliphatic Hydrocarbons

***Alkanes and cycloalkanes*:** Preparation and general reactions of alkanes and cycloalkanes, Bayer Strain theory of strainless ring; Conformation of ethane, *n*-butane and cyclohexane, chlorination of methane and side chain chlorination of toluene.

***Alkenes*:** General methods for preparation of alkenes, Reactions of alkenes: Addition reactions (Electrophilic and free radical), Halogenation, Hydrohalogenation, Hydration, Hydroxylation, Hydroboration-oxidation, Mercuration-demercuration, Epoxidation and Ozonoloysis.

***Dienes*:** Conjugated and isolated Dienes; 1,2- versus 1,4-addition. Diels-Alder reaction of dienes: Mechanism

***Alkynes*:** Preparation of alkynes, acidity and metal acetylides, Electrophilic addition reactions viz., Halogenation, Hydrohalogenation, Hydration, Hydroboration-oxidation, Mercuration-demercuration and Ozonoloysis.

(9 Lectures)

Unit – II: Stereochemistry:

Optical activity and plane-polarized light. Plane and centre of Symmetry, Chirality, enantiomers, diasteroisomers, mesomers, and racemic mixtures. Fischer, Newman and Sawhorse Projection Formula. E/Z, D/L and R/S nomenclature. Walden inversion. Stereochemistry of allenes and biphenyls.

(6 Lectures)

Inorganic Chemistry

Unit – I: Chemistry of s, p, and d Block Elements

Inert pair effect, Relative stability of different oxidation states, diagonal relationship and anomalous behaviour of first member of each group. Allotropy and Catenation, Complex formation tendency of s and p block elements. Classification of Metal-Hydrides. Structure, Bonding, and Uses: Boric acid and borates, boron nitrides, borohydrides (diborane) carboranes and graphitic compounds, silanes, Oxides and oxoacids of Nitrogen, Phosphorus Sulphur and Chlorine. Occurrence and uses, rationalization of inertness of noble gases, Bonding in noble gas compounds (Valence bond and MO treatment for XeF_2).

d-block elements: General electronic configuration, colour, variable valency, magnetic and catalytic properties, and ability to form complexes. Stability of various oxidation states. Difference between the first, second and third-row transition elements.

(10 Lectures)

Unit – II: Bioinorganic Chemistry

Metal ions present in biological systems, classification of elements according to their action in biological systems. Geochemical effect on distribution of metals. Sodium/K-pump, Excess and deficiency of some trace metals. Toxicity of metal ions (Hg, Pb, Cd, and As), iron and its application in biosystems, Haemoglobin.

(5 Lectures)

Recommended Books/References:

- P. Atkins, J. d. Paula and K. James, *Physical Chemistry*, 11th Ed., Oxford University Press, **2018**.
- B. R. Puri, L. R. Sharma and M. S. Pathania, *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing Co., **2018**.
- D. R. Crow, *Principles and Applications of Electrochemistry*, 4th Ed., Blackie Academic & Professional, **1994.**
- Morrison, R. N. & Boyd, R. N. *Organic Chemistry*, 6th Edn., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- F. A. Carey, Organic Chemistry, Seventh Edition, Tata McGraw Hill (2008).
- P Sykes, *A Guide Book to Mechanism in Organic Chemistry*, 6th Edition (1997), Orient Longman, New Delhi.
- "*Stereochemistry of Organic Compounds"*, D. Nasipuri, New Age International.
- "*Stereochemistry of Organic Compounds"*, P.S. Kalsi, New Age International.
- Lee, J.D. Concise Inorganic Chemistry, ELBS,1991.
- Cotton, F.A. & Wilkinson, G. Advanced Inorganic Chemistry, Wiley, VCH,1999.
- Rodger, G.E. Inorganic and Solid-State Chemistry, Cengage Learning India Edition, 2002.
- Atkins, P. W and Shriver D. N. Atkins' Inorganic Chemistry 5th Ed. Oxford University Press (2010).

CYUBMJL1: Basic Concepts in Chemistry-II (Lab)

Credit 1 (30 Hours)

Physical Chemistry

1. Thermochemistry:

(a) Determination of heat capacity of a calorimeter for different volumes using change of enthalpy data of a known system (method of back calculation of heat capacity of calorimeter from known enthalpy of solution or enthalpy of neutralization).

(b) Determination of heat capacity of the calorimeter and enthalpy of neutralization of hydrochloric acid with sodium hydroxide.

(c) Calculation of the enthalpy of ionization of ethanoic acid.

(d) Determination of heat capacity of the calorimeter and integral enthalpy (endothermic and exothermic) solution of salts.

(e) Determination of enthalpy of hydration of copper sulfate.

(f) Study of the solubility of benzoic acid in water and determination of ΔH.

2. pH metry

(a) Determination of pH of the given unknown solutions.

(b) Study the effect on pH of the addition of HCl/NaOH to solutions of acetic acid, sodium acetate, and their mixtures.

(c) Preparation of buffer solutions of different pH by:

(i) Sodium acetate-acetic acid

(ii) Ammonium chloride-ammonium hydroxide

Inorganic Chemistry

1. Iodo / IodimetricTitrations

(a) Estimation of Cu(II) and $K_2Cr_2O_7$ using sodium thiosulphate solution(Iodometrically).

(b) Estimation of available chlorine in bleaching powder iodometrically.

2. Inorganic preparations

(a) Preparation of Aluminium potassium sulphate (Potash alum) and Chrome alum.

Organic Chemistry

1. Identify elements (N, S, Cl, Br & I) present in organic compounds.
2. Identification of Functional groups (Acids, Phenolic OH & Keto) present in organic compounds.

Any other experiment will be carried out in the class if permitted.

Reference Books:

- J. Elias, *A Collection of Interesting General Chemistry Experiments*, Revised Ed., University Press, **2007**.
- C. W. Garland, J. W. Nibler and D. P. Shoemaker, *Experiments in Physical Chemistry*, 8th Ed., McGraw-Hill, **2003**.
- A. M. Halern and G. C. McBane, *Experimental Physical Chemistry: A Laboratory Textbook*, 3rd Ed., W. H. Freeman and Company, **2006**.
- P. C. Kamboj, *University Practical Chemistry*, 1st Ed., Vishal Publishing, **2013**.
- Mendham, J., A. I. Vogel's Quantitative Chemical Analysis Sixth Edition Pearson, 2009.
- Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis*, University Press (2000)

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	2		3	1	2		1	3	2	3	1	3
CO2	3	1	2		3	1	1		1	3	2	3	1	3
CO3	3	1	2		3	1	1		1	3	2	3	1	3
CO4	3	2	2		3	1	2		1	3	2	3	1	3
CO5	3	2	2		3	1	1		1	3	2	3	1	3
CO6	3	1	2		3	1	2		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
III	Major (Level 3)	CYUCMJT1	Basic Concepts in Chemistry-III	Theory 3 (45 Lectures)
		CYUCMJL1	Basic Concepts in Chemistry-III (Lab)	Practical: 1 (30 Hours)

CYUCMJT1: Basic Concepts in Chemistry-III

Level 3, Credit 3 (45 Lectures)

Course Outcomes:

Graduates will understand:

1. purification processes of various elements, Ellingham diagram, etc.
2. crystal field and ligand field theories, John-Teller theorem, and stereochemistry of coordination compounds.
3. Grignard reagents and its applications.
4. Nucleophilic and elimination organic reactions.
5. Alcohols and ethers and their reactions.

Unit – I: General Principles of Metallurgy

Standard Electrode Potential and its application to inorganic reactions. Occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides. Electrolytic Reduction, Hydrometallurgy. Methods of purification of metals: Electrolytic Kroll process, Parting process, van Arkel- de Boer process and Mond's process, Zone refining.

(10 Lectures)

Unit – II: Coordination Chemistry

Werner's theory, EAN rule, valence bond theory (inner and outer orbital complexes), Crystal field theory: d-orbital splitting, weak and strong fields, pairing energies, factors affecting the magnitude of (Δ). Octahedral vs. tetrahedral coordination, Jahn-Teller theorem, d orbital splitting in square planar complexes, CFSE, Qualitative aspect of Ligand field theory, IUPAC nomenclature and isomerism in coordination compounds, Stereochemistry of complexes with the coordination number 4 and 6.

(10 Lectures)

Unit – III: Alkyl Halides

Preparation and general reactions of alkyl halides; Grignard reagents: preparation and synthetic applications; Reformatsky reaction; Wurtz reactions.

(7 Lectures)

Unit – IV: Substitution Reaction at Saturated Carbon

Nucleophilic substitution reactions at saturated aliphatic carbon: SN1, SN2 and SNi mechanisms; Elimination reactions at saturated aliphatic carbon: E1 and E2 mechanisms; Elimination vs Substitution reactions; energy profile diagrams.

(8 Lectures)

Unit – V: Aliphatic Alcohols and Ethers:

General properties of alcohols. Synthesis of alcohols from alkenes via hydroboration-oxidation, oxymercuration-demercuration. Reactions of alcohols: Dehydration, oxidation and distinction of primary, secondary and tertiary alcohols. Acetal and ketal formation, Pinacole-pinacolone rearrangement. Preparation and general reactions of ethers; C-O bond cleavage reactions, nucleophilic ring-opening of epoxides.

(10 Lectures)

Recommended Books/References:

- Purcell, K.F & Kotz, J.C. Inorganic Chemistry W.B. Saunders Co, 1977. Huheey, J.E., Inorganic Chemistry, Prentice Hall, 1993.
- Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry Wiley-VCH, 1999.
- Lee, J.D. Concise Inorganic Chemistry, ELBS,1991.
- Atkins, P. W and Shriver D. N. Atkins' Inorganic Chemistry 5th Ed. Oxford University Press (2010).
- 'Organic Chemistry", R. T. Morrison and R. N. Boyd, 6th Edition (1992), Prentice-Hall of India (P) Ltd., New Delhi.
- "Organic Chemistry", S. M. Mukherjee, S. P. Singh, and R. P. Kapoor, 1st Edition (1985), New Age International (P) Ltd. Publishers, New Delhi.
- "Organic Chemistry – Structure and Reactivity", Seyhan N. Ege, 3rd Edition (1998), ITBS Publishers and Distributors, Delhi.
- "Organic Chemistry", I. L. Finar, [Vol. I, 6th Edition (1973), Reprinted in 1980 & Vol. II, 5th Edition (1975), Reprinted in1996], ELBS and Longman Ltd., New Delhi.
- "A Guide Book to Mechanism in Organic Chemistry", P. Sykes, 6th Edition (1997), Orient Longman Ltd., New Delhi.
- "Organic Chemistry", J. Clayden, N. Greeves, S. Warren, and E. Wothers, Oxford Univ. Press, Oxford (2001).
- "Organic Chemistry", G. Solomon, Willey India, Paper Back, 9th Edition.
- "Modern Organic Chemistry", M. K. Jain and S. C. Sharma, Vishal Publishing CO. Jalandhar, India, 4th Edition (2012).

CYUCMJL1: Basic Concepts in Chemistry-III (Lab)

Credit 1 (30 Hours)

Inorganic Chemistry

1. Preparation of tetraaminecopper(II) sulfate, [Cu(NH3)4H2O]SO4.
2. Preparation of *cis*- and *trans*- potassium dioxalatodiaquachromate(III) complex.
3. Preparation of potassium trioxalatoferrate(III) complex.

Organic Chemistry

1. Functional group detection of organic compounds containing carboxylic acid & sulphonic acid.
2. Functional group detection of organic compounds containing aliphatic alcohol & aromatic alcohol.
3. Functional group detection of organic compounds containing aldehyde & ketone.

Note: Experiments may be added/deleted subject to availability of time and facilities.

Recommended Books:

- Marr and Rockett, Practical Inorganic Chemistry, John Wiley & Son 1972.
- Vogel's Qualitative Inorganic Analysis, Revised by G. Svehla. Pearson Education,2002.
- Marr & Rockett Practical Inorganic Chemistry. John Wiley & Sons1972.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	3		3	1	1		1	2	2	3	1	3
CO2	2	1	2		3	2	1		1	3	2	2	1	3
CO3	2	1	2		2	1	1		1	3	2	3	2	3
CO4	3	1	2		3	1	1		1	3	2	3	1	3
CO5	3	1	2		3	1	2		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
III	Major (Level 3)	CYUCMJT2	Basic Concepts in Chemistry-IV	Theory 3 (45 Lectures)
		CYUCMJL2	Basic Concepts in Chemistry-IV (Lab)	Practical: 1 (30 Hours)

CYUCMJT2: Basic Concepts in Chemistry-IV

Level 3, Credit 3 (45 Lectures)

Course Outcomes:

After completing this course, students will be able to understand:

1. second and third laws of thermodynamics and its applications.
2. thermodynamics of open systems, chemical potential, thermodynamic functions of mixing, fugacity and activity.
3. the concept of rate laws, order and molecularity of reaction, and theory of reaction rates.
4. safety measures required in a chemical laboratory, solution preparation.
5. significant figures, accuracy, precision, and uncertainties, including use of computers for chemical science.

Unit – I: Second and Third Law of Thermodynamics

Second Law: Limitation of the first Law, spontaneous processes and different statements of second law of thermodynamics, Carnot cycle and its efficiency, Carnot theorem; thermodynamic scale of temperature.

Concept of Entropy: Entropy changes in reversible and irreversible processes and of universe, physical concept of entropy (molecular and statistical interpretation of entropy), Clausius inequality; entropy as a function of V & T, and P & T; entropy changes of an ideal gas in different processes, entropy change in mixing of gases.

Free Energy Functions: Free energy and its concept, Gibbs (G) and Helmholtz (A) free energies as thermodynamic quantities and their relationship; variation of free energy with temperature and pressure. Maxwell's relations, thermodynamic equation of state; criteria for reversible and irreversible processes (spontaneity); Gibbs-Helmholtz equations, its applications.

Third Law: Variation of entropy with temperature (Nernst heat theorem), statement of third law, the concept of residual entropy. Applications of third law for the determination of absolute entropies of liquids and gases.

(10 Lectures)

Unit – II: Thermodynamics of Open Systems

Partial molal quantities, dependence of thermodynamic parameters on composition; the Gibbs-Duhem equation, chemical potential, variation of chemical potential with temperature and

pressure, chemical potential in case of a system of ideal gases, chemical potential of real gases; concept and physical significance of fugacity, activity and activity coefficient, reference and standard states, thermodynamic functions of mixing ($\Delta_{mix}G$, $\Delta_{mix}S$, $\Delta_{mix}V$, and $\Delta_{mix}H$) of ideal gases.

(9 Hours)

Unit – III: Chemical Kinetics

The concept of reaction rate, order and molecularity of a reaction, rate laws in terms of the advancement of a reaction, differential and integrated forms of rate expressions up to second-order reactions, experimental methods of the determination of rate laws; half-life of a reaction. Temperature dependence of reaction rates; Arrhenius equation; activation energy. Collision theory of reaction rates, qualitative treatment of the theory of absolute reaction rates.

(8 Lectures)

Unit – IV: Safety Measures in Chemical Laboratory and Solution Preparation

Introduction to the chemical laboratory: general guidelines, cleanness, reagents, glassware, and equipment; safety symbols and regulations in the chemical laboratory. Materials Safety Data Sheet (MSDS). Globally CAS registry number. Global overview of chemical regulations in India. Fundamental units of measure.

Analytical balance and weights: general purpose chemical balance, electronic balance, analytical weight box and classification, calibration of weights and handling of electronic balance. Handling of laboratory apparatus and hazardous chemicals. Calibration of glassware (pipette, burette, etc.).

Types of solutions: mole and mole concept, equivalent weight, formula weight. Expression of concentration, molarity (M), molality (m), mole fraction, normality (N); weight, volume, and weight-to-volume ratios; parts per million (ppm), parts per billion (ppb).

(8 Lectures)

Unit – V: Treatment of Experimental Data

Significant figures, accuracy and precision in calculations. Uncertainties (error) in Data and Results, classification of errors, minimizations of errors, distribution of random errors, propagation of error. Reliability of Results, Confidence Interval, Rejection of data (t-test, F-test, and Q-test), Mean and Standard Deviations, Correlation and Regression,

Use of Computer: Excel spreadsheet, data entry and manipulation, formula entry and addressing, significance test, Graph plotting, curve fitting (linear and non-linear), and its analysis (including origin software).

Microsoft PowerPoint presentation, Molecule design and its properties determination using computational softwares, Introduction of various computational softwares for chemical sciences.

(10 Lectures)

Recommended Books/References:

- P. Atkins, J. d. Paula and K. James, *Physical Chemistry*, 11th Ed., Oxford University Press, **2018**.
- T. Engel and P. Reid, *Physical Chemistry*, 3rd Ed., Pearson, **2014**.
- K. L. Kapoor, *A Text Book of Physical Chemistry: Thermodynamics and Chemical Equilibrium, Vol. 2*, 5th Ed., McGraw-Hill, **2015**.
- K. J. Laidler and J. H. Meiser, *Physical Chemistry*, 2nd Ed., CBS Publishers, **2006**.
- B. R. Puri, L. R. Sharma and M. S. Pathania, *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing Co., **2018**.
- R. P. Rastogi and R. R. Mishra, *An Introduction to Chemical Thermodynamics*, 6th Ed., Vikash Publishing House, **2018**.
- S. Alberty, *Physical Chemistry*, 3rd Ed., John Wiley & Sons, Inc., **2003**.
- A. M. Halern and G. C. McBane, *Experimental Physical Chemistry: A Laboratory Textbook*, 3rd Ed., W. H. Freeman and Company, **2006**.
- P. Patnaik, *Dean's Analytical Chemistry Handbook*, 2nd Ed., Mc-Graw Hill, **2004**.
- C. W. Garland, J. W. Nibler, and D. P. Shoemaker, *Experiments in Physical Chemistry*, 8th Ed., McGraw-Hill, **2003**.
- G. H. Jeffery, J. Bassett, J. Mendham, and R. C. Denny, *Vogel's Text book of Quantitative Chemical Analysis*, 5th Ed., John Wiley & Sons, **1989**.
- R. de Levie, *How to use excel® in analytical chemistry and in general scientific data analysis*, Cambridge University Press, **2004**.

CYUCMJL2: Basic Concepts in Chemistry-IV (Lab)

Credit 1 (30 Hours)

1. Calibration of weights and glasswares.
2. Preparation of solutions for given concentrations.
3. Programming of computer applications.
4. Graph plotting with data provided.
5. pH metry

(a) pH metric titration of (i) strong acid *versus* strong base, (ii) weak acid *versus* strong base.

(b) Determination of dissociation constant of a weak acid.

6. Chemical Equilibrium:

- Equilibrium constant of methyl acetate hydrolysis reaction.
- Study the equilibrium of at least one of the following reactions by the distribution method:

(a) $I_2(aq) + I^-(aq) \rightleftharpoons I_3^-(aq)$

(b) $Cu^{2+}(aq) + nNH_3(aq) \rightleftharpoons [Cu(NH_3)_n]^{2+}$

7. Chemical Kinetics:

- Study the kinetics of the following reactions.
  - **(a)** Order of reaction of I_2 – acetone – H^+ ion.
  - **(b)** Integrated rate method:
    - **i.** Acid hydrolysis of methyl acetate with hydrochloric acid
    - **ii.** Saponification of ethyl acetate.

Note: *Any other experiment will be carried out in the class if permit.*

Recommended Books:

- J. Elias, *A Collection of Interesting General Chemistry Experiments*, Revised Ed., University Press, **2007**.
- C. W. Garland, J. W. Nibler and D. P. Shoemaker, *Experiments in Physical Chemistry*, 8th Ed., McGraw-Hill, **2003**.
- A. M. Halern and G. C. McBane, *Experimental Physical Chemistry: A Laboratory Textbook*, 3rd Ed., W. H. Freeman and Company, **2006**.
- S. K. Maity and N. K. Ghosh, *Physical Chemistry Practical*, NCBA, **2015**.
- A. K. Nad, B. Mahapatra and A. Ghoshal, *An Advanced Course in Practical Chemistry*, 3rd Ed., New Central Book Agency, **2014**.
- J. B. Yadav, *Advanced Practical Physical Chemistry*, Krishna Prakashan Media, **2010**.
- B. Viswanathan and P. S. Raghavan, *Practical Physical Chemistry*, Viva Books, **2009**.
- G. H. Jeffery, J. Bassett, J. Mendham, and R. C. Denny, *Vogel's Text book of Quantitative Chemical Analysis*, 5th Ed., John Wiley & Sons, **1989**.
- R. Brent, *The Golden Book of Chemistry Experiments*, Golden Press, **1960**.
- https://www.originlab.com

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	3		3	1	1		1	2	2	3	1	3
CO2	2	1	3		3	2	1		1	3	1	2	2	3
CO3	3	1	2		2	1	1		1	3	2	3	2	3
CO4	3	1	2		3	1	1		1	3	2	3	1	3
CO5	3	1	2		3	1	2		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
IV	Major (Level 3)	CYUDMJT1	Inorganic Chemistry-I	Theory 3 (45 Lectures)
		CYUDMJL1	Inorganic Chemistry-I (Lab)	Practical: 1 (30 Hours)

CYUDMJT1: Inorganic Chemistry-I

Level 3, Credit 3 (45 Lectures)

Course Outcomes:

Graduate will understand:

1. Transition metals, its stability, color, oxidation states and complexes. Chemistry of 3d metals.
2. Lanthanides, Actinides –separation, color, spectra and magnetic behavior.
3. Chemistry of metallic carbonyls and nitrosyls compounds.
4. Chemistry of inorganic polymers.
5. Bioinorganic chemistry –metal ions in biological system, its toxicity; hemoglobin.

Unit – I: Transition Elements

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

(9 Lectures)

Unit – II: Lanthanides and Actinides

10 Lectures

Lanthanides: Definition, Position of lanthanides in periodic table, General properties-electronic configuration, oxidation state, chemistry of +2, +3 and +4 state, Atomic and ionic radii, lanthanide contraction, cause of lanthanide contraction, consequences of lanthanide contraction, Color and absorption spectra of Ln^{3+} ion, magnetic properties. Separation of lanthanides (ion-exchange method and solvent extraction), uses of lanthanide compounds. Actinides: Definition, Position of actinides in periodic table, General properties and their comparison with lanthanides like - electronic configuration, oxidation state, chemistry of +2, +3, +4, +5, +6 and +7 oxidation state, Atomic and ionic radii, color and absorption spectra, magnetic properties.

(12 Lectures)

Unit – III: Chemistry of Metallic Carbonyls and Nitrosyls

Metallic Carbonyls: General methods of preparation, general properties, Structure and nature of M-CO bonding in carbonyls, Effective atomic number (EAN) rule as applied to metallic carbonyls, 18-electron rule as applied to metallic carbonyls. Metallic Nitrosyls: Some metallic nitrosyls, Effective atomic number (EAN) rule as applied to metallic nitrosyls. Metal carbonyl nitrosyls.

(10 Lectures)

Unit – IV: Inorganic Polymers

Types of inorganic polymers, comparison with organic polymers, synthesis, structural aspects and applications of silicones and siloxanes. Borazines, silicates and phosphazenes, and polysulphates.

(8 Lectures)

Unit – V: Bioinorganic Chemistry

Inorganic composition of living organisms, Carbonic anhydrase and carboxypeptidase. Toxicity of metal ions (Hg, Pb, Cd, and As), toxicity, chelating agents in medicine. Iron and its application in biosystems, Haemoglobin; Storage and transfer of iron.

(6 Lectures)

Recommended Books/References:

- Purcell, K.F & Kotz, J.C. Inorganic Chemistry W.B. Saunders Co, 1977. Huheey, J.E., Inorganic Chemistry, Prentice Hall, 1993.
- Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry Panima Publishing Company 1994.
- Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry Wiley-VCH, 1999
- Basolo, F, and Pearson, R.C. Mechanisms of Inorganic Chemistry, John Wiley & Sons, NY, 1967.
- Greenwood, N.N. & Earnshaw A. Chemistry of the Elements, Butterworth-Heinemann, 1997.
- Selected Topics in Inorganic Chemistry by Wahid U. Malik, G. D. Tuli and R. D. Madan

CYUDMJL1: Inorganic Chemistry-I (Lab)

Credit 1 (30 Hours)

1. Qualitative Analysis:

Qualitative semimicro analysis of mixtures containing 3 anions and 3 cations. Emphasis should be given on understanding of the chemistry of different reactions. Following radicals may be analyzed: Carbonate, nitrate, nitrite, sulphide, sulphate, sulphite, acetate, fluoride, chloride, bromide, iodide, borate, oxalate, phosphate, ammonium, potassium, lead, copper, cadmium,

bismuth, tin, iron, aluminium, chromium, zinc, manganese, cobalt, nickel, barium strontium, calcium, magnesium. Mixtures containing one interfering anion, or insoluble component ($BaSO_4$, $SrSO_4$, $PbSO_4$, CaF_2 or Al_2O_3) or combination of anions e.g. CO_3^{2-} and SO_3^{2-}, NO_2^- and NO_3^-, Cl^- and Br^-, Cl^- and I^-, Br^- and I^-, NO_3^- and Br^-, NO_3^- and I^-. Spot analysis/tests should be done whenever possible.

2. Gravimetric Analysis:

(i) Estimation of nickel (ll) using Dimethylglyoxime (DMG).
(ii) Estimation of copper as CuSCN
(iii) Estimation of iron as Fe_2O_3 by precipitating iron as $Fe(OH)_3$.

3. Preparation of acetylacetanato complexes of Cu^{2+}/Fe^{3+}. (Also find the λ_{max} of the prepared complex using instrument).
4. Synthesis of ammine complexes of Ni(II) and its ligand exchange reactions (e.g. bidentate ligands like acetylacetone, DMG, glycine) by substitution method.

Recommended Books:

- *Vogel's Qualitative Inorganic Analysis*, Revised by G. Svehla. Pearson Education, **2002**.
- *Marr & Rockett Practical Inorganic Chemistry*, John Wiley & Sons **1972**.
- *Vogel's Quantitative Chemical Analysis*, 5th Edition, John Wiley & Sons, **1989**.

Course Outcomes and their mapping with Programme Outcomes

PO CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	3		3	1	1		1	2	2	3	1	3
CO2	2	2	1		3	2	1		1	3	3	2	2	3
CO3	3	1	2		2	1	1		1	3	2	3	2	3
CO4	3	1	2		3	1	1		1	3	2	3	1	3
CO5	3	1	2		3	1	2		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
IV	Major (Level 3)	CYUDMJT2	Organic Chemistry-I	Theory 4 (60 Lectures)
		CYUDMJL2	Organic Chemistry-I (Lab)	Practical: 1 (30 Hours)

CYUDMJT2: Organic Chemistry-I

Level 3, Credit 4 (60 Lectures)

Course Outcomes:

Graduate will understand:

1. Carbonyl compounds and their reactivity.
2. Carboxylic acids and derivatives.
3. Organic name reactions.
4. Organic rearrangement reactions.
5. Organic synthesis via enolates.

Unit – I: Carbonyl Compounds

Nomenclature, General properties: Solubility; Preparation of carbonyl compounds: From Grignard reagents, alcohols, nitriles, via Ozonolysis reactions etc.; General reactions of carbonyl compounds: Comparison of reactivity of aldehyde and ketones towards nucleophilic addition reactions. Nucleophilic addition reactions: Hydrations, acetal-ketal formations, etc.; Oxidation and reduction reaction, Condensation reactions: Synthesis of imines, oximes, hydrazones, semicarbazones etc. Keto-enol tautomerism.

(12 Lectures)

Unit – II: Carboxylic Acids & Its Derivatives

Nomenclature, General properties: Solubility, melting points, boiling points, Comparison of acidity of carboxylic acids; General method for the preparation of carboxylic acids, amides, esters, anhydrides, acid halides, and acid azides; Relative reactivity of carboxylic acids and their chemical reactions.

(12 Lectures)

Unit – III: Organic Name Reactions

Rosenmud reduction, Aldol condensation reaction, Perkin reaction, Wittig Reaction, Cannizzaro reaction, Benzoin condensation, Haloform reaction.

(12 Lectures)

Unit – IV: Important Organic Rearrangement Reactions

Beckmann rearrangement, Lossen rearrangement, Curtius rearrangement, Smith rearrangement, Wolf rearrangement: Arndt-Eistert synthesis.

(12 Lectures)

Unit – V: Organic Synthesis *via* Enolates

Preparation of DEM and EAA. Synthesis of mono- and di-carboxylic acids, Synthesis of diketones, uracil, barbutric acid using DEM/EAA: Michael addition reaction.

(12 Lectures)

Recommended Books/References:

- '*Organic Chemistry",* R. T. Morrison and R. N. Boyd, 6th Edition (1992), Prentice-Hall of India (P) Ltd., New Delhi.
- "*Organic Chemistry",* S. M. Mukherjee, S. P. Singh, and R. P. Kapoor, 1st Edition (1985), New Age International (P) Ltd. Publishers, New Delhi.
- *"Organic Chemistry",* I. L. Finar**,** [Vol. I, 6th Edition (1973), Reprinted in 1980 & Vol. II, 5th Edition (1975), Reprinted in1996], ELBS and Longman Ltd., New Delhi.
- *"A Guide Book to Mechanism in Organic Chemistry",* P. Sykes**,** 6th Edition (1997), Orient Longman Ltd., New Delhi.
- *"Organic Chemistry"*, J. Clayden, N. Greeves, S. Warren, and E. Wothers, Oxford Univ. Press, Oxford (2001).
- "*Organic Chemistry"*, G. Solomon, Willey India, Paper Back, 9th Edition.
- "*Modern Organic Chemistry"*, M. K. Jain and S. C. Sharma**,** Vishal Publishing CO. Jalandhar, India, 4th Edition (2012)

CYUDMJL2: Organic Chemistry-I (Lab)

Credit 1 (30 Hours)

1. Functional group detection of organic compounds containing nitro and its derivatives.
2. Functional group detection of organic compounds containing amine and its derivatives.
3. Functional group detection of organic compounds containing amide and its derivatives.
4. Functional group detection of aromatic hydrocarbons and its derivatives.

Recommended Books:

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

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		3	1	1		1	2	3	3	1	3
CO2	3	2	1		3	2	1		1	3	3	2	2	3
CO3	3	2	2		2	1	1		1	3	2	3	1	3
CO4	2	1	2		3	1	1		1	3	2	3	1	3
CO5	3	1	2		3	1	2		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
IV	Major (Level 3)	CYUDMJT3	Physical Chemistry-I	Theory 4 (60 Lectures)
		CYUDMJL3	Physical Chemistry-I (Lab)	Practical: 1 (30 Hours)

CYUDMJT3: Physical Chemistry-I

Level 3, Credit 4 (60 Lectures)

Course Outcomes:

After completing this course, students will be able to understand:

1. Phase rule and its applications for one, two, and three-component (s) systems.
2. Raoult's and Henry's laws and their applications.
3. Gibbs-Duhem-Margules equation for the binary solution, Lever rule, azeotropes, and Nernst distribution law.
4. Molar conductivity, Kohlrausch law of independent migration of ions. Debye-Hückel-Onsager equation, transference numbers, application of conductance measurement.
5. chemical and concentration cells, EMF measurement, and its applications.

Unit – I: Phase Equilibrium

Concept of phases, components and degrees of freedom, derivation of Gibbs Phase Rule for nonreactive and reactive systems; Phase diagrams with applications for one-component systems (water and sulfur) and two-component systems involving eutectics, congruent, incongruent melting points and solid solution (lead-silver, $FeCl_3$-H_2O and Na-K *etc*.).

Three Component System: Graphical representation of three three-component system; system of three liquids: having partial miscibility.

Type-I Formation of one pair of partially miscible liquids, **Type-II** Formation of two pairs of partially miscible liquids, **Type-III** Formation of three pairs of partially miscible liquids

(12 Lectures)

Unit – II: Dilute Solutions and Colligative Properties

The chemical potential of liquids; ideal solutions; lowering of vapor pressure, Raoult's and Henry's Laws and their applications. Excess thermodynamic functions.

Thermodynamic derivation using chemical potential to derive relations between the four colligative properties [(i) relative lowering of vapor pressure, (ii) elevation of boiling point, (iii) Depression of freezing point, (iv) osmotic pressure] and amount of solute. Applications in calculating molar masses of normal, dissociated, and associated solutes in solution.

(13 Lectures)

Unit – III: Binary Solutions

Binary solutions: Gibbs-Duhem-Margules equation, its derivation and applications to fractional distillation of binary miscible liquids (ideal and non-ideal), vapor pressure-

composition and temperature-composition curves of ideal and non-ideal solution; distillation of solution, Lever rule, azeotropes. Partial miscibility of liquids, CST, miscible pairs, Immiscibility of liquids – Principle of steam distillation.
Nernst distribution law: its derivation and applications.

(10 Lectures)

Unit – IV: Conductance

Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes (Kohlrausch square root law). Molar conductivity at infinite dilution. Kohlrausch law of independent migration of ions. Debye-Hückel-Onsager equation (No derivation).

Ionic velocities, mobilities and their determinations, transference numbers and their relation to ionic mobilities, determination of transference numbers using Hittorf and Moving Boundary methods. Applications of conductance measurement: (i) degree of dissociation of weak electrolytes, (ii) ionic product of water (iii) solubility and solubility product of sparingly soluble salts, (iv) conductometric titrations, and (v) hydrolysis constants of salts.

(10 Lectures)

Unit – V: Electrochemistry

Chemical cells, reversible and irreversible cells with examples. Electromotive force of a cell and its measurement, Nernst equation; Single electrode potential, its measurement and sign convention. Standard electrode (reduction) potential and its application to different kinds of half-cells. Application of EMF measurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants, and (iii) pH values, using hydrogen, quinone-hydroquinone, glass and SbO/Sb_2O_3 electrodes (iv) qualitative discussion of potentiometric titrations (acid-base, redox, precipitation). Concentration cells with and without transference, liquid junction potential and its elimination; determination of activity coefficients and transference numbers. Fuel cell (Hydrogen-Oxygen), Commercial Cell (Primary & Secondary cell), dry cell, acid-alkali storage cell & introduction of lithium-ion cells.

(15 Lectures)

Recommended Books/References:

- P. Atkins, J. d. Paula and K. James, *Physical Chemistry*, 11th Ed., Oxford University Press, **2018**.
- T. Engel and P. Reid, *Physical Chemistry*, 3rd Ed., Pearson, **2014**.
- S. Glasstone, *Thermodynamics for Chemists*, Affiliated East-West Press P. Ltd, **2003**.
- K. L. Kapoor, *A Text Book of Physical Chemistry: Thermodynamics and Chemical Equilibrium, Vol. 2*, 5th Ed., MsGraw-Hill, **2015**.
- K. L. Kapoor, *A Text Book of Physical Chemistry: Applications of Thermodynamics, Vol. 3*, 5th Ed., McGraw-Hill, **2015**.
- B. R. Puri, L. R. Sharma and M. S. Pathania, *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing Co., **2018**.
- S. Alberty, *Physical Chemistry*, 3rd Ed., John Wiley & Sons, Inc., **2003**.
- D. R. Crow, *Principles and Applications of Electrochemistry*, 4th Ed., Blackie Academic & Professional, **1994**.

CYUDMJL3: Physical Chemistry-I (Lab)

Credit 1 (30 Hours)

1. Conductometry:

(a) Determination of cell constant.

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

(c) Perform the following conductometric titrations:

(i) Strong acid *versus* strong base

(ii) Weak acid *versus* strong base

(iii) Dibasic acid *versus* strong base

2. Potentiometry:

(a) Perform the following potentiometric titrations:

(i) Strong acid *versus* strong base

(ii) Weak acid *versus* strong base

(iii) Dibasic acid *versus* strong base

3. To construct the phase diagram for a three-component liquid system consisting of Chloroform, Acetic acid, and Water.

4. Determination of the partial molal volume of methanol solution in water

5. Determination of the transport number by moving boundary method.

Reference Books:

- J. Elias, *A Collection of Interesting General Chemistry Experiments*, Revised Ed., University Press, **2007**.
- C. W. Garland, J. W. Nibler and D. P. Shoemaker, *Experiments in Physical Chemistry*, 8th Ed., McGraw-Hill, **2003**.
- A. M. Halern and G. C. McBane, *Experimental Physical Chemistry: A Laboratory Textbook*, 3rd Ed., W. H. Freeman and Company, **2006**.
- S. K. Maity and N. K. Ghosh, *Physical Chemistry Practical*, NCBA, **2015**.
- F. Daniels, R. A. Alberty, J. W. Williams, C. D. Cornwell, P. Bender and J. E. Harriman, *Experimental Physical Chemistry*, 7th Ed., McGraw-Hill, **1970**.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		3	1	1		1	2	3	3	1	3
CO2	3	2	1		3	2	3		1	3	1	2	2	3
CO3	3	1	2		2	1	1		2	3	2	3	1	3
CO4	2	1	3		3	1	1		1	3	2	3	1	3
CO5	3	2	2		3	1	2		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
V	Major (Level 4)	CYUEMJT1	Inorganic Chemistry-II	Theory 4 (60 Lectures)
		CYUEMJL1	Inorganic Chemistry-II (Lab)	Practical: 1 (30 Hours)

CYUEMJT1: Inorganic Chemistry-II

Level 4, Credit 4 (60 Lectures)

Course Outcomes:

Learners shall be able to understand the following upon completion of the course:

1. Various acid base theories and solvent effects, including acid-base strengths, HSAB principles, acid-base equilibria.
2. Redox balancing, redox potentials, Nernst equation and redox titration.
3. Solubility product, common ion effect and ion removal techniques.
4. Electronic spectra, Orgel diagrams, Jahn-Teller effects, Stability and reactions of metal complexes.
5. H-bonding and various weak chemical forces.

Unit – I: Acids and Bases

Acid-Base concept: Arrhenius concept, theory of solvent system (in H_2O, NH_3, SO_2 and HF), Bronsted-Lowry's concept, Lux Flood concept, Lewis concept, group characteristics of Lewis acids, solvent levelling and differentiating effects. Relative strength of acids, Pauling's rules. HSAB principle. Thermodynamic acidity parameters, Drago-Wayland equation. Superacids, Gas phase acidity and proton affinity. Acid-base equilibria in aqueous solution: Proton transfer equilibria in water, pH, buffer. Acid-base neutralization curves; indicator, choice of indicators.

(12 Lectures)

Unit – II: Redox Reactions

Basic principle of redox reactions: Ion-electron method of balancing equation of redox reaction. Elementary idea on standard redox potentials with sign conventions. Nernst equation (without derivation). Influence of complex formation, precipitation and change of pH on redox potentials; formal potential.

Redox titrations: Feasibility of a redox titration, redox potential at the equivalence point, redox indicators. Redox potential diagram (Latimer and Frost diagrams) of common elements and their applications. Disproportionation and comproportionation reactions (typical examples)

(12 Lectures)

Unit – III: Theoretical Principles of Inorganic Qualitative Analysis

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

(12 Lectures)

Unit – IV:

(A) **Thermodynamic and Kinetic Aspects of Metal Complexes:** A brief outline of thermodynamic stability of metal complexes and factors affecting the stability, substitution reaction of square planar complexes. Trans effect.

(B) **Electronic Spectra of Metal Complexes**: Electronic spectra of transition metal complexes, Laporte orbital and spin selection rules. Orgel energy level diagram of d^5 and combined diagrams of d^1- d^9, $d^2 – d^8$, $d^3 – d^7$, $d^4 – d^6$ and their spectra. Jahn Teller distortion. Spectrochemical series.

(14 Lectures)

Unit – V: Weak Chemical Forces

Weak Chemical Forces: van der Waals, ion-dipole, dipole-dipole, induced dipole dipole-induced dipole interactions, Lenard-Jones 6-12 formula, Hydrogen bonding (theories of hydrogen bonding, valence bond treatment), receptor-guest interactions, Halogen bonds. Effects of chemical force, melting, and boiling points, solubility, dissolution.

(10 Lectures)

Recommended Books/References:

- Lee, J. D. Concise Inorganic Chemistry, *Wiley, 5th Edn.*, **2008**.
- Douglas, B.E., McDaniel, D.H., Alexander J.J., Concepts & Models of Inorganic Chemistry, *(Third Edition) John Wiley &Sons*, **1999**.
- Atkins, P. W. and De Paula, J. Physical Chemistry, *Tenth Edition, Oxford University Press*, **2014**.
- Rodger, G. E. Inorganic and Solid State Chemistry, *Cengage Learning*, **2002**.
- Principles of Physical Chemistry by Puri, Sharma and Pathania.
- J. E. Huheey, E. A. Keiter, R. L. Keiter, Okhil K. Medhi , Principles of Structure and Reactivity, *5th Edition ,Pearson India*, **2022**.
- G. L. Miessler, D. A. Tarr, Inorganic Chemistry, *3rd Edition, Pearson India*, **2008**.
- A. G. Sharpe, C. E. Housecroft, Inorganic Chemistry *3rd Edition , Pearson India*, **2002**.

CYUEMJL1: Inorganic Chemistry-II (Lab)

Credit 1 (30 Hours)

Oxidation-Reduction Titrimetric Analysis:

1. Standardization of $KMnO_4$ standard oxalic acid solution.

2. Estimation of Fe(II) using standardized $KMnO_4$ solution.
3. Estimation of carbonate and bicarbonate present together in a mixture
4. Estimation of acetic acid in commercial Vinegar.
5. Estimation of Fe(III) using standard $K_2Cr_2O_7$ solution.
6. Estimation of Fe(II) and Fe(III) in a given mixture using standard $K_2Cr_2O_7$ solution.
7. Estimation of Fe(II) and Cu(II) in a given mixture.

Qualitative Semi-Micro Analysis:

Objective: Analysis of mixtures containing three radicals, with an emphasis on understanding the chemistry behind different reactions.

Cation Radicals: Ni^{2+}, Cu^{2+}, Zn^{2+}, Pb^{2+}, Cd^{2+}, Bi^{3+}, Sn^{2+}/Sn^{4+}, As^{3+}/As^{5+}, $Sb^{3+/5+}$, NH_4^+, Mg^{2+}

Anion Radicals: PO_4^{3-}, AsO_4^{3-}, BO_3^{3-}, CrO_4^{2-} / $Cr_2O_7^{2-}$, $Fe(CN)_6^{4-}$, $Fe(CN)_6^{3-}$

Insoluble Materials: Al_2O_3(ig), Fe_2O_3(ig), Cr_2O_3(ig), SnO_2, $SrSO_4$, $BaSO_4$, CaF_2, $PbSO_4$

Recommended Books:

- Vogel's Qualitative Inorganic Analysis, Revised by G. Svehla *Pearson Education*, **2002**.
- Marr & Rockett Practical Inorganic Chemistry. *John Wiley & Sons*, **1972**.
- Mendham, J., A. I. Vogel's Quantitative Chemical Analysis *6th Ed., Pearson*, **2009**.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	1		3	1	1		1	2	3	3	1	3
CO2	3	2	1		1	2	3		1	3	1	2	2	3
CO3	3	1	2		2	1	1		2	3	2	3	1	3
CO4	2	1	3		3	1	1		1	3	2	3	1	3
CO5	3	2	2		3	1	2		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
V	Major (Level 4)	CYUEMJT2	Organic Chemistry-II	Theory 4 (60 Lectures)
		CYUEMJL2	Organic Chemistry-II (Lab)	Practical: 1 (30 Hours)

CYUEMJT2: Organic Chemistry-II

Level 4, Credit 4 (60 Lectures)

Course Outcomes:

Learners shall be able to understand the following upon completion of the course:

1. Structural theories of benzene, Huckel's rule, and classification of aromatic compounds.
2. Electrophilic substitution reactions, their mechanisms, and the effect of substituents on reactivity.
3. Nucleophilic substitution reactions, mechanisms (SNAr, ANDN, benzyne), and applications.
4. Preparation, reactions, and acidity comparisons of phenols with alcohols and carboxylic acids.
5. Properties, reactivity, and synthetic applications of nitrogen-containing compounds, including amines, amides, and diazonium salts, and basics of transport properties.

Unit – I: Aromatic Compounds

Introduction, nomenclature of benzene derivatives, the Kekule structure of benzene, Valance bond & molecular orbital theories of the structure of benzene, Huckel's rule: (4n+2) π electron rule, Anti-aromatic compounds, non-aromatic, homoaromatic.

(12 Lectures)

Unit – II: Electrophilic Substitution Reactions of Aromatic Compounds

Electrophilic substitution reactions (S_EAr), A general mechanism for electrophilic aromatic substitution – Arenium ions, Halogenation, Nitration and sulphonation of benzene, Friedel–Crafts alkylation and its limitations, Friedel–Crafts acylation; Effect of substituents on reactivity and orientation.

(12 Lectures)

Unit – III: Nucleophilic Substitution Reactions of Aromatic Compounds

Halobenzenes, and nucleophilic aromatic substitutions (SNAr), bimolecular mechanism (ANDN), benzyne mechanism (DNAN). Preparation and uses of DDT and BHC.

(12 Lectures)

Unit – IV: Phenols

General methods of preparation and reactions of phenol. Relative acidity of phenol, alcohol and carboxylic acid. Reimer-Tiemann and Kolbe reactions; Claisen and Fries rearrangements.

(12 Lectures)

Unit – V: Nitrogen Containing Compounds

Nitrobenzene and reduction products. Amines and amides. Comparative basicity of aliphatic and aromatic amines, Diazonium salts: preparation (Diazo reaction) and synthetic applications (Sandmeyer reactions).

(12 Lectures)

Recommended Books/References:

- "Organic Chemistry", R. T. Morrison and R. N. Boyd, *6th Edition* (**1992**), *Prentice-Hall of India (P) Ltd., New Delhi*.
- "Organic Chemistry", S. M. Mukherji , S. P. Singh, and R. P. Kapoor, *1st Edition* (**1985**), *5th Reprint* (**1999**), *New Age International (P) Ltd.Publishers, New Delhi*.
- "Organic Chemistry – Structure and Reactivity", Seyhan N. Ege, *AITBS publishers, Delhi* (**1998**).
- "Organic Chemistry", Paula Y. Bruice, *2nd Edition , Prentice-Hall Internattional Inc, New Jersey, International Edition* (**1998**).
- Organic Chemistry, J. Clayden, N. Greeves, S. Warren, and E. Wothers, *Oxford Univ. Press, Oxford* (**2001**).
- "Organic Chemistry", G. Solomon, *Willey India, Paper Back, 9th Edition*.

CYUEMJL2: Organic Chemistry-II (Lab)

Credit 1 (30 Hours)

Organic preparations:

1. Acetylation of one of the following compounds: amines (aniline, o-, m-, p-toluidines and o-, m-, p-anisidine) and phenols (β -naphthol, vanillin, salicylic acid) by any one method:
2. Benzolyation of one of the following amines (aniline, o-, m-, p- toluidines and o-, m-, p-anisidine) and one of the following phenols (β -naphthol, resorcinol, p- cresol)
3. Hydrolysis of amides and esters.
4. Aldol condensation reactions.

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

Recommended Books:

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

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	1		3	1	1		1	2	3	3	1	3
CO2	3	2	1		1	2	3		1	3	1	2	2	3
CO3	3	1	2		2	1	1		2	3	2	2	1	3
CO4	2	1	1		3	1	1		1	3	2	3	1	2
CO5	3	1	2		3	1	2		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
V	Major (Level 4)	CYUEMJT3	Physical Chemistry-II	Theory 4 (60 Lectures)
		CYUEMJL3	Physical Chemistry-II (Lab)	Practical: 1 (30 Hours)

CYUEMJT3: Physical Chemistry-II

Level 4, Credit 4 (60 Lectures)

Course Outcomes:

After completing this course, students will be able to understand:

1. Clausius-Clapeyron equation and its applications, thermodynamics of phase transition, and basics of transport properties.
2. curved surface, Gibbs adsorption isotherm, surface-active agents and micellization.
3. opposing, parallel, and consecutive reactions, steady-state approximation,
4. catalyst: mechanism of the heterogeneous and homogeneous catalyzed reactions, Michaelis-Menten kinetics.
5. electromagnetic radiation and chemical reactions, Jablonski diagram, Lambert-Beer's law, and kinetics of photochemical reactions.

Unit – I: Phase Transformation and Transport Properties

Stability of phases; Clapeyron equation; Clausius-Clapeyron equation and its applications to solid-liquid, liquid-vapor and solid-vapor equilibria. Thermodynamics of phase transition; Ehrenfest classification of phases - bubbles, cavities and droplets-Kelvin equation.

General Transport equation: Thermal conductivity, viscosity, and diffusion. Intermolecular force: Long-range force, Lennard-Jones potential

(12 Lectures)

Unit – II: Surface Chemistry

***Surface Tension*:** Capillary action, pressure difference across curved surface (Laplace equation), vapor pressure of droplets (Kelvin equation), Gibbs adsorption isotherm, surface film and liquids (electro-kinetic phenomenon), catalytic activities at surface.

***Surface Active Agents*:** Classification of surface-active agents. Micellization, hydrophobic interaction, critical micellar concentration (CMC), factor affecting the CMC of surfactants, counterion binding to micelles, thermodynamics of micellization-phase separation and mass action models, solubilization, micro-emulsion, reverse micelles.

(12 Lectures)

Unit – III: Complex Reactions

Kinetics of complex reactions (integrated rate expressions up to first order only): (i) opposing reactions (ii) parallel reactions and (iii) consecutive reactions and their differential rate equations (steady-state approximation, rate-determining step and applications in reaction mechanisms) (iv) chain reactions (v) uni-molecular gas reaction (Lindemann mechanism).

(12 Lectures)

Unit – IV: Catalysis

Type of catalysts, specificity and selectivity, mechanism of catalyzed reaction at solid surface; effect of temperature on surface reaction, promoters and poisons.

***Heterogeneous Catalysis* (*Surface Reactions*):** Physical adsorption, chemisorption, nature of adsorbed state, adsorption isotherm; Langmuir and Freundlich adsorption isotherms. Multi-layer adsorption-BET equation and its application to surface area measurement.

Kinetics Homogeneous Catalysis: Nature of surface, concept of active centers. Kinetics of enzymatic reactions: Michaelis-Menten equation, Lineweaver-Burk and Eadie plot, effect of temperature and pH.

(12 Lectures)

Unit – V: Photochemistry

Characteristics of electromagnetic radiation and interaction of radiation with matter, difference between thermal and photochemical processes. Laws of photochemistry: Grothus-Drapper law, Stark-Einstein law, Jablonski diagram depicting various processes occurring in the excited state, qualitative description of fluorescence, phosphorescence, non-radiative processes (internal conversion, intersystem crossing). Lambert-Beer's law and its limitation, physical significance of absorption coefficient; quantum efficiency, reasons for low and high quantum efficiency. Kinetics of photochemical reactions ($H_2 + Br_2 = HBr$ and $2HI = H_2 + I_2$), photostationary state. Chemical actinometers (ferri-oxalate, uranyl oxalate, MGL [malachite green leucocyanide)] and Reinecke's salt); chemiluminescence, role of photochemical reactions in biological process.

(12 Lectures)

Recommended Books/References:

- P. Atkins, J. d. Paula and K. James, *Physical Chemistry*, 11th Ed., Oxford University Press, **2018**.
- T. Engel and P. Reid, *Physical Chemistry*, 3rd Ed., Pearson, **2014**.
- K. L. Kapoor, *A Text Book of Physical Chemistry: Applications of Thermodynamics, Vol. 3*, 5th Ed., McGraw-Hill, **2015**.
- K. J. Laidler, *Chemical Kinetics*, 3rd Ed., Pearson, **2011**.
- B. R. Puri, L. R. Sharma and M. S. Pathania, *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing Co., **2018**.
- S. Alberty, *Physical Chemistry*, 3rd Ed., John Wiley & Sons, Inc., **2003**.

CYUEMJL3: Physical Chemistry-II (Lab)

Credit 1 (30 Hours)

1. Determination of CMC of the surfactant by conductance measurement.

2. Chemical Kinetics:

- Kinetics of Reaction between ferric nitrate and potassium iodide using initial reaction rates.
- Determination of the rate constant for the catalytic decomposition of hydrogen peroxide by Fe^{3+} and Cu^{2+} ions.
- Flowing clock reactions (Experiments in physical Chemistry by Shoemaker).

3. Catalysis:

- Kinetics of enzymatic reaction (starch-amylase system).
- Kinetics of catalytic decomposition of H_2O_2

4. Surface Chemistry:

- Verify the Freundlich and Langmuir isotherms for adsorption of acetic acid on activated charcoal.

5. Photochemistry:

- Photochemical reduction of ferric oxalate in cyanotype blueprinting.

Recommended Books:

- J. Elias, *A Collection of Interesting General Chemistry Experiments*, Revised Ed., University Press, **2007**.
- C. W. Garland, J. W. Nibler and D. P. Shoemaker, *Experiments in Physical Chemistry*, 8th Ed., McGraw-Hill, **2003**.
- A. M. Halern and G. C. McBane, *Experimental Physical Chemistry: A Laboratory Textbook*, 3rd Ed., W. H. Freeman and Company, **2006**.
- J. B. Yadav, *Advanced Practical Physical Chemistry*, Krishna Prakashan Media, **2010**.
- J. Rose, *Advanced Physico-Chemical Experiments: A textbook of Practical Physical Chemistry and Calculations*, Sir Isaac Pitman & Sons, **1964**.
- F. Daniels, R. A. Alberty, J. W. Williams, C. D. Cornwell, P. Bender and J. E. Harriman, *Experimental Physical Chemistry*, 7th Ed., McGraw-Hill, **1970**.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	1		3	1	1		1	2	3	3	1	3
CO2	3	2	1		1	1	3		1	3	1	2	2	3
CO3	3	1	2		2	1	1		2	3	2	2	2	3
CO4	3	1	1		3	1	1		1	3	2	3	1	2
CO5	3	1	1		3	1	2		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VI	Major (Level 4)	CYUFMJT1	Advanced Inorganic Chemistry-I	Theory 4 (60 Lectures)
		CYUFMJL1	Advanced Inorganic Chemistry-I (Lab)	Practical: 1 (30 Hours)

CYUFMJT1: Advanced Inorganic Chemistry-I

Level 4, Credit 4 (60 Lectures)

Course Outcomes:

After completing this course, students will be able to understand:

1. Understanding reaction mechanisms and predict reactivity of substitution reactions using VBT and CFT.
2. Different mechanisms, rate laws for electron transfer process and Marcus-Husch theory.
3. Supramolecules and their chemistry, host-guest interactions, macrocyclic effects, and molecular machines. Principles of ORD and CD techniques
4. Molecular symmetry and point groups, great orthogonality theorem, and character tables.
5. Radioactivity, nuclear reactions, isotopes, radiochemical dating, and radiation safety.

Unit – I: Kinetics and Mechanism of Substitution Reactions

Nature of substitution reactions; prediction of reactivity of octahedral, tetrahedral and square-planar complexes in terms of VBT and CFT; rates of reactions; acid hydrolysis, base hydrolysis and anation reactions.

(8 Lectures)

Unit – II: Electron Transfer Reactions

Mechanism and rate laws; various types of electron transfer reactions, Marcus-Husch theory, correlation between thermal and optical electron transfer reactions.

(10 Lectures)

Unit – III: Supramolecular Chemistry

Definition, supramolecular host-guest compounds, macrocyclic effect, nature of suparmolecular interactions, molecular machine, biomodelling.

(10 Lectures)

Unit – IV: Optical Rotatory Dispersion and Circular Dichroism

Basic Principles of ORD and CD techniques. ORD and Cotton effect, Faraday and Kerr effects; Applications in determining absolute configuration of metal complexes.

(10 Lectures)

Unit – V: Symmetry and Point groups

Symmetry elements and symmetry operations; point groups, Schoenflies notation for point group, representation of group by matrix, character of a representation, reducible and irreducible representation, great orthogonality theorem and its importance.
Application of group theory to atomic orbitals in ligand fields, molecular orbitals, and hybridization. Selection rules for IR and Raman spectra, procedure for determining symmetry of normal modes of vibration - hybrid orbitals in BF_3, CH_4, NH_3, H_2O, SF_6, etc.

(10 Lectures)

Unit – VI: Radioactivity

Nuclear Reactions, Artificial radioactivity, transmutation of elements, fission, fusion and spallation. Nuclear energy and power generation. Separation and uses of isotopes. Radiochemical methods: principles of determination of age of rocks and minerals, radiocarbon dating, hazards of radiation, and safety measures.

(12 Lectures)

Books Recommended

- F. Basalo and R. G. Pearson, Mechanism of Inorganic Reactions, 2nd Edn (1967), Wiley Eastern Ltd., New Delhi.
- D. F. Shriver and P. W. Atkins, Inorganic Chemistry, 3rd Edn. (1999), ELBS, London.
- F. A. Cotton and G. Wilkinson, Advanced Inorganic Chemistry, 6th Edn., John Wiley & Sons, New York (1999).
- D.N. Sathyanarayana, Electronic Absorption Spectroscopy and Related Techniques, University Press (India) Ltd., Hyderabad (2001).
- J.-M. Lehn; Supramolecular Chemistry-Concepts and Perspectives, Wiley-VCH, (1995).
- P. D. Beer, P. A. Gale, D. K. Smith; Supramolecular Chemistry, Oxford University Press, (1999).
- J. W. Steed and J. L. Atwood; Supramolecular Chemistry, Wiley, (2000).
- H. J. Arnikar, Essentials of Nuclear Chemistry, 5th Edition, New Age International Pvt, Ltd., 2022
- G. Friedlander, J.W. Kennedy, E. S. Macias, J.M. Miller, Nuclear and radiochemistry, 3rd Edition, John Wiley, 1981
- Introductory Quantum Chemistry, A.K. Chandra, 4th Edition (1994), Tata Mcgraw Hill, New Delhi.
- Atomic & Molecular Symmetry Groups and Chemistry, S.C. Rakshit, Aug 2021, CRC Press Chemical Applications of Group Theory, 3ed, F. A. Cotton, Willey.

CYUFMJL1: Advanced Inorganic Chemistry-I (Lab)

Credit 1 (30 Hours)

(A) **Complexometric titration**

1. Zn(II)
2. Ca(II)and Mg(II) in a mixture.

3. Total Hardness of water.
4. Zn(II) and Al (II) in a mixture

(B) Inorganic preparations

1. Cis and trans $K[Cr(C_2O_4)_2(H_2O)_2]$
2. Tetraamminecarbonatocobalt(III) ion
3. Potassiumtris(oxalato)ferrate(III)
4. Tris-(ethylenediamine) nickel(II) chloride.
5. $[Mn(acac)_3]$and $Fe(acac)_3]$ (acac= acetylacetonate)

(C) Synthesis of compounds using Microwave Synthesiser

Books Recommended:

- Vogel's Qualitative Inorganic Analysis, Revised by G. Svehla Pearson Education, 2002.
- Marr & Rockett Practical Inorganic Chemistry. John Wiley & Sons, 1972.
- Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	1		3	1	1		1	2	2	3	1	3
CO2	3	2	1		1	1	3		1	3	1	2	2	3
CO3	3	1	2		3	1	1		2	3	2	2	2	3
CO4	3	1	1		3	1	1		1	3	2	3	1	3
CO5	3	1	1		3	1	2		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VI	Major (Level 4)	CYUFMJT2	Advanced Organic Chemistry	Theory 4 (60 Lectures)
		CYUFMJL2	Advanced Organic Chemistry (Lab)	Lab: 1 (30 Hours)

CYUFMJT2: Advanced Organic Chemistry

Level 4, Credit 4 (60 Lectures)

Course Outcomes:

Learners shall be able to understand the following upon completion of the course:

1. Photochemistry of carbonyl compounds and olefins.
2. Basic concept with handful examples of pericyclic chemistry
3. Alkaloids, terpenes isolation, structural elucidation.
4. Carbohydrates structures and reactions, degradation of monosaccharides.
5. Amino acids, peptide bonds, protein structure, deficiency diseases, oxygen uptake proteins.

Unit – I: Photochemistry

Principles of photochemistry, Photochemical energy, Jablonski diagram, photosensitisation and quenching, Types of photochemical reactions; photochemical reactions of carbonyl compounds and olefins.

(12 Lectures)

Unit – II: Pericylic Chemistry: Introduction. Woodward-Hoffmann rules; cycloaddition [2+2] and [4+2], and electrocylic reactions, Sigmatropic rearrangements.

(12 Lectures)

Unit – III: Chemistry of Alkaloids and Terpenoids

A study of the following compounds involving their isolation, structure elucidation and synthesis: Alkaloids- Hofmann exhaustive methylation, nicotine; Terpenes- Isoprene rule, citral.

(12 Lectures)

Unit – IV: Carbohydrates

Introduction, monosaccharadies, glycoside bond formation, mutarotation. Reactions of aldoses and ketoses. Killiani synthesis, Osazone formation. Glucose and Fructose cyclic and acyclic structure. Degradation of monosaccharaides: Ruff degradation.

(12 Lectures)

Unit – V: Amino Acids, Peptides and Proteins

Amino acids – Introduction and Importance, Preparative methods, physical properties, chemical reactions. Peptides: Peptide synthesis and structure of polypeptides. Proteins: Primary, secondary and tertiary, quaternary structure.

(12 Lectures)

Recommended Books/References:

- "Organic Chemistry", I. L. Finar, *Vol. I, 6th Edition* (**1973**), *Reprinted in 1980 & Vol. II, 5th Edition* (**1975**), *Reprinted in1996], ELBS and Longman Ltd., New Delhi*.
- "A Guide Book to Mechanism in Organic Chemistry", P. Sykes, *6th Edition*, *Orient Longman Ltd., New Delhi*, **1997**.
- "Organic Chemistry", R. T. Morrison and R. N. Boyd, *6th Edition, Prentice-Hall of India (P) Ltd., New Delhi*, **1922**.
- "Organic Chemistry", S. M. Mukherji , S. P. Singh, and R. P. Kapoor, *1st Edition* (**1985**), *5th Reprint* (**1999**), *New Age International (P) Ltd.Publishers, New Delhi*.
- "Organic Chemistry", J. Clayden, N. Greeves, S. Warren, and E. Wothers, *Oxford Univ. Press, Oxford* (**2001**).
- "Organic Chemistry", G. Solomon, *Willey India, Paper Back, 9th Edition*.
- "Organic Chemistry", I. L. Finar, [*Vol. 2, 6th Edition* (**1973**), *Reprinted in 1980 & Vol. II, 5th Edition* (**1975**), *Reprinted in1996*], *ELBS and Longman Ltd., New Delhi*.

CYUFMJL2: Advanced Organic Chemistry-I (Lab)

Credit 1 (30 Hours)

Functional group test:

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

Organic preparations:

1. Preparation of organic dyes.

Recommended Books:

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

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	1		3	1	1		1	2	2	3	1	3
CO2	3	2	3		1	1	3		1	3	1	2	2	3
CO3	3	1	2		3	1	1		2	3	2	2	2	3
CO4	3	1	1		3	1	1		1	3	2	2	1	2
CO5	3	1	1		3	1	2		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VI	Major (Level 4)	CYUFMJT3	Advanced Physical Chemistry	Theory 4 (60 Lectures)
		CYUFMJL3	Advanced Physical Chemistry (Lab)	Practical: 1 (30 Hours)

CYUFMJT3: Advanced Physical Chemistry

Level 4, Credit 4 (60 Lectures)

Course Outcomes:

After completing this course, students will be able to understand:

1. postulates of quantum mechanics, operators, and some exactly soluble 1-D systems.
2. Schrödinger equation and solution of rigid rotor, H-like atoms, angular momentum, and approximation method.
3. Schrödinger equation for many-electron atoms, Pauli antisymmetric principle, Hund's rules; Slater determinant; Hatree and Hatree-Fockself consistent, and electronic term symbol.
4. chemical bonding in diatomic and MO and VB theories, semi-empirical and *ab-initio* calculations, and Density Functional Theory (DFT).
5. thermodynamic probability, Boltzmann, Fermi-Dirac, and Bose-Einstein statistics, partition function, and applications.

Unit – I: Origin of Quantum Mechanics

***Historic Background*:** Introduction to black-body radiation and distribution of energy, photo-electric effect, concept of quantization, wave-particle duality (de-Broglie's hypothesis), Heisenberg's uncertainty principle.

***Schrödinger Wave Equation*:** normalization and orthogonality of wave functions; time-dependent and time-independent Schrödinger equations, postulates of quantum mechanics.

***Operators*:** Basic idea about operators, eigenfunctions, and eigenvalues.

Solution of the Schrödinger Equations for Some Exactly Soluble Systems: particle-in-a-box, tunnelling one-dimensional potential barrier and well, harmonic oscillator.

(12 Lectures)

Unit – II: Atomic Structure

Rigid Rotor, spherical coordinates, Schrödinger wave equation in spherical coordinates, separation of the variables, the phi equation, wave-function, quantum number, the theta equation, wave function, quantization of rotational energy, spherical harmonics.

***Angular Momentum*:** Basis functions and representation of orbital angular momentum operators, eigenfunctions, and eigenvalues of orbital angular momentum operator, Ladder operator, Spin, spin angular momenta, coupling (orbital and spin) of angular momentum, Clebsch-Gordan coefficients, and Wigner-Eckart theorem.

***Hydrogen and Hydrogen-Like Atoms*:** Radial and angular probability distributions, atomic orbitals.

***Approximate Methods of Quantum Mechanics*:** Variational principle; time-independent perturbation theory up to second order in energy for non-degenerate and degenerate systems with simple examples; application to the two-electron system, such as He and He like atoms.

(15 Lectures)

Unit – III: Atomic Structure and Spectroscopy

***Atomic Structure and Spectroscopy*:** Many-electron atoms, Pauli antisymmetric principle, Hund's rules; Slater determinant; Hatree and Hatree-Fockself consistent field model for atoms; electronic term symbol (Russell-Saunders and JJ coupling) for atoms and spectroscopic states (selection rules for atomic spectra).

(7 Lectures)

Unit – IV: Molecular Structure

Chemical bonding in diatomic; elementary concepts of MO and VB theories; Born-Oppenheimer approximation, MO treatment for H_2^+ ion, MO treatment of homo- and heteronuclear diatomic molecules; comparison of MO and VB theories. Hückel MO theory for conjugated π-systems. Polyatomic molecules, hybridization, and valence MOs of simple molecules like H_2O, NH_3, CH_4, C_2H_6, *etc*. Introductory treatment of semi-empirical, *ab-initio* calculations, and Density Functional Theory (DFT) on molecular systems.

(13 Lectures)

Unit – V: Statistical Thermodynamics

Review of Thermodynamics, Concept of distribution, thermodynamic probability, and most probable distribution. Ensemble averaging, postulates of ensemble averaging; conical, grand conical and micro-canonical ensembles. Boltzmann distribution laws (using Lagrange's method of undetermined multipliers). Partition function – translational, rotational, vibrational, and electronic partition functions, calculation of thermodynamic properties in terms of partition function, Applications of partition functions. Heat capacity behaviour of solid–chemical equilibria and equilibrium constant in terms of partition function. Fermi-Dirac statistics, distribution law, and application to metal. Bose-Einstein statistics, distribution law, and application to helium.

(13 Hours)

Recommended Books/References:

- P. Atkins, J. d. Paula and K. James, *Physical Chemistry*, 11th Ed., Oxford University Press, **2018**.
- C. N. Banwell and E. M. McCash, *Fundamentals of Molecular Spectroscopy*, 4th Ed., Tata McGraw-Hill, **1996**.
- A. Chandra, *Introductory Quantum Chemistry*, 4th Ed., McGraw Hill Education, **2017**.
- T. Engel and P. Reid, *Quantum Chemistry and Spectroscopy*, 5th Ed., Pearson, **2011**.
- K. L. Kapoor, *A Text Book of Physical Chemistry: Quantum Chemistry and Molecular Spectroscopy, Vol. 4*, 5th Ed., McGraw-Hill, **2015**.
- I. N. Levine, *Quantum Chemistry*, 7th Ed., Pearson, **2014**.

- D. A. McQuarrie and J. D. Simon, *Physical Chemistry: A Molecular Approach*, Viva Book Private Limited, **2005**.
- R. K. Prasad, *Quantum Chemistry*, 4th Ed., New Age International, **2020**.

CYUGMJL3: Advanced Physical Chemistry (Lab)

Credit 1 (30 Hours)

Computational Experiments:

Learning chemistry through computers: List the open-source and commercial software packages for computational simulation.

Using *ab initio* quantum mechanical calculations, compute the following:

1. Perform single-point energy, geometry optimization, and population analysis by various basis sets.
2. Potential energy surface for the rotation in H_2O_2 molecule.
3. Compute the potential energy difference of staggered and eclipsed ethane molecules.
4. Calculate the HNH bond angle of the Ammonia molecule and the barrier for umbrella rotation of ammonia.
5. Electronic structure calculation of IR and Raman frequencies using various basis sets. (CO_2, H_2O, $CHCl_3$, CH_2Cl_2, CCl_4).
6. Compute the dissociation energy of H_2 molecule using 6-31G basis set.
7. Perform conformational analysis of butane.
8. Calculate the rate constant for the following gas-phase reaction:
   a. $FH + Cl \rightarrow FHCl \rightarrow F + HCl$
9. Find the transition state of silane formation is given below:
   a. $SiH_4 \rightarrow SiH_2 + H_2$
10. To calculate ΔH^o and ΔG^o of the given reaction using HF/STO-3G

$$C_2H_5^{\bullet} + H_2 \rightarrow C_2H_6 + H^{\bullet}$$

$$C_2H_4 + H_2 \rightarrow C_2H_6$$

Recommended Books:

- D. C. Young, *Computational Chemistry: A Practical Guide for Applying Techniques to Real-World Problems*, John Wiley, 2001.
- D. W. Rogers, *Computational Chemistry Using the PC*, Ed: 3rd, John Wiley, 2003.
- C. J. Cramer, *Essentials of Computational Chemistry Theories and Models*, Ed: 2nd, John Wiley, 2004.
- R. Leach, *Molecular Modelling: Principle and Applications*, Longman, 2001.
- N. Levine, *Quantum Chemistry*, 7th Ed., Pearson, **2014**.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	1		3	1	1		1	2	2	3	1	3
CO2	3	2	1		2	1	3		1	3	1	2	2	3
CO3	3	1	2		3	1	1		2	3	2	2	2	3
CO4	3	1	1		3	1	1		1	3	2	2	1	3
CO5	3	1	1		3	1	2		1	3	2	2	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VII	Major (Level 5)	CYUGMJT1	Advanced Inorganic Chemistry-II	Theory 4 (60 Lectures)
		CYUGMJL1	Advanced Inorganic Chemistry-II (Lab)	Practical: 1 (30 Hours)

CYUFMJT1: Advanced Inorganic Chemistry-II

Level 5, Credit 4 (60 Lectures)

Course Outcomes:

After completing this course, students will be able to understand:

Graduate will be understanding:

1. Basics of organometallic chemistry, classification, and applications.
2. Preparations, structures and bonding for organometallic complexes.
3. Catalytic applications of organometallic complexes.
4. Fluxional properties of organometallic compounds.
5. Magnetic properties of inorganic compounds. Magnetic moments and Ground state terms for complexes.

Unit – I: Introduction to Organometallic Chemistry

Definition, Brief history, classification of organometallic compounds on the basis of bond type. Common notation used in organometallic chemistry, concept hapticity of organic ligands, importance organometallic chemistry, organometallic compounds as reagents, additives, and catalysts.

(10 Lectures)

Unit – II: Organometallic Compounds: Preparation, Structure and Bonding

Preparation and Structures of mononuclear and binuclear carbonyls of Cr, Mn, Fe, Co and Ni using VBT. pi-acceptor behaviour of CO (MO diagram of CO to be discussed), synergic effect and use of IR data to explain extent of back bonding. Bonding mode of CO, symmetry of metal carbonyls.

Synthesis and Bonding between metal atoms and organic π-systems: linear (ethylene, allyl, butadiene) and cyclic (cyclopentadiene, benzene), Zeise's salt and comparison of synergic effect with that in carbonyls. Metal alkyls and metal-carbene complexes

Cyclopentadienyl complexes: Preparation of metallocenes and their derivatives, Some properties of ferrocene molecule, Strcture and bonding in ferrocene molecule, Ionic cyclopentadienyl compounds.

(16 Lectures)

Unit – III: Catalysis by Organometallic Compounds

A) General principles of catalysis, properties of catalysts, homogeneous and heterogeneous catalysis, deactivation and regeneration of catalysts (catalytic poisons and promoter).

B) Organometallic catalysis of the following reactions importance and their mechanism:

Alkene hydrogenation (using Wilkinson's Catalyst), Synthetic gasoline preparation (Fischer Tropsch reaction), Polymerization of ethane using Ziegler-Natta catalyst, Wacker oxidation process (Smidth process), Hydroformylation reaction (Oxo-process) and Monsanto Acetic acid process, Asymmetric catalysis.

(16 Lectures)

Unit – IV: Fluxional Organometallic Compounds (Structural non-rigidity)

General introduction, Classification of Fluctional Organometallic Compounds, Some simple examples of non-rigid molecules in different coordination geometries.

(6 Lectures)

Unit – V: Magnetochemistry

Introduction and basic concepts of Magnetism: Definition, Units and Origin of magnetism, Instrumentation (VSM, SQUID), Experimental Measurement of Magnetic Susceptibility. Classes of Magnetism- Diamagnetism- Paramagnetism, Classes of Paramagnetism, Zeeman effect, Temperature dependence of Magnetic Susceptibility, The Curie Law and the Curie-Weiss Law, Calculating magnetic susceptibilities by Van Vleck equation.

Magnetic moments and Ground state terms: Magnetic moments of first row transition metal ions and their orbital contribution to the magnetic moment, High spin octahedral transition metal complexes and their magnetic properties with A and E ground terms, Orbital contribution in f-block elements and the magnetic properties of f-block coordination complexes.

(8 Lectures)

Books Recommended

- Organometallic Chemistry: A Unified Approach; R.C. Mehrotra. New Age International Publisher. Second Edition 2020.
- Basic Organometallic Chemistry, B.D. Gupta, A J Elias, Universities Press, Second Edition. 2009
- J. E. Huheey, E. A. Keiter, R. L. Keiter, Okhil K. Medhi , Principles of Structure and Reactivity, 5th Edition ,Pearson India, 2022
- Advanced Inorganic Chemistry, 6ed Paperback – 1 January 2007 by Cotton (Author), Wilkinson (Author), Murillo (Author), Bochmann (Author)
- The Organometallic Chemistry of the Transition Metals. Editor(s): Robert H. Crabtree. Wiley, 2014.
- G. L. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Edition, Pearson India, 2008
- A. G. Sharpe, C. E. Housecroft, Inorganic Chemistry 3rd Edition, Pearson India ,2002
- R. L. Carlin, Magnetochemistry, Springer, 1985.
- O. Kahn, Molecular Magnetism, VCH Publishers, 1993.
- R. L. Dutta, A. Syamal, Elements of Magnetochemistry, Affiliated East-West Press, 2004.

CYUFMJL1: Advanced Inorganic Chemistry-II (Lab)

Level – 5 (Credit – 1, 30 Hours)

Determination of

1. Available oxygen in pyrolusite
2. Available chlorine in bleaching powder
3. Estimation of Ca and Mg in Dolomite
4. Estimation of Cr and Mn in steel. Calculation of error percentage in the above experiments

Spectrophotometry

5. Measurement of 10Dq by spectrophotometric method
6. To separate a mixture of Ni^{2+} and Fe^{3+} by complexation with DMG and extracting the Ni^{2+}-DMG complex in chloroform, and determine its concentration by spectrophotometry.
7. Determination of λmax of $[Mn(acac)^3]$ and $[Fe(acac)^3]$ complexes

Recommended Books/References:

- L. Carlin, Magnetochemistry, Springer, 1985.
- O. Kahn, Molecular Magnetism, VCH Publishers, 1993.
- R. L. Dutta, A. Syamal, Elements of Magnetochemistry, Affiliated East-West Press, 2004.
- C. Benelli and D. Gatteschi, Introduction to Molecular Magnetism, Wiley-VCH Verlag GmbH & Co. KGaA, Weinhei

Course Outcomes and their mapping with Programme Outcomes

PO CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	1		3	1	1		1	2	2	3	1	3
CO2	2	2	1		2	1	2		1	3	2	2	2	3
CO3	3	1	2		3	1	1		2	3	2	3	2	3
CO4	3	1	1		3	1	1		1	3	2	2	1	3
CO5	3	1	1		3	1	2		1	3	2	2	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VII	Major (Level 5)	CYUGMJT2	Fundamentals of Molecular Spectroscopy	Theory 4 (60 Lectures)
			Fundamentals of Molecular Spectroscopy (Tutorial)	Tutorial: 1 (15 Hours)

CYUGMJT2: Fundamentals of Molecular Spectroscopy

Level 5, Theory Credit 4 (60 Lectures)
Tutorial Credit 1 (15 Hours)

Unit – I: Unifying Principles

Electromagnetic radiation, interaction of electromagnetic radiation with matter, absorption, emission, transmission, reflection, refraction, dispersion, polarization, and scattering. Uncertainty relation and natural line width and natural line broadening, transition probability, result of the time dependent perturbation theory, transition moment selection rules, intensity of spectral line. Born-Oppenheimer approximation, rotational, vibrational, and electronic energy levels. Fourier Transform Spectroscopy.

(10 Lectures)

Unit – II: Microwave Spectroscopy

***Rotational spectroscopy*:** Classification of molecules, rigid rotor model, selection rule, intensity of spectral line, effect of isotopic substitution on the transition frequencies, intensities, non-rigid rotor. Stark effect nuclear and electron spin interaction and effect of external field. Applications (determination of bond lengths of diatomic and linear triatomic molecules *etc*.)

(10 Lectures)

Unit – III: Vibrational Spectroscopy

A. *Infrared Spectroscopy*: Review of linear harmonic oscillator, vibrational energies of diatomic molecules, zero-point energy, force constant and bond strength; anharmonicity, Morse potential energy diagram, vibration-rotation spectroscopy, P, Q, R branches. Breakdown of Oppenheimer approximation; vibration of polyatomic molecules. Selection rules, normal modes of vibration, group frequencies, overtones, hot bands, factor affecting the band positions and intensities, far IR region, metal-ligand vibrations, normal co-ordinate analysis. Fourier Transform Infra-red Spectroscopy (FTIR)

B. *Raman Spectroscopy*: Classical and quantum theories of Raman Effect, pure rotational, vibrational, and vibrational-rotational Raman spectra, selection rules, mutual exclusion principle. Resonance Raman spectroscopy, coherent anti-stokes Raman spectroscopy (CARS).

(10 Lectures)

Unit – IV: Electronic Spectroscopy

A. *Atomic Spectroscopy*: Energies of atomic orbitals, vector representation of momenta and vector coupling, spectra of hydrogen atom and alkali metal atoms.

B. *Molecular Spectroscopy*: Energy levels, molecular orbitals, vibranic transition, vibrational progressions and geometry of excited state, Franck-Condon principle, electronic spectra of polyatomic molecules. Emission spectra; radiative and non-radiative decay, internal conversion, spectra of transition metal complex, charge transfer spectra.

C. *Photoelectron Spectroscopy*: Basic principle; photo-electronic effect, ionization process, Koopman's theorem. Photoelectron spectra of simple molecules, ESCA, chemical information from ESCA, basic idea of Auger electron spectroscopy.

(10 Lectures)

Unit – V: Magnetic Resonance, Photoacoustic, and Mössbauer Spectroscopy

A. *Nuclear Magnetic Resonance Spectroscopy*: Nuclear spin, nuclear resonance, saturation, shielding of magnetic nuclei, chemical shift and its measurement, factors influencing chemical shift, deshielding, spin-spin interaction, factors influencing coupling constant 'J'. Classification (ABX, AMX, ABC, A_2B_2 etc), spin decoupling; basic idea about instrument, NMR studies of nuclei other than proton – 13C, 19F, and 31P; FT NMR, advantage of FT NMR, use of NMR in medical diagnostics.

B. *Electron Spin Resonance Spectroscopy*: Basic principles, zero field splitting and Kramer's degeneracy, factors affecting the 'g' value. Isotropic and anisotropic hyperfine coupling constants, spin Hamiltonian, spin densities and McConnell relationship, measurement techniques, applications.

C. *Nuclear Quadrupole Resonance Spectroscopy*: Quadrupole nuclei, quadrupole moments, electric field gradient, coupling constant, splitting, applications.

D. *Photoacoustic Spectroscopy*: Basic principles of photoacoustic spectroscopy (PAS). PAS-gases and condensed systems, chemical and surface applications.

E. *Mössbauer Spectroscopy*: Basic principles, spectral parameters and spectrum display. Application of technique to the studies of (i) bonding and structure of Fe^{2+} and Fe^{3+} compounds – nature of M-L bond, coordination number, structure and (ii) detection of oxidation state and inequivalent MB atom.

(20 Lectures)

Recommended Books/References:

- T. Engle and P. Reid: *Quantum Chemistry and Spectroscopy*, Pearson, New Delhi, 2011.
- B. K. Sharma: *Instrumental Methods of Chemical Analysis* - 9th Edition.
- William Kemp: *Organic Spectroscopy* –3rd Edition.
- C. N. Banwell and E. M. McCash: *Fundamentals of Molecular Spectroscopy*, Ed. 4th, Tata McGraw-Hill, 1994.
- G. M. Barrow: *Introduction to Molecular Spectroscopy*

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	1		3	1	1		1	2	2	3	1	3
CO2	2	2	1		3	1	2		1	3	2	2	2	3
CO3	3	1	2		3	1	1		2	3	2	3	2	1
CO4	3	1	1		3	1	1		1	3	2	2	1	3
CO5	3	1	1		3	1	2		1	3	2	2	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VII	Major (Level 5)	CYUGMJT3	Analytical Chemistry	Theory 4 (60 Lectures)
		CYUGMJL3	Analytical Chemistry (Lab)	Practical: 1 (30 Hours)

CYUGMJT3: Analytical Chemistry

Level 5, Theory Credit 4 (60 Lectures)

Course Outcomes:

After completing this course, students will be able to understand:

1. Basic of analytical methods, sample processing and steps involved in quantitative analysis.
2. Basics of quality control, quality process models and process tools and charts.
3. Basics of solvent extraction and chromatographic techniques and their analytical applications.
4. Basics of precipitation, types of precipitates, conditions for precipitation and contamination in precipitates.
5. Principal and applications of thermal (thermogravimetry); Various types of analytical separation techniques and their separation mechanism

Unit – I: Analytical Methods

Analytical chemistry and chemical analysis, Classification of analytical methods. The tools of analytical chemistry and good lab practices. Method selection, Sample processing, Steps in quantitative analysis, Quantitative range (bispartite classification), Analytical validations, Limit of detection and limit of quantitation, and analytical chemometrics.

(13 Lectures)

Unit – II: Quality Control in Analytical Chemistry

Elements of quality assurance, quality assurance in design, development, production and services, quality and quantity management system, ISO 9000 and ISO 14000 series-meaning of quality, quality process model, customer requirement of quality calibration and testing, statistical process control, process control tools, control chart, statistical quality control, acceptance sampling, quality control-principles of Ruggedness test.

(13 Lectures)

Unit – III: Solvent Extraction and Chromatography

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 techniques: 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 using LC, GLC, TLC and HPLC.

(15 Lectures)

Unit – IV: Precipitation

Desirable properties of gravimetric precipitates, Formation of gravimetric precipitates, Conditions for quantitative precipitations, Contamination in precipitates, Method for removal of impurities in precipitates, Steps involved in quantitative precipitation, Organic precipitants (oxime, dithizone, α-nitroso-(naphthol, cooperon, dimethyl glyoxime) in chemical analysis.

(13 Lectures)

Unit – V: Thermal Analysis

Theory of thermogravimetry (TG and DTG), instrumentation, estimation of Ca and Mg from their mixture.

(6 Lectures)

Recommended Books/References:

1. Skoog D.A., Holler F.J., Nieman T.A., Principles of instrumental analysis, 5thEdn., Brooks & Cole (1997).
2. Christian, G.D, *Analytical Chemistry*, 6th Ed. John Wiley & Sons, New York, 2004.
3. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6th Ed.,* Pearson,2009.
4. Willard, H.H. *et al.*: *Instrumental Methods of Analysis*, 7th Ed. Wardsworth Publishing California, USA,1988.
5. Harris, D.C.: *Exploring Chemical Analysis*, 9th Ed. New York, W.H. Freeman,2016.
6. Skoog, D.A. Holler F.J. & Nieman, T.A. *Principles of Instrumental Analysis, Saunder College Publications (1998).*
7. Mikes, O. *Laboratory Handbook of Chromatographic & Allied Methods*, Elles Harwood John Wiley1979.
8. Ditts, R.V. Analytical Chemistry; Methods of Separation, van Nostrand,1974.
9. Khopkar, S. M., Basic Concepts of Analytical Chemistry, New Age (Second edition)1998

CYUGMJL3: Analytical Chemistry

Level – 5 (Credit – 1, 30 Hours)

I. Chromatography:

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

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

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

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

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

II. **Solvent Extractions:**

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

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

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

Note: Experiments may be added/deleted subject to availability of time and facilities

Recommended Books/References:

1. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6th Ed.,* Pearson, 2009.
2. Willard, H.H. *et al.*: *Instrumental Methods of Analysis*, 7th Ed. Wards worth Publishing Company, Belmont, California, USA, 1988.
3. Christian, G.D. *Analytical Chemistry*, 6th Ed. John Wiley & Sons, New York, 2004.
4. Harris, D.C. *Exploring Chemical Analysis*, 9th Ed. New York, W.H. Freeman, 2016.
5. Khopkar, S.M. *Basic Concepts of Analytical Chemistry*. New Age International Publisher, 2009.
6. Skoog, D.A. Holler F.J. and Nieman, T.A. *Principles of Instrumental Analysis*, Cengage Learning India Edition.
7. Mikes, O. & Chalmes, R.A. *Laboratory Handbook of Chromatographic & Allied Methods*, Elles Harwood Ltd. London.
8. Ditts, R.V. *Analytical Chemistry: Methods of separation.* Van Nostrand, New York, 1974.

Course Outcomes and their mapping with Programme Outcomes

PO CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	1		3	1	1		1	2	2	3	1	3
CO2	2	2	1		3	1	2		1	3	2	2	2	3
CO3	3	1	2		3	2	1		2	3	2	3	2	3
CO4	3	1	3		3	1	1		1	3	2	2	1	3
CO5	3	1	1		3	1	2		1	3	2	2	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VIII	Major (Level 5)	CYUHMJT1	Advanced Spectroscopy for Structural Determination	Theory 4 (60 Lectures)
			Advanced Spectroscopy for Structural Determination (Tutorial)	Tutorial: 1 (15 Hours)

CYUHMJT1: Advanced Spectroscopy for Structural Determination

Level 5, Theory Credit 4+Tutorial 1 (15 Lectures)

Course Outcomes:

Learners shall be able to understand the following upon completion of the course:

1. Basic concepts of UV-Vis, IR, NMR spectroscopy
2. An overview of spectroscopic instruments, their advancement, and limitations
3. Identification of functional groups and molecular skeleton
4. Basic concept and various fundamental rules of Mass spectrometry
5. Structure elucidation of unknown organic compounds using Spectroscopic techniques

Spectroscopic Techniques for Organic Structure Determination (UV-Vis, IR, and NMR)

Unit – I: *UV-Vis* Spectroscopy*:* Electromagnetic radiation, UV Spectroscopy – Electronic transitions, auxochromes, chromophores, bathochromic and hypsochromic shift, Wood words-Fieser rule for calculating λmax for conjugated dienes and α,β-unsaturated aldehydes and ketones. Interpretation of UV spectra.

(10 Lectures)

Unit – II: *IR* Spectroscopy*:* Vibration modes and bond stretching. Absorption of common functional groups, Factors affecting vibrational frequency, effects of Hydrogen bonding. Fingerprint region and interpretation of IR spectra.

(10 Lectures)

Unit – III: *NMR* Spectroscopy*:* NMR phenomenon, processional motion, Chemical shift, Shielding and de-shielding effects, Spin-spin splitting, Coupling constant, Interpretation of NMR spectra.

(12 Lectures)

Unit – IV: Mass Spectrometry: Introduction, ion production-EI, CI, FD and FAB, factors affecting fragmentation, ion analysis, ion abundance. Mass spectral fragmentation of organic compounds, common functional groups, molecular ion peak, metastable peak, McLafferty rearrangement. Nitrogen rule, example of Mass fragmentation of organic compounds with respect to their structure determination. Problems based on spectroscopic techniques

(12 Lectures)

Unit – V: Structural elucidation using spectroscopic methods

(16 Lectures)

Recommended Books/References:

- T. Engle and P. Reid: Quantum Chemistry and Spectroscopy, Pearson, New Delhi, 2011.
- B. K. Sharma: Instrumental Methods of Chemical Analysis - 9th Edition.
- William Kemp: Organic Spectroscopy –3rd Edition.
- C. N. Banwell and E. M. McCash: Fundamentals of Molecular Spectroscopy, Ed. 4th, Tata McGraw-Hill, 1994.
- G. M. Barrow: Introduction to Molecular Spectroscopy

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	1		3	1	1		1	2	2	3	1	3
CO2	2	1	3		3	1	2		1	3	2	2	2	3
CO3	3	1	2		3	2	1		2	2	2	3	3	3
CO4	3	1	3		3	1	1		1	3	2	2	1	3
CO5	3	1	1		3	1	2		1	3	2	2	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

Chemistry Major Courses (Optional)

Semester	Nature of Course	Course Code	Name of the course	Credits
VIII	Major (Optional) (Level 5)	CYUHMJT2	Introduction to Nanomaterials and Nanotechnology	Theory 4 (60 Lectures)
		CYUHMJL2	Introduction to Nanomaterials and Nanotechnology (Lab)	Practical: 1 (30 Hours)

CYUHMJT2: Introduction to Nanomaterials and Nanotechnology

Level 5, Theory Credit 4 (60 Lectures)
Lab Credit 1 (30 Hours)

Course Outcomes:

After completing this course, the learner will be able to:

1. Why nanoscience and nanotechnology is important.
2. Characterization techniques of nanomaterials
3. Synthesis of nanomaterials.
4. Properties of nanomaterials.
5. Recent research and nanomaterials-based applications.

Unit – I: Nanoscience and Nanotechnology

***Introduction*:** Underlying physical principles of nanotechnology: *Nanostructured Materials: Size is Everything*. Fundamental physicochemical principles, size and dimensionality effects; quantum confinement; properties dependent on density of states; central importance of nanoscale morphology. Societal aspects of nanotechnology: health, environment, hype and reality.

***Type of Nanostructures*:** Definition of a nano system; one dimensional (1D), two dimensional (2D), three dimensional (3D) nanostructured materials; quantum dots; quantum wire, and core/shell structures.

(10 Lectures)

Unit – II: The Basic Tools of Nanotechnology

Electron microscopy (SEM, TEM with EDX analysis) and X-ray diffraction, A brief historical overview of atomic force microscopy (AFM); an introduction and basic principles & applications of XPS, UV-VIS principle and application for band gap measurement.

(15 Lectures)

Unit – III: Synthesis of Nanomaterials

Top down and bottom-up approaches to synthesis of nanomaterials:

***Chemical Routes for Synthesis of Nanomaterials*:** Chemical precipitation and co-precipitation; sol-gel synthesis; microemulsions or reverse micelles; solvothermal synthesis; thermolysis routes, microwave heating synthesis biomimetic and electrochemical approaches; sonochemical synthesis; photochemical synthesis; synthesis in supercritical fluids.

***Physical Routes for Preparation of Nanomaterial*:** Inert gas condensation, arc discharge, RF plasma, plasma arc technique, ion sputtering, laser ablation, laser pyrolysis, spray pyrolysis, ball milling, molecular beam epitaxy, chemical vapor deposition method, Langmuir-Blodgett (LB) films, spin coating and electro deposition.

(10 Lectures)

Unit – IV: Nanomaterials and Properties

Synthesis and size dependent properties (mechanical, physical and chemical properties) of carbon nanotubes (CNT); metals (Au, Ag); metal oxides (TiO2, CeO2, ZnO); semiconductors (Si, Ge, CdS, ZnSe); dilute magnetic semiconductor.

(10 Lectures)

Unit -V: Applications of Nanomaterials

Basic ideas of nanodevices (molecular electronics and nanoelectronics, and quantum electronic devices); CNT based transistor and field emission display; biological applications; biochemical sensor; membrane-based water purification, energy storage devices, catalysis, and various related fields. Journal paper presentation from any recent work of metal, oxide, nitride, sulfide, etc., -based nanosystems.

(15 Lectures)

Recommended Books/References:

- G. Cao, *Nanostructures and nanomaterials synthesis, properties and applications*, Imperial College Press, London, **2004**.
- G. L. Hornyak, J. J. Moore, H. F. Tibbals and J. Dutta, *Fundamentals of Nanotechnology*, 1st Ed., CRC Press, **2008**.
- T. Pradeep, *A textbook of Nanoscience and Nanotechnology*, MsGraw-Hill Education, **2015**.
- T. Pradeep, *NANO: The Essentials: Understanding Nanoscience and Nanotechnology*, 1st Ed., McGraw Hill Education, **2017**.
- B. D. Cullity, *Elements of x-ray diffraction*, 2nd Ed., Addison-Wesley Publishing Company Inc, California, **1978**.
- J. I. Goldstein, D. E. Newbury, J. R. Michael, N. W. M. Ritchie, J. H. J. Scott and D. C. Joy, *Scanning Electron Microscopy and X-Ray Microanalysis*, 4th Ed., Springer, New York, **2018**.
- D. B. Williams and C. B. Carter, *Transmission electron microscopy: a textbook for materials science*, Plenum Press, New York, **1996**.

CYUHMJL2: Introduction to Nanomaterials and Nanotechnology (Lab)

Credit 1 (30 Hours)

- Verification of the Beer-Lambert law using gold/silver nanoparticles.
- Preparation and characterization of nanomaterials by bottom-up with special reference to wet chemical strategies (sol-gel, reverse micelles, hydrothermal, co-precipitation, solid-state chemistry, *etc*.)
- Synthesis and characterization of nanomaterials by top-up approaches (ball milling, grinding, *etc*.)
- Synthesis and characterization of core-shell nanocomposite (bimetallic and oxides)
- Synthesis and characterization of mixed metal oxide (bimetallic and oxides)
- Studies of catalytic conversion (e.g. *p*-nitrophenol to *p*-aminophenol) using nanoparticles.
- Determination of the band gap of semiconductor nanomaterials.
- Study of surface enhanced Raman scattering activity of silver nanostructures.
- Study of photocatalytic dye degradation by using nanomaterials.

Some others experiment based on the application of nanomaterials may be carried out in the class if permitted.

Recommended Books:

- G. E. J. Poinern, *A Laboratory Course in Nanoscience and Nanotechnology*, CRC Press, **2015**.
- T. Pradeep, *A textbook of Nanoscience and Nanotechnology*, MsGraw-Hill Education, **2015**.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		3	1	1		1	3	2	3	1	3
CO2	3	1	2		3	1	1		1	3	2	3	1	3
CO3	3	1	2		3	1	1		1	3	2	3	1	3
CO4	3	1	2		3	1	1		1	3	2	3	1	3
CO5	3	1	2		3	1	1		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VIII	Major (Optional) (Level 5)	CYUHMJT3	Modern Physical Methods in Chemistry Research	Theory 4 (60 Lectures)
			Modern Physical Methods in Chemistry Research (Tutorial)	Tutorials: 1 (15 Hours)

CYUHMJT3: Modern Physical Methods in Chemistry Research

Level 5, Theory Credit 4 (60 Lectures)
Tutorials Credit 1 (15 Lectures)

Course Outcomes:

After completing this course, the learner will be able to:

1. Principles of spectroscopy and interaction of light with matter.
2. The basics of rotational and vibrational spectroscopy
3. Spin resonance spectroscopy and electronic spectroscopy.
4. XRD and Mössbauer analysis.
5. Brief idea of electron spectroscopy and other imaging techniques.

Unit – I: General Principles

Electromagnetic radiation, interaction of electromagnetic radiation with matter, absorption, emission, transmission, reflection, refraction, dispersion, polarization, and scattering. Uncertainty relation and natural line width and natural line broadening, transition probability, result of the time dependent perturbation theory, transition moment selection rules, intensity of spectral line. Born-Oppenheimer approximation, rotational, vibrational, and electronic energy levels. Fourier Transform Spectroscopy.

(12 Lectures)

Unit – II: Rotational and Vibrational Spectroscopy

Review of Microwave, Infrared Spectroscopy, FTIR, and Raman Spectroscopy

(12 Lectures)

Unit – III: Electronic Spectroscopy and Magnetic Resonance Spectroscopy

Electronic Spectroscopy: Atomic Spectroscopy Molecular Spectroscopy and Photoelectron Spectroscopy

Magnetic Resonance Spectroscopy: Nuclear Magnetic Resonance Spectroscopy; Electron Spin Resonance Spectroscopy; Nuclear Quadrupole Resonance Spectroscopy

(12 Lectures)

Unit – IV: X-ray Diffraction and Mössbauer Spectroscopy

X-ray Diffraction: Bragg condition, Miller indices, Laue method, Bragg Method, Debye-Scherrer method of X-ray structural analysis of crystals, index reflections, identification of unit cells from systematic absence in diffraction pattern. Structure of simple lattice and X-ray

intensity, structure factor and its relation to intensity and electron density phase problem. Description of the procedure of an X-ray structure analysis.

***Mössbauer Spectroscopy*:** Basic principles, spectral parameters and spectrum display. Application of technique to the studies

(12 Lectures)

Unit – V: Microscopy

Electron microscopy (SEM, TEM with EDX analysis). A brief historical overview of atomic force microscopy (AFM).

(12 Lectures)

Reference Books:

- C. N. Banwell and E. M. McCash: *Fundamentals of Molecular Spectroscopy*, Ed. 4th, Tata McGraw-Hill, 1994.
- B. D. Cullity: *Elements of X-ray Diffraction*, Eds: 2nd, Addison-Wesley, USA, 1959.
- D. B. Williams and C. B. Carter: *Transmission Electron Microscopy: A Textbook for Materials Science*, Plenum Press, New York, 1996.
- S. Hüfner: *Photoelectron Spectroscopy: Principles and Applications*, Springer-Verlog, Germany, 1995.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		3	2	1		1	3	2	3	1	3
CO2	3	1	2		3	1	1		1	3	1	3	1	2
CO3	3	1	2		3	2	1		1	2	2	3	1	3
CO4	3	1	2		3	3	1		1	3	2	3	1	1
CO5	3	1	2		3	1	1		1	1	3	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VIII	**Major (Optional) (Level 5)**	CYUHMJT4	Principles of X-ray Diffraction and Electron Microscope	Theory 4 (60 Lectures)
			Principles of X-ray Diffraction and Electron Microscope (Tutorial)	Tutorials: 1 (15 Hours)

CYUHMJT4: Principles of X-ray Diffraction and Electron Microscope

Level 5, Theory Credit 4 (60 Lectures)
Tutorials Credit 1 (15 Lectures)

Course Outcomes:

After completing this course, the learner will be able to:

1. Crystal system and crystal structure.
2. Symmetry elements in crystals
3. X-ray diffraction and determination of crystal structure.
4. Basic of electron microscopy.
5. SEM and TEM imaging techniques.

Unit – I: Geometry of Crystal Structure

Form of solids, space lattice, seven crystal systems; unit cell, primitive and non-primitive cell, Bravais lattice, lattice direction and crystal planes; Miller indices of crystal planes, separation between crystal planes, reciprocal lattice

Crystal Structure; closed packed structure- hcp and ccp, rack salt (NaCl), Wurzite and zinc blend of ZnS, diamond, CsCl, Fluoride (CaF_2) and antifluoride (Na_2O), Rutile (TiO_2) *etc*.

(12 Lectures)

Unit – II: Point and Space Groups

Symmetry operation and symmetry elements, Plane of symmetry, inversion centre, proper and improper axis of rotation, product of symmetry operation, Relation among symmetry elements and symmetry operation, Thirty-two point groups, representation of point groups with selected examples like 222, mm2, mmm, 32 centrosymmetric and non-centrosymmetric point groups.

Space group: Triclinic P1, monoclinic C2, monoclinic C2/m, orthorhombic $P222_1$ orthorhombic F222, Tetragonal 14_1, space group and crystal structure of perovskite ABO_3 and rutile structure of TiO_2 etc

(12 Lectures)

Unit – III: X-ray Diffraction by Crystal

Properties of X-rays, production and detection of X-ray, diffraction of X-ray by crystal, Bragg's condition, Bragg's law, diffractometer and diffractometer methods (Laue, rotating-crystal, and powder methods), Scherrer formula, scattering of an electron, atom, by a unit cell, structure factor, systematic absence, intensity of powder pattern line.

Determination of crystal structure, chemical analysis by X-ray diffraction, and chemical analysis by X-ray spectroscopy (EDX, energy dispersive X-ray spectroscopy).

(12 Lectures)

Unit – IV: Electron Microscope

Introduction: optical microscope versus electron microscopy, brief history of electron microscope, interaction of electrons and matter, elastic and inelastic scattering of electrons,

Instrument: scanning electron microscope (SEM), transmission electron microscope (TEM); electron source; lenses and lens defects, apertures and resolution, electron detection and display, pumps and sample holders, calibration of imaging system, specimen preparation for TEM

(12 Lectures)

Unit – V: Transmission Electron Microscope

Forming diffraction patterns and images; principle of image contrast, bright field and dark field imaging, and SAED and obtaining SAED, high-resolution TEM, grain boundary, phase boundary, and other imaging techniques.

Reciprocal space; diffraction from crystals; diffraction from particles, and dislocation, indexing of diffraction patterns, Kikuchi diffraction.

(12 Lectures)

References Books:

- A. R. West: *Solid State Chemistry and Its Applications*, John Wiley & Sons, 1989.
- L. Smart and E. Moore, *Solid State Chemistry*, Chapman and Hall, 1992.
- A. K. Cheetham and P. Day: *Solid State Chemistry Compounds*, Clarendon Press, Oxford 1992.
- C. N. R. Rao and J. Gopalkrishanan: *New Directions in Solid State Chemistry*, Cambridge Univ. Press 1997.
- D. B. Williams and C. B. Carter: *Transmission Electron Microscopy: A Textbook for Materials Science*, Plenum Press, New York, 1996.
- B. D. Cullity: *Elements of X-ray Diffraction*, Eds: 2nd, Addison-Wesley, USA, 1959.

Tutorials: **Credit: 01**

- Indexing and calculating of powder XRD pattern for cubic and non-cubic system.
- Indexing of SAED pattern and quantifying and processing of TEM, HRTEM images.

References Books:

- D. B. Williams and C. B. Carter: *Transmission Electron Microscopy: A Textbook for Materials Science*, Plenum Press, New York, 1996.
- B. D. Cullity: *Elements of X-ray Diffraction*, Eds: 2nd, Addison-Wesley, USA, 1959.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		3	2	1		1	3	2	3	1	3
CO2	3	1	1		3	1	1		1	3	1	3	1	2
CO3	3	2	2		1	2	1		2	2	2	3	1	3
CO4	3	1	2		3	3	1		1	3	2	3	2	1
CO5	3	1	1		3	1	1		1	1	3	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VIII	**Major (Optional) (Level 5)**	CYUHMJT5	Supramolecular Chemistry	Theory 4 (60 Lectures)
			Supramolecular Chemistry (Tutorial)	Tutorials: 1 (15 Hours)

CYUHMJT5: Supramolecular Chemistry

Level 5, Theory Credit 4 (60 Lectures)
Tutorials Credit 1 (15 Lectures)

Course Outcomes:

After completing this course, the learner will be able to:

1. Basic aspects of supramolecular chemistry.
2. Crown ethers and their derivatives
3. Macrobicyclic compounds and applications
4. Synthesis and applications of cryptands.
5. Synthesis of dendrimers and applications.

Unit – I: Introduction

Introductory remarks and relevance of study. The original meaning of "Supramolecular Chemistry" and how it has changed over the years to include various systems of study. Various intermolecular interactions and the meaning of molecular recognition. Concepts of positive and negative cooperativity. Thermodynamic treatment of molecular recognition. Introduction of supramolecular synthons, synthesis of macrocycles, thermodynamic and kinetic template effects.

(12 Lectures)

Unit – II: Macrocyclic Compounds and Applications

Macrocyclic effects and stability, crown ethers and lariat crown ethers, thermodynamic and kinetic stability of complexes. Calixarenes and the art of molecular basket making, conformational flexibility of calixarenes at room temperature and their binding characteristics. Hybrids of calixarenes and their uses. Cucurbiturils of different sizes and their characteristics. Use of cucurbiturils in chemical reactions. Cyclodextrins and their structural characteristics as supramolecular reaction vessels.

(12 Lectures)

Unit – III: Macrobicyclic and Applications

Macrobicyclic cryptands with structural characteristics. Synthesis: strategy and methodology. Rigidity and conformational lability of cryptands, layer effects. Synthesis of cryptands and cryptates of cations and anions and the cryptate effects. Mononuclear and multinuclear cryptates of transition metal ions and their uses in homogeneous catalysis. Examples of recent developments in homogeneous catalysis from current literature.

(12 Lectures)

Unit – IV: Cyclophanes and Cryptophanes

Cyclophanes and cryptophanes. Inclusion of non-polar organic molecules and other properties. Spherands and their synthesis and metal binding properties. Dendrimers and their structural characteristics.

Molecular devices: molecular electronic devices, molecular wires, molecular rectifiers, molecular switches, molecular logic.

(12 Lectures)

Unit – V: Dendrimers, Synthesis and Applications

Synthesis of dendrimers by divergent and convergent methods. Binding properties of dendrimers and mimicry of metalloproteins' active sites, catalysis. Interlocked structures of different designs: pseudo-rotaxanes, rotaxanes, molecular shuttle.

Metal helicates, catenanes and catenates, trefoil knots. Synthesis of these complex structures via metal templating and p-p stacking interactions.

(12 Lectures)

References Books:

- J. -M. Lehn, *Supramolecular Chemistry-Concepts and Perspectives*, Wiley-VCH, **1995**.
- D. Beer, P. A. Gale, D. K. Smith, *Supramolecular Chemistry*, Oxford University Press, **1999**.
- W. Steed and J. L. Atwood, Supramolecular Chemistry, Wiley, **2000**.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	3		3	2	1		1	3	2	3	1	3
CO2	3	1	2		3	1	1		1	3	1	3	1	2
CO3	3	2	2		1	2	1		2	2	2	3	1	3
CO4	3	1	3		3	3	1		1	3	2	3	2	1
CO5	3	1	1		3	1	1		1	1	3	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VIII	Major (Optional) (Level 5)	CYUHMJT6	Self-Assembly and Supramolecular Architectures	Theory 4 (60 Lectures)
		CYUHMJL6	Self-Assembly and Supramolecular Architectures (Lab)	Lab: 1 (30 Hours)

CYUHMJT6: Self-Assembly and Supramolecular Architectures

Level 5, Credit 4 (60 Lectures)
Lab Credit 1 (30 hours)

Course Outcomes:

Learners shall be able to understand the following upon completion of the course:

1. Principles of non-covalent interactions (e.g., hydrogen bonding, π–π stacking, van der Waals, etc.) and their role in the formation of supramolecular assemblies.
2. Design host molecules for selective guest binding and analyze thermodynamic parameters and binding constants using modern techniques.
3. Self-assembly processes and apply them in developing supramolecular structures like molecular cages, frameworks, and interlocked molecules.
4. Supramolecular systems in real-world applications, including molecular machines, chemical sensors, drug delivery systems, and sustainable energy materials.
5. Supramolecular catalytic systems, and mimic enzyme-like catalysis, contributing to green and sustainable chemistry innovations.

Unit – I: Introduction

Historical background and development; Key definitions: supramolecular chemistry, host, guest, molecular recognition; Nature of non-covalent interactions: electrostatic forces (ion–ion, ion–dipole, dipole–dipole), hydrogen bonding, halogen bonding, van der Waals interactions, π–π stacking, hydrophobic and hydrophilic interactions; Thermodynamic and kinetic aspects of supramolecular interactions; Concept of molecular complementarity and preorganization.

(15 Lectures)

Unit – II: Host–Guest Chemistry and Molecular Recognition

Principles of host–guest complexation; Binding constants, stoichiometry, and selectivity; Chelate effect, cooperativity, enthalpic and entropic contributions; Determination of complex geometry and stability; Molecular recognition mechanisms: lock-and-key, induced fit, allosteric regulation; Design and synthesis of common host molecules: crown ethers, cryptands, spherands, podands, Calixarenes, cyclophanes, cucurbiturils, cyclodextrins.

(10 Lectures)

Unit – III: Self-Assembly

Concepts of self-assembly and self-organization; Types of self-assembly: static vs. dynamic; Supramolecular aggregates: micelles, vesicles, bilayers, gels; Self-assembly in coordination compounds; Multicomponent and hierarchical self-assembly; Dynamic covalent chemistry: imines, boronic esters, hydrazones; Discrete supramolecular systems: metal-organic cages, covalent organic cages; Mechanically interlocked molecules: rotaxanes, catenanes, molecular knots.

(15 Lectures)

Unit – IV: Supramolecular Materials and Applications

Supramolecular polymers, dendrimers, and gels; Extended frameworks: MOFs, COFs; Applications in: drug delivery, molecular sensors, membrane transport, phase-transfer catalysis; Molecular machines and motors; Supramolecular devices: switches, logic gates, data storage; Energy applications: light-harvesting systems, artificial photosynthesis, solar cells.

(10 Lectures)

Unit – V: Supramolecular Catalysis

Concepts and mechanisms of supramolecular catalysis; Catalysis by macrocyclic hosts: crown ethers, cyclodextrins, calixarenes; Supramolecular metallocatalysis; Host–guest catalysis: preorganization and effective molarity; Hydrogen bonding and anion-binding catalysis; Molecular containers and encapsulation catalysis; Supramolecular mimicry of enzymatic functions (e.g., ATPase mimics); Emerging trends in catalytic supramolecular systems.

(10 Lectures)

Recommended Books/References:

- J. M. Lehn, *Supramolecular Chemistry*, VCH, Weinheim, **1995**.
- J. W. Steed & J. L. Atwood, *Supramolecular Chemistry*, 2ndEdn John Wiley, **2009**.
- P. D. Beer, P. A. Gale, D. K. Smith; *Supramolecular Chemistry*, Oxford University Press, **1999**.
- F. Diederich, P. J. Stang, R. T, *Modern Supramolecular Chemistry*, Tykwinski, **2008**.
- G. W. Gokel (Editor), *Advances in Supramolecular Chemistry*, JAI Press, Greenwich, Vol 1 (**1990**), Vol 2 (**1992**), Vol 3 (**1993**).
- T. Kunitake, K Ariga, *Supramolecular Chemistry – Fundamentals and Applications*, Berlin: Springer-Verlag Heidelberg, **2006**.

CYUHMJL6: Self-Assembly and Supramolecular Architectures (Lab)

Credit 1 (30 Hours)

1. Synthesis of macrocycles (Schiff Base or Crown Ether Type).
2. Synthesis and characterization of supramolecular cage architectures (Imine-based organic cage).
3. UV-Vis study of host–guest complexation.
4. Metal ion detection and binding by molecular hosts.
5. Calculation of binding constant (K_a) from UV-Vis data.

Recommended Books:

- Jonathan W. Steed and Jerry L. Atwood, *Supramolecular Chemistry*, 2nd Edition, Wiley, **2009**.
- Hans-Jörg Schneider and A. Yatsimirsky, *Principles and Methods in Supramolecular Chemistry*, 1st Edition, John Wiley & Sons, **2000**.
- Katsuhiko Ariga and Toyoki Kunitake, *Supramolecular Chemistry – Fundamentals and Applications: A Textbook*, 1st Edition, Springer, **2006**.
- Thomas M. Devlin, *Textbook of Biochemistry*.
- Jeremy M. Berg, John L Tymoczko, Lubert Stryer, *Biochemistry*.
- John Leonard, Barry Lygo, and Garry Procter, *Advanced Practical Organic Chemistry*, 3rd Edition, CRC Press (Taylor & Francis Group), **2013**.
- Douglas A. Skoog, F. James Holler, and Stanley R. Crouch, *Principles of Instrumental Analysis*, 7th Edition, Cengage Learning, **2017**.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	3		3	2	1		1	3	2	3	1	3
CO2	3	1	2		3	1	1		1	3	1	3	1	2
CO3	3	2	2		1	2	1		2	2	2	3	1	3
CO4	3	1	3		3	3	1		1	3	2	3	1	1
CO5	3	1	3		3	1	1		1	1	3	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VIII	Major (Optional) (Level 5)	CYUHMJT7	Photo-Organic Chemistry	Theory 4 (60 Lectures)
		CYUHMJL7	Photo-Organic Chemistry (Lab)	Lab: 1 (30 Hours)

CYUHMJT7: Photo-Organic Chemistry

Level 5, Credit 4 (60 Lectures)
Lab Credit 1 (30 Hours)

Course Outcomes:

Learners shall be able to understand the following upon completion of the course:

1. Describe the photo-induced free radical reactions with examples with interaction of excited states with their surroundings.
2. Describe the photochemical intermolecular reactions and C-C bond formation, carbonyl chemistry and name reactions.
3. Explain photochemical intramolecular and intermolecular hydrogen transfer and influence of surroundings during H-transfer process.
4. Describe fundamental, symmetry conservations and theories with examples of cycloaddition reactions.
5. Describe fundamental, symmetry conservations and theories with examples of Sigmatropic reactions.

Unit – I: Free radical reactions

Types of free radical reactions, detection by ESR, free radical substitution mechanism, mechanism at aromatic substrates, neighbouring group assistance. Reactivity for aliphatic and aromatic substitution at a bridge head. Reactivity in attacking radicals. The effect of solvent on reactivity. Allylic hydrogenation (NBS), Oxidation of aldehydes to carboxylic acids, auto-oxidation, coupling of alkynes and arylation of aromatic compounds by diazonium salt, Sandmeyers reaction. Free radical rearrangement, Hunsdiecker reaction; Photochemistry of (π, $\pi*$) transitions: Excited state of alkenes, cis-trans isomerisation, photochemistry state, di π-methane rearrangement.

(12 Lectures)

Unit – II: Intermolecular reactions

Photocycloadditions, photodimerization of sample and conjugated olefins, addition of olefins to α, β unsaturated carbonyl compounds, excimers and exciplexes. Photoaddition reactions. Excited states of aromatic compounds, photodimerization of benzene, photo substitution reactions of aromatic compounds and Photo-Fries rearrangement, Paterno-Buchi reaction, photodecarboxylation, photochemistry of alkyl peroxides, hypohalites and nitriles. Barton reaction. Photochemistry of azo compounds, diazo compounds, azides and diazonium salts.

Singlet oxygen-photo oxygenation reactions. Carbonyl Chemistry: Excited state of carbonyl compounds, haemolytic cleavage of α-bond-Norrish type I reaction in acyclic, cyclic ketones and strained cyclo-alkanedione.

(12 Lectures)

Unit – III: Intermolecular and Intramolecular abstraction of hydrogen

Concepts of self-assembly and self-organization; Types of self-assembly: static vs. dynamic; Supramolecular aggregates: micelles, vesicles, bilayers, gels; Self-assembly in coordination compounds; Multicomponent and hierarchical self-assembly; Dynamic covalent chemistry: imines, boronic esters, hydrazones; Discrete supramolecular systems: metal-organic cages, covalent organic cages; Mechanically interlocked molecules: rotaxanes, catenanes, molecular knots.

(6 Lectures)

Unit – IV: Pericyclic Reactions-I

7 Features and classification of pericyclic reactions, Phases, nodes and symmetry properties of molecular orbital in ethylene, 1,3-butadiene, 1,3,5-hexatriene. allyl cation, allyl radical, pentadienyl cation and pentadienyl radical, Thermal and photochemical reactions. Electrocyclic reactions: Con-rotation and dis-rotation, electrocyclic closure and opening in 4n and 4n+2 systems, Woodward-Hoffmann selection rules for electrocyclic reactions. Explanation for the mechanism of electrocyclic reactions by: (i) Symmetry properties of HOMO of open chain partner; (ii) Conservation of orbital symmetry and orbital symmetry correlation diagram and (iii) Huckel-Mobius aromatic and antiaromatic transition state method.

(12 Lectures)

Unit – V: Pericyclic Reactions-II

(a). Cycloaddition reactions: Suprafacial and antarafacial interactions. (π2-cycloadditions, Cycloreversions, Stereochemical aspects in supra–supra, antara-supra and antara-antara (π2 and π4 cycloadditions, Diels-Alder reaction, Woodward-Hoffmann selection rules for cycloaddition reactions, Explanation for the mechanism of cycloaddition reactions by 1) Conservation of orbital symmetry and orbital symmetry correlation diagrams 2), Fukui Frontier Molecular Orbital (FMO) theory and (3) Huckel-Mobius aromatic and antiaromatic transition state method. Endo-exo selectivity in Diels-Alder reaction and it's explanation by FMO theory, Examples of cycloaddition reactions.

(b) Sigmatropic reactions: [1,j] and [i,j] shifts. Suprafacial and antarafacial shifts, Selection rules for [i, j] shifts. Cope, degenerate Cope and Claisen rearrangements, Explanation for the mechanism of sigmatropic reactions: 1) symmetry properties of HOMO 2) Huckel-Mobius aromatic and antiaromatic transition state method, chelotropic reactions and explanation of mechanism by FMO theory.

(18 Lectures)

Recommended Books/References:

- J. M. Lehn, *Supramolecular Chemistry*, VCH, Weinheim, **1995**.
- J. W. Steed & J. L. Atwood, *Supramolecular Chemistry*, 2ndEdn John Wiley, **2009**.
- P. D. Beer, P. A. Gale, D. K. Smith; *Supramolecular Chemistry*, Oxford University Press, **1999**.
- F. Diederich, P. J. Stang, R. T, *Modern Supramolecular Chemistry*, Tykwinski, **2008**.
- G. W. Gokel (Editor), *Advances in Supramolecular Chemistry*, JAI Press, Greenwich, Vol 1 (**1990**), Vol 2 (**1992**), Vol 3 (**1993**).
- T. Kunitake, K Ariga, *Supramolecular Chemistry – Fundamentals and Applications*, Berlin: Springer-Verlag Heidelberg, **2006**.

CYUHMJL7: Photo-Organic Chemistry (Lab)

Credit 1 (30 Hours)

1. Benzophenone-Benzopinacol Conversion through UV light https://doi.org/10.1021/acs.jchemed.3c01012
2. Spiropyran/Merocyanine Photochromism in Nonpolar Solvents https://doi.org/10.1002/cptc.202100141
3. Photochemcial decomposition of aromatic diazonium salts

Recommended Books:

- Jonathan W. Steed and Jerry L. Atwood, *Supramolecular Chemistry*, 2nd Edition, Wiley, **2009**.
- Hans-Jörg Schneider and A. Yatsimirsky, *Principles and Methods in Supramolecular Chemistry*, 1st Edition, John Wiley & Sons, **2000**.
- Katsuhiko Ariga and Toyoki Kunitake, *Supramolecular Chemistry – Fundamentals and Applications: A Textbook*, 1st Edition, Springer, **2006**.
- Thomas M. Devlin, *Textbook of Biochemistry*.
- Jeremy M. Berg, John L Tymoczko, Lubert Stryer, *Biochemistry*.
- John Leonard, Barry Lygo, and Garry Procter, *Advanced Practical Organic Chemistry*, 3rd Edition, CRC Press (Taylor & Francis Group), **2013**.
- Douglas A. Skoog, F. James Holler, and Stanley R. Crouch, *Principles of Instrumental Analysis*, 7th Edition, Cengage Learning, **2017**.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	3		3	2	1		1	3	2	3	1	3
CO2	3	1	2		3	1	1		1	3	1	3	1	2
CO3	3	2	2		3	2	1		2	2	2	3	1	3
CO4	3	1	3		3	3	1		1	3	2	3	1	1
CO5	3	1	3		3	1	1		1	1	3	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VIII	Major (Optional) (Level 5)	CYUHMJT8	Homogeneous and Heterogeneous Catalysis: Lab to Industry	Theory 3 (45 Lectures)
			Homogeneous and Heterogeneous Catalysis: Lab to Industry (Tutorial)	Practical: 1 (30 Hours)
		CYUHMJL8	Homogeneous and Heterogeneous Catalysis: Lab to Industry (Lab)	Practical: 1 (30 Hours)

CYUHMJT8: Homogeneous and Heterogeneous Catalysis: Lab to Industry

Level 5, Credit 3 (45 Lectures)
Tutorial Credit 1 (15 Lectures)
Lab Credit 1 (30 Hours)

Course Outcomes:

Learners shall be able to understand the following upon completion of the course:

1. Familiarize with the concept of homogeneous and heterogeneous catalysts.
2. Homogeneous cross-coupling reactions.
3. Heterogenous cross-coupling reactions.
4. Asymmetric aspect and bio-catalysis.
5. Bulk scale preparation and applications.

Unit – I: Introduction

Definition and language of catalysis, general considerations and types of catalyst, difference between homogeneous and heterogeneous catalysis, types of catalyst, basic concepts of stoichiometric and catalytic reactions of organometallic compounds. Metal atoms as centre of acid-base behavior in complexes. Reactions of coordinated ligands. Coordination and electronic unsaturation. Oxidative addition and reductive elimination, Insertion reactions, □-hydride elimination, nucleophilic attack on a coordinated ligand. Catalytic cycle and catalytic intermediates and their identification through spectral techniques. Energy considerations thermodynamic and kinetics.

(7 Lectures)

Unit – II: Homogeneous Catalysis

Hydrogenation of alkenes, hydrosilylation, C-C coupling and cyclopropanation reactions, Carbonylation, Monsanto Process, Water-shift gas reactions, Fisher Tropsch reactions, hydroformylation reactions, Polymerization, Cossee-Arlman mechanism, metallocene

catalysts; structure, special features and stereocontrol by metallocene catalysts. Wacker oxidation, epoxidation of propylene. Oxo complexes and mechanism of oxidation reactions. Basic building block to downstream products by homogeneous catalysis.

(8 Lectures)

Unit – III: Heterogeneous Catalysis

Methods of heterogenization/immobilization, benefits of heterogeneous catalysts, why heterogeneous catalysis? Catalytically active surface area, total surface area and pore size distribution, catalytically active surface area per unit weight of catalyst, solid-acid and base catalysis, catalytic hydrogenations, oxidations and C-C bond formations, solid catalyst employed in fine chemical industry, Feed stock and definitions, feedstock to basic building blocks by heterogeneous catalysis.

(10 Lectures)

Unit – IV: Asymmetric Catalysis and Biocatalysis

Asymmetric catalysis, chiral Lewis acids, general features of chiral ligands and complexes, organometallic and organic catalysts, asymmetric hydrogenation, oxidation, kinetic resolutions, asymmetric epoxidations, asymmetric hydrolysis of epoxides, kinetics, mechanism, catalytic cycles and non-linear effect, enzymes, kinetic aspects of selectivity, Enzymatic catalysis, cooperative kinetics, inhibition, effects of pH, software, case study.

(10 Lectures)

Unit – V: Industrial Catalysis

Chemical industry and homogeneous catalysis, Fine chemicals slurry phase catalyst, fixed bed catalysts, integration of the catalyst and the reactor, reactors employed in a fine chemical industry, slurry phase catalysts, fixed bed catalysts, integration of the catalyst and reactor, three-phase-catalytic reactions (G-L-S), reactors with moving and fixed bed of catalyst, Zeolites as catalysts, asymmetric catalysis on industrial scale.

(10 Lectures)

Recommended Books/References:

- G. W. Parshall and S.D. Ittel, *Homogensous Catalysis, The applications and chemistry of catalysis by soluble Transition Metal Complexes*, Wiley, New Yor, 1992.
- B. Cornils and W.A.Herrmann, *Applied Homogeneous catalysis with Organometallic Compounds*, Vol 1 and 2, Weinheim, New York, 1996.
- S. Bhaduri and D. Mukesh, *Homogeneous Catalysis, Mechanism and Industrial Applications*, Wiley, New York, 2000.
- P. W. N. M. Van Leeuwen, *Homogeneous Catalysis: Understanding the art*, Kluwer, Academic Publishers, 2003.
- R. A. Sheldon, H. van Bekkum (Eds.) *Fine chemicals through heterogeneous catalysis* Wiley-VCH, Weinheim 2001.
- H.U. Blaser, E. Schmidt *Aymmetric catalysis on industrial scale: challenges, approaches and solutions*, Wiley-VCH, Weinheim 2004.
- D. Murzin, T. Salmi *Catalytic Kinetics*, Elsevier, Amsterdam, 2005.

- F.A. Cotton, G. Wilkinson & P. L. Gauss *Basic Inorganic Chemistry* Wiley-India, Third edition, 2001
- I. Ojima, (Ed.) *Catalytic Asymmetric Synthesis* (Second Edition), Wiley-VCH, New York, 2000
- E. N. Jacobsen, A. Pfaltz, H. Yamamoto, (Eds.) *Comprehensive Asymmetric Catalysis I-III*, Springer Verlag, Berlin, 1999;
- R. Noyori, *Asymmetric Catalysis in Organic Synthesis*, Wiley, New York, 1994, Chapter 2.
- D. E. De Vos, I. F. J. Vankelecom, P. A. Jacobs, (Eds.) *Chiral Catalyst Immobilization and Recycling*, Wiley-VCH, New York, 2000.
- G. V. Smith, F. Notheisz *Heterogeneous Catalysis in Organic Syntheis* Academic Press, London, 1999.
- M. Morbidelli, A. Gavriilidis and Arvind Verma *Catalyst Design*, Cambridge University Press, 2001.
- B. Vishwanathan *Catalysis: Selected Applications,* Narosa Publishing House Pvt. Ltd. New Delhi, 2009.
- G. K. Patra, S. S. Thakur (Eds.), *Fundamentals and Prospects of Catalysis*, Bentham Books, 2020.
- K. Ding , Y. Uozumi (Eds.) *Handbook of Asymmetric Heterogeneous Catalysis* Wiley-VCH Verlag, Weinheim, First Edition, 2008.
- G. K. Patra, S. S. Thakur (Eds.), *Catalysis: Current and Future Developments*, Bentham Books, 2020.
- A. N. Collins, G. N. Sheldrake, J. Crosby, (Eds.) *Chirality in Industry I and II*, John Wiley & Sons, Chichester, 1992 and 1996.
- D. E. De Vos, I. F. J. Vankelecom, P. A. Jacobs, (Eds.) *Chiral Catalyst Immobilization and Recycling*, Wiley-VCH, New York 2000.
- D. Ager, (Ed.), *Handbook of Chiral Chemicals* (Second Edition), D. Ager, (Ed.), CRC Press LLC, Boca Raton FL, 2006.

CYUHMJL8: Homogeneous and Heterogeneous Catalysis: Lab to Industry (Lab)

Credit 1 (30 Lectures)

1. Synthesis and characterization of Chiral ligand and application in Asymmetric calalysis.
2. Synthesis and characterization of Chiral metal complex and application in Asymmetric calalysis.
3. Synthesis and characterization of nanoparticle and its application in catalysis.
4. Catalytic oxidation reaction of organic substrates
5. Catalytic reduction or C-C bond formation of organic substrates.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	3		3	2	1		1	3	2	3	1	3
CO2	3	1	2		3	2	1		1	3	1	3	1	2
CO3	3	1	2		3	2	1		2	2	2	3	1	3
CO4	3	1	3		3	3	1		1	3	2	3	1	1
CO5	3	1	3		3	1	1		1	1	3	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VIII	Major (Optional) (Level 5)	CYUHMJT9	Polymer Science and Technology	Theory 4 (60 Lectures)
		CYUHMJL9	Polymer Science and Technology (Lab)	Practical: 1 (30 Hours)

CYUHMJT9: Polymer Science and Technology

Level 5, Credit 4 (60 Lectures)

Course Outcomes:
After completing this course, the learner will be able to:

1. To learn about fundamentals of polymerization processes.
2. To get in-depth knowledge of the polymer structure and its correlation with thermal, mechanical, viscoelastic and structural properties.
3. Polymer technology.
4. Applications of polymer in industrial products.
5. To describe the working principle of the Polymer Processing Machines.

Unit – I: Introduction

Introduction: History of polymer, concept of macromolecules, introduction to polymer science, Classification of Polymers, Intermolecular forces in Polymers, polymerization method and techniques.

(12 Lectures)

Unit – II: Mechanism and kinetics of step-growth and chain growth polymerization

Radical, Cationic, Anionic and Condensation Polymerization Mechanism of Living Radical Polymerizations: Nitroxide Mediated Polymerization (NMP), Metal-Catalyzed Living Radical Polymerization, Reversible Addition-Fragmentation Chain Transfer (RAFT) Radical Polymerization. Coordination Polymerization.

(12 Lectures)

Unit – III: Polymer solutions

Thermodynamics of polymer dissolution, The Flory-Huggins Theory of Polymer solutions, Nature of polymer macromolecules in solution, Size and shape of macromolecules in solution.

(12 Lectures)

Unit – IV Polymer structure Physical properties and molecular weight of polymer

Polymer structure, properties and molecular weight: Microstructure of polymer chains, crystallinity in polymers, Thermal Properties, Rheological Properties, degradation of polymers, Glass transition temperature. polymer fractionation, molecular weight

determination, molecular weight distribution curve, DP, PDI and methods of polymer molecular weight determination.

Polymers processing and technology: Polymer additives, polymer processing and mold design, rubber, fiber and resin technology, Fabrication of polymer products, recycling of polymers.

(12 Lectures)

Unit – V: Industrial polymers and processing of polymers

Industrial polymers and applications: plastics, HDPE, PET, PVC, Polymers in biomedical applications, biopolymer and applications, Green Polymers and environmental impacts.

Specialty polymers: Liquid Crystalline Polymer, Conducting Polymers, Electroluminescent Polymers (Organic light emitting diodes), fire retardant polymers, hydrogels, nanogels and aerogels. Inorganic Polymers, polymer blends and Nanocomposites of polymer.

(12 Lectures)

Recommended Books/References:

- F. W. Billmayer, Jr., *Text Book of Polymer Science*, 3rd Edition (1984), Willey-Interscience, New York.
- G. Odian, P. W. Atkins, *Physical Chemistry*, 6th Edition, Oxford University Press, New York.
- G. Odian, *Principles of Polymerization*, 3rd edition (1991) John Wiley, Singapore
- P.Bahadur and N.V. Sastry, Principle of Polymer Sciences , Narosa Publishing House, New Delhi (2002)
- V.R. Gowarikar, N.V. Vishwanathan, J. Shreedhar , *Polymer Sciences*, Wiley Eastern, New Delhi (1986)

CYUHMJL9: Polymer Science and Technology (Lab)

Credit 1 (30 Lectures)

Experiments

l. Purification of monomers:

Acrylamide, vinyl pyrrolidone, vinyl formamide, acrylic acid, acrylates etc.

2. Polymer synthesis:

i. Synthesis of homopolymer and their copolymers by Free radical polymerization in aqueous solution.

ii. Preparation of resin

iii. Preparation of hydrogel

3. Polymer molecular weight Determination:

i. Determination of molecular weight by viscometry:

ii. Determination of the viscosity-average molecular weight of poly(vinyl alcohol) (PVOH) and the fraction of "head-to-head" monomer linkages in the polymer.

2. Characterization Techniques:
i. FTlR studies of Polymers
ii. NMR studies
iii. SEM and XRD analysis

Reference Books:

- Harry R. All.cock, Frederick W. Lampe and James E. Marh Contem Chemistry, 3rd ed. Prentice-Hall (**2003**)
- Fred W. Billmeyer, *Textbook of Polymer Science, 3rd edition, Wiley Jnterscience* (**1984**).
- Joel R. Fried, *Polymer Science and Technology' 2nd ed' Prentice-Hall* (**2003**).
- L. H. Sperling, *Introduction to Physical Polymer Science, 4th ed.* John Wiley & Sons (**2005**)
- Charles E, Carraher, *Polymer Chemistry, 9th ed.* by (**2013**)
- M.B. Smith, J. March, *March's Advanced Organic Chemistry*, John Wiley & Sons (**2007**)

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	3		3	2	1		1	3	2	3	1	3
CO2	3	1	2		3	2	1		1	3	1	3	1	2
CO3	3	1	2		3	2	1		2	2	2	3	1	3
CO4	3	1	3		3	3	1		1	3	2	3	1	3
CO5	3	1	3		3	1	1		1	1	3	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VIII	**Major (Optional) (Level 5)**	CYUHMJT10	Heterocycle Chemistry	Theory 4 (60 Lectures)
			Heterocycle Chemistry (Tutorial)	Tutorials: 1 (15 Hours)

CYUHMJT10: Heterocycle Chemistry

Level 5, Theory Credit 4 (60 Lectures)
Tutorials Credit 1 (15 Lectures)

Course Outcomes:

1. Students will understand the various types of systematic nomenclature of mono-heteroatom containing heterocyclic compounds.
2. Students will get the sound knowledge on the structure, and synthesis of various three, four, five, and six membered simple heterocyclic compounds with one heteroatom
3. Reactions of various three, four, five, and six membered simple heterocyclic compounds
4. Study the use of heterocycles in functional group and ring transformations.
5. Students will acquire knowledge about the medicinal importance of heterocyclic compounds.

Unit – I: **Introduction**

Introduction and importance of heterocyclic compound, classification, aromaticity, Nomenclature: Familiarizing with both trivial and systematic naming conventions for heterocyclic compounds, Hantzsch-Widman system for monocyclic, Molecular orbital picture: Understanding the electronic structure of simple aromatic heterocycles like pyrrole and pyridine, Biologically important heterocycles.

(10 Lectures)

Unit – II: Three and Four-Membered Heterocyclic Chemistry

Introduction, Nomenclature of 3 and 4-membered heterocycles, Replacement and systematic nomenclature, fused and bridged heterocycles. Synthesis and reactions of three membered heterocycles-aziridines, oxiranes, episulfides. Synthesis and reactions of four membered heterocycles-oxetanes, azetidines and thietanes.

(15 Lectures)

Unit – III: Five and Six-Membered Heterocyclic Chemistry

Introduction, aromaticity, synthesis & reactions of five membered eterocycles: furan, pyrrole, thiophene. Introduction, aromaticity, synthesis & reactions of six membered eterocycles: pyridine, α- and γ-Pyrones.

(15 Lectures)

Unit – IV: Heterocycles in Functional Group and Ring Transformations

Alkanes from thiophenes, dienes from pyrroles, alcohols from isooxazolines, conversion of coumarin to benzofuran, sydnone to pyrazole, chromones to pyrazoles, furans to pyridines, pyrrole to pyridines, pyrimidine to pyrazole, isatins to quinolines, indoles to quinoline. Dimroth and Cornforth rearrangements.

(10 Lectures)

Unit – V: Medicinal Importance of Heterocycle Chemistry

Medicinal applications of Pyrrole, Furan, and Thiophene: some examples of drugs and drug candidates containing these ring systems, Enzyme inhibition, anti-inflammatory, antimicrobial (antibacterial, antifungal, and antiviral agent) anti-cancer, anticonvulsant, anti-diabetic, anti-hypertensive, and anti-viral activities agents, Roles of 6-membered heterocycles in drug development.

(10 Lectures)

References:

1 An Introduction to the Chemistry of Heterocyclic Compounds-Acheson (Wiley Eastern),1997.

2. Heterocyclic Chemistry- J. Joule & G. Smith (Van Nostrand ELBS), 1978.

3. Polymer Science- V. R. Gowariker, N. V. Vishwanathan & T. Shridhar (Wiley Eastern)

4. Comprehensive Heterocyclic Chemistry Vol-I-VI Ed. Katritzky & Rees (Pergamon), 1984.

5. Organic Chemistry, Vol I & II, I.L. Finar (Longmann ELBS, London), 1973.

6. Natural Products Chemistry, Vol-I & II- G. R. Chatwal (Himalaya), 1990

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	3		3	2	1		1	3	2	3	1	3
CO2	3	1	2		3	2	1		1	3	1	3	1	2
CO3	3	2	2		3	2	1		1	2	2	3	1	3
CO4	3	1	3		3	3	1		1	3	2	3	1	3
CO5	3	1	3		3	1	1		1	1	3	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VIII	Major (Optional) (Level 5)	CYUHMJT11	Inorganic Materials Chemistry	Theory 4 (60 Lectures)
			Inorganic Materials Chemistry (Tutorial)	Tutorials: 1 (15 Hours)

CYUHMJT11: Inorganic Materials Chemistry

Level 5, Theory Credit 4 (60 Lectures)
Tutorials Credit 1 (15 Lectures)

Course Outcomes:

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

1. Crystalline solids – parameters, symmetry.
2. Mesoporous/microporous silica-based materials, functionalized hybrid materials and its applications.
3. Technological importance of ionic liquids, preparation of materials using sol-gel technique.
4. Understanding self-assembled structures, nano-structured materials, carbon nanotubes, applications.
5. Composites materials and inorganic solids, host-guest chemistry, ionic liquids and its significance and their industrial applications.

Self-study:

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

Unit – I: Basics of crystalline solids

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

(15 Lectures)

Unit – II: Porous materials

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

metal organic frameworks: H_2 /CO_2 gas storage and catalytic applications.

(12 Lectures)

Unit – III: Inorganic Solids/Ionic Liquids Of Technological Importance

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

(12 Lectures)

Unit – IV: Nanomaterials

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

(9 Lectures)

Unit – V: Composite Materials

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

(12 Lectures)

Recommend Books/References:

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

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	3		3	2	1		1	2	2	3	1	3
CO2	3	1	3		3	2	1		1	3	1	3	1	2
CO3	3	2	2		3	2	1		2	2	2	3	1	3
CO4	3	1	3		3	3	1		1	3	2	3	1	3
CO5	3	1	3		3	1	1		1	1	3	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

Chemistry Minor Courses

Semester	Nature of Course	Course Code	Name of the course	Credits
I	Minor (Level 2)	CYUAMNT1	Fundamental Chemistry-I	Theory 3 (45 Lectures)
		CYUAMNL1	Fundamental Chemistry-I (Lab)	Practical: 1 (30 Hours)

CYUAMNT1: Fundamental Chemistry-I

Level 2, Credit 3 (45 Lectures)

Course Outcomes:

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

1. Understand the atomic structure of an atom, quantum numbers, etc.
2. Know the ionic, covalent, and metallic bonds.
3. Understand aliphatic and aromatic compounds and their nomenclatures
4. Understand reaction intermediates and their characteristics.
5. Know the gaseous state of matter, deviation from ideal behaviors, and distribution laws of molecular velocities of gases.
6. Understand the basic knowledge of liquid and solid states of matter.

Inorganic Chemistry

Unit – I: Atomic Structure

Bohr's theory, its limitations and atomic spectrum of hydrogen atom. Wave mechanics: de' Broglie equation, Heisenberg's Uncertainty Principle and its significance, Schrödinger's wave equation, significance of ψ and ψ^2. Quantum numbers and their significance. Normalized and orthogonal wave functions. Sign of wave functions. Radial and angular wave functions for hydrogen atom. Radial and angular distribution curves. Shapes of s, p, d, and f orbitals. Contour boundary and probability diagrams. Variation of orbital energy with atomic number.

(6 Lectures)

Unit – II: Chemical Bonding

(i) Ionic bond: General characteristics, radius ratio rule and its limitations. Born-Landé equation with derivation, expression for lattice energy. Born-Haber cycle and its application.

(ii) Covalent bond: Valence Bond theory, (Heitler-London approach). Hybridization containing s, p and s, p, d atomic orbitals, shapes of hybrid orbitals, Bents rule, Molecular orbital theory. Molecular orbital diagrams of simple homonuclear and heteronuclear diatomic molecules e.g., N_2, O_2, C_2, B_2, F_2, CO, NO, and their ions; HCl, BeF_2, CO_2. Covalent character in ionic compounds, polarizing power and polarizability. Fajan rules, polarization. Ionic character in covalent compounds: Bond moment and dipole moment. Ionic character from dipole moment and electronegativities.

(iii) Metallic Bond: Qualitative idea of free electron model, Semiconductors, Insulators.

(9 Lectures)

Organic Chemistry

Unit – I: Basics of Organic Chemistry

Organic Compounds: Classification, and Nomenclature, Hybridization, Shapes of molecules, Influence of hybridization on bond properties. Electronic Displacements: Inductive, electromeric, resonance and mesomeric effects, hyperconjugation and their applications; Dipole moment; Organic acids and bases; their relative strength. Aromaticity: Huckel's rule, aromatic character of arenes, cyclic carbocations/carbanions and heterocyclic compounds with suitable examples.

(7 Lectures)

Unit – II: Reactive Organic Species and Reaction Intermediates

Homolytic and Heterolytic fission with suitable examples. Curly arrow rules, formal charges; Electrophiles and Nucleophiles; Nucleophilicity and basicity; types, shape and relative stabilities of reaction intermediates (Carbocations, Carbanions, Free radicals and Carbenes). Organic reactions and their mechanism: Addition, Elimination and Substitution reactions.

(8 Lectures)

Physical Chemistry

Unit – I: Gaseous State

Postulates of Kinetic Theory of Gases and derivation of the kinetic gas equation.

Behavior of real gases: Deviations from ideal gas behavior, compressibility factor. Causes of deviation from ideal behavior: van der Waals equation of state, its derivation and application in explaining real gas behavior, van der Waals equation expressed in virial form, and calculation of Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, the relation between critical constants and van der Waals constants, and law of corresponding states.

Maxwell-Boltzmann's distribution laws of molecular velocity and molecular energies (graphic representation – derivation not required) and its use in evaluating molecular velocities, law of equipartition of energy, degrees of freedom and molecular basis of heat capacities.

Collision frequency, collision diameter, and mean free path; viscosity of gases; calculation of collision diameter from coefficient of viscosity; variation of viscosity with temperature and pressure.

(8 Lectures)

Unit – II: Liquid and Solid States

Qualitative treatment of the structure of the liquid state, Radial distribution function, physical properties of liquids, vapor pressure, surface tension, and coefficient of viscosity and their determination. Temperature variation of viscosity of liquids and comparison with that of gases. Qualitative discussion of the structure of water.

Nature of the solid state, definition of space lattice, unit cell; laws of crystallography – (i) law of constancy of interfacial angles, (ii) law of rational indices (Miller indices) and, (iii) law of symmetry, elementary ideas of symmetry, symmetry elements and symmetry operations. Qualitative idea of point and space groups, seven crystal systems, and fourteen Bravais lattices; X-ray diffraction, Bragg's law.

(7 Lectures)

Recommended Books/References:

- Lee, J.D. *Concise Inorganic Chemistry*, ELBS, **1991**.
- Atkins, P. W and Shriver D. N. Atkins' *Inorganic Chemistry* 5th Ed. Oxford University Press, **2010**.
- Morrison, R. N. & Boyd, R. N. *Organic Chemistry*, 6th Edn., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Pine S. H. *Organic Chemistry*, Fifth Edition, McGraw Hill, **2007**.
- J. Clayden, N. Greeves, S. Warren, *Organic Chemistry*, 2nd Ed., Oxford University Press, **2012**.
- P Sykes, *A Guide Book to Mechanism in Organic Chemistry*, 6th Edition, Orient Longman, New Delhi, **1997**.
- Atkins, P. W. & Paula, J. de *Atkin's Physical Chemistry* 8th Ed., Oxford University Press, **2006**.
- BR Puri, LR Sharma, MS Pathania, *Principles of Physical Chemistry*, Vishal Publishing Co., **2018**.

CYUAMNL1: Fundamental Chemistry-I (Lab)

Credit 1 (30 Hours)

Inorganic Chemistry

1. Acid-Base Titrations
   (a) Titration of very weak acid-boric acid
   (b) Estimation of carbonate and hydroxide present together in a mixture.
   (c) Estimation of carbonate and bicarbonate present together in a mixture.

2. Redox Titrations
   (a) Estimation of Fe(II) and oxalic acid using standardized $KMnO_4$ solution.
   (b) Estimation of oxalic acid and sodium oxalate in a given mixture.

Physical Chemistry

1. Surface tension measurements:
   (a) Determine the surface tension by (i) drop number (ii) drop weight method.
   (b) Study the variation of surface tension of detergent solutions with concentration.
   (c) Surface tension composition curve for a binary liquid mixture.

2. Viscosity measurement using Ostwald's viscometer:
   (a) Determination of viscosity of aqueous solutions of (i) polymer (ii) ethanol and (iii) sugar at room temperature.
   (b) Study the variation of viscosity of sucrose solution with the concentration of solute.
   (c) Viscosity composition curve for a binary liquid mixture.

Note: *Any other experiment will be carried out in the class if permitted.*

Recommended Books:

- J. Elias, *A Collection of Interesting General Chemistry Experiments*, Revised Ed., University Press, **2007**.
- C. W. Garland, J. W. Nibler and D. P. Shoemaker, *Experiments in Physical Chemistry*, 8th Ed., McGraw-Hill, **2003**.
- A. M. Halern and G. C. McBane, *Experimental Physical Chemistry: A Laboratory Textbook*, 3rd Ed., W. H. Freeman and Company, **2006**.
- P. C. Kamboj, *University Practical Chemistry*, 1st Ed., Vishal Publishing, **2013**.
- Mendham, J., A. I. Vogel's *Quantitative Chemical Analysis* Sixth Edition Pearson, **2009**.
- Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis,* University Press, **2000**.
- Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry,* R. Chand & Co.: New Delhi, **2011**.
- Athawale V. D. and Mathur P. *Experimental Physical Chemistry*, New Age International, **2001**.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PSO1**	**PSO2**	**PSO3**	**PSO4**	**PSO5**
CO1	**3**	**1**	**2**		**3**	**1**	**1**		**1**	**3**	**2**	**3**	**1**	**3**
CO2	**3**	**2**	**2**		**2**	**1**	**3**		**1**	**3**	**2**	**3**	**1**	**3**
CO3	**2**	**1**	**2**		**3**	**1**	**1**		**1**	**1**	**2**	**1**	**1**	**3**
CO4	**3**	**1**	**3**		**3**	**2**	**1**		**1**	**3**	**3**	**3**	**1**	**2**
CO5	**3**	**1**	**2**		**3**	**1**	**1**		**1**	**3**	**2**	**3**	**1**	**3**
CO6	**3**	**1**	**2**		**3**	**1**	**1**		**1**	**3**	**2**	**3**	**1**	**3**
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
II	Minor (Level 2)	CYUBMNT1	Fundamental Chemistry-II	Theory 3 (45 Lectures)
		CYUBMNL1	Fundamental Chemistry-II (Lab)	Practical: 1 (30 Hours)

CYUBMNT1: Fundamental Chemistry-II

Level 2, Credit 3 (45 Lectures)

Course Outcomes:

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

1. Understand the first law of thermodynamics and its applications.
2. Know the chemical equilibrium, pH of solution, buffer solution and application.
3. Understand aliphatic hydrocarbons alkanes, alkenes, alkynes.
4. Understand reaction intermediates and their characteristics.
5. Know the chemistry of s, p, and d block elements.
6. Understand the role of metals in biological systems.

Physical Chemistry

Unit – I: First Law of Thermodynamics

Introduction of different terms and processes in thermodynamics: State and path functions and their mathematical differentials treatment, partial derivatives, Euler's reciprocity, and cyclic rule.

First Law: Concept of heat, q, work, w, internal energy, U, and sign convention for heat and work; Statement of first law; Enthalpy, H; heat capacities (C_v and C_p) and their relationships. Reversible and irreversible processes, maximum work. Calculations of q, w, U, and H for reversible, irreversible, and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions. Ideal gas law for adiabatic reversible expansion; comparison of adiabatic and isothermal reversible expansion. Joule-Thomson effect. Standard state and Thermochemistry (Hess's Laws and Kirchhoff's equation).

(8 Lectures)

Unit – II: Chemical Equilibrium

Law of mass action; K_p, K_c, and K_x; Effect of temperature on K; Le-Chatelier principle; Ionic equilibria in solutions; pH and buffer solutions; Derivation of Henderson-Hasselbalch equation, buffer capacity, buffer range, buffer action and applications of buffers in analytical chemistry, Salt hydrolysis, hydrolysis constant, degree of hydrolysis and pH for different salts; Solubility and solubility product; Acid-base titration curves; Theory of acid-base indicators; selection of indicators and their limitations.

(7 Lectures)

Organic Chemistry

Unit – I: Chemistry of aliphatic hydrocarbons

Alkanes and cycloalkanes: Preparation and general reactions of alkanes and cycloalkanes, Bayer Strain theory of strainless ring; Conformation of ethane, *n*-butane and cyclohexane, chlorination of methane and side chain chlorination of toluene.

Alkenes: General methods for preparation of alkenes, Reactions of alkenes: Addition reactions (Electrophilic and free radical), Halogenation, Hydrohalogenation, Hydration, Hydroxylation, Hydroboration-oxidation, Mercuration-demercuration, Epoxidation and Ozonoloysis.

Dienes: Conjugated and isolated Dienes; 1,2- versus 1,4-addition. Diels-Alder reaction of dienes: Mechanism

Alkynes: Preparation of alkynes, acidity and metal acetylides, Electrophilic addition reactions viz., Halogenation, Hydrohalogenation, Hydration, Hydroboration-oxidation, Mercuration-demercuration and Ozonoloysis.

(9 Lectures)

Unit – II: Stereochemistry

Optical activity and plane-polarized light. Plane and centre of Symmetry, Chirality, enantiomers, diasteroisomers, mesomers, and racemic mixtures. Fischer, Newman and Sawhorse Projection Formula. E/Z, D/L and R/S nomenclature. Walden inversion. Stereochemistry of allenes and biphenyls.

(6 Lectures)

Inorganic Chemistry

Unit – I: Chemistry of s, p, and d Block Elements

Inert pair effect, Relative stability of different oxidation states, diagonal relationship and anomalous behavior of first member of each group. Allotropy and Catenation, Complex formation tendency of s and p block elements. Classification of Metal-Hydrides. Structure, Bonding, and Uses: Boric acid and borates, boron nitrides, borohydrides (diborane) carboranes and graphitic compounds, silanes, Oxides and oxoacids of Nitrogen, Phosphorus Sulphur and Chlorine. Occurrence and uses, rationalization of inertness of noble gases, Bonding in noble gas compounds (Valence bond and MO treatment for XeF_2).

d-block elements: General electronic configuration, colour, variable valency, magnetic and catalytic properties, and ability to form complexes. Stability of various oxidation states. Difference between the first, second and third-row transition elements.

(10 Lectures)

Unit – II: Bioinorganic Chemistry

Metal ions present in biological systems, classification of elements according to their action in biological systems. Geochemical effect on distribution of metals. Sodium/K-pump, Excess and deficiency of some trace metals. Toxicity of metal ions (Hg, Pb, Cd and As), iron and its application in biosystems, Haemoglobin.

(5 Lectures)

Recommended Books/References:

- P. Atkins, J. d. Paula and K. James, *Physical Chemistry*, 11th Ed., Oxford University Press, **2018**.
- K. L. Kapoor, *A Text Book of Physical Chemistry: Thermodynamics and Chemical Equilibrium, Vol. 2*, 5th Ed., MsGraw-Hill, **2015**.
- B. R. Puri, L. R. Sharma and M. S. Pathania, *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing Co., **2018**.
- D. R. Crow, *Principles and Applications of Electrochemistry*, 4th Ed., Blackie Academic & Professional, **1994.**
- Morrison, R. N. & Boyd, R. N. *Organic Chemistry*, 6th Edn., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- F. A. Carey, *Organic Chemistry,* Seventh Edition, Tata McGraw Hill, **2008**.
- J. Clayden, N. Greeves, S. Warren, *Organic Chemistry,* 2nd Ed., Oxford University Press, **2012**.
- P Sykes, *A Guide Book to Mechanism in Organic Chemistry*, 6th Edition, Orient Longman, New Delhi, 1997.
- "*Stereochemistry of Organic Compounds"*, D. Nasipuri, New Age International.
- "*Stereochemistry of Organic Compounds"*, P.S. Kalsi, New Age International.
- Lee, J.D. *Concise Inorganic Chemistry,* ELBS,**1991**.
- Douglas, B.E; Mc Daniel, D.H. & Alexander, J.J. *Concepts & Models of Inorganic Chemistry* 3rd Ed., John Wiley Sons, N.Y., **1994**.
- Cotton, F.A. & Wilkinson, G. *Advanced Inorganic Chemistry,* Wiley, VCH, **1999**.
- Rodger, G.E. *Inorganic and Solid-State Chemistry, Cengage Learning India Edition*, **2002**.
- Atkins, P. W and Shriver D. N. Atkins' *Inorganic Chemistry* 5th Ed. Oxford University Press, **2010**.

CYUBMNL1: Fundamental Chemistry-II (Lab)

Credit 1 (30 Hours)

Physical Chemistry

1. Thermochemistry:
   (a) Determination of heat capacity of a calorimeter for different volumes using change of enthalpy data of a known system (method of back calculation of heat capacity of calorimeter from known enthalpy of solution or enthalpy of neutralization).
   (b) Determination of heat capacity of the calorimeter and enthalpy of neutralization of hydrochloric acid with sodium hydroxide.
   (c) Calculation of the enthalpy of ionization of ethanoic acid.
   (d) Determination of heat capacity of the calorimeter and integral enthalpy (endothermic and exothermic) solution of salts.
   (e) Determination of enthalpy of hydration of copper sulfate.
   (f) Study of the solubility of benzoic acid in water and determination of ΔH.

2. pH metry

(a) Determination of pH of the given unknown solutions.

(b) Study the effect on pH of addition of HCl/NaOH to solutions of acetic acid, sodium acetate, and their mixtures.

(c) Preparation of buffer solutions of different pH by:

(i) Sodium acetate-acetic acid

(ii) Ammonium chloride-ammonium hydroxide

Inorganic Chemistry

1. Iodo / Iodimetric Titrations

(a) Estimation of Cu(II) and $K_2Cr_2O_7$ using sodium thiosulphate solution(Iodometrically).

(b) Estimation of available chlorine in bleaching powder iodometrically.

2. Inorganic preparations

(a) Preparation of Aluminium potassium sulphate (Potash alum) and Chrome alum.

Organic Chemistry

1. Identify elements (N, S, Cl, Br & I) present in organic compounds.
2. Identification of Functional groups (Acids, Phenolic OH & Keto) present in organic compounds.

***Note**: Any other experiment will be carried out in the class if permitted.*

Reference Books:

- J. Elias, *A Collection of Interesting General Chemistry Experiments*, Revised Ed., University Press, **2007**.
- C. W. Garland, J. W. Nibler and D. P. Shoemaker, *Experiments in Physical Chemistry*, 8th Ed., McGraw-Hill, **2003**.
- A. M. Halern and G. C. McBane, *Experimental Physical Chemistry: A Laboratory Textbook*, 3rd Ed., W. H. Freeman and Company, **2006**.
- P. C. Kamboj, *University Practical Chemistry*, 1st Ed., Vishal Publishing, **2013**.
- Mendham, J., A. I. Vogel's *Quantitative Chemical Analysis* Sixth Edition Pearson, **2009**.
- Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis,* University Press, **2000**.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		3	1	1		1	3	2	3	1	3
CO2	3	2	2		2	1	3		1	3	2	3	1	3
CO3	2	2	2		3	1	2		1	2	2	2	1	3
CO4	2	1	1		3	2	1		1	3	1	3	1	1
CO5	3	1	2		3	1	1		1	3	2	3	1	3
CO6	3	1	2		3	1	1		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
III	Minor (Level 3)	CYUCMNT1	Fundamental Chemistry-III	Theory 3 (45 Lectures)
		CYUCMNL1	Fundamental Chemistry-III (Lab)	Practical: 1 (30 Hours)

CYUCMNT1: Fundamental Chemistry-III

Level 3, Credit 3 (45 Lectures)

Course Outcomes:

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

1. Second and third laws of thermodynamics and its applications.
2. The concept of rate laws, order and molecularity of reaction, and theory of reaction rates.
3. Understand periodic table and its properties, acid-base concept.
4. Know the chemistry of s, p, block elements.
5. Chemistry of d-block Elements.

Section – A: Physical Chemistry

Unit – I: Second and Third Law of Thermodynamics

Second Law: Limitation of first Law, spontaneous processes and different statements of second law of thermodynamics.

Concept of Entropy: Entropy changes in reversible and irreversible processes and of universe, physical concept of entropy (molecular and statistical interpretation of entropy), Clausius inequality; entropy as a function of V & T, and P & T; entropy changes of an ideal gas in different processes, entropy change in mixing of gases.

Free Energy Functions: Free energy and its concept, Gibbs (G) and Helmholtz (A) free energies as thermodynamic quantities and their relationship; variation of free energy with temperature and pressure. Gibbs-Helmholtz equations, its applications.

Third Law: Variation of entropy with temperature (Nernst heat theorem), statement of third law, the concept of residual entropy. Applications of third law for the determination of absolute entropies of liquid and gases.

(10 Lectures)

Unit – II: Chemical Kinetics

The concept of reaction rates. Effect of temperature, pressure, catalyst and other factors on reaction rates. Order and molecularity of a reaction. Derivation of integrated rate equations for zero, first and second order reactions (both for equal and unequal concentrations of reactants). Half–life of a reaction. General methods for determination of order of a reaction. Concept of activation energy and its calculation from Arrhenius equation.

Theories of Reaction Rates: Collision theory and Activated Complex theory of bimolecular reactions. Comparison of the two theories (qualitative treatment only).

(10 Lectures)

Section – B: Inorganic Chemistry

Unit – III: Periodic Properties & Acid-Base Concepts

Periodic Properties*:* Division of elements into *s*, *p*, *d*, and *f* blocks, covalent radii, van der Waals radii and ionic radii; ionization enthalpy, electron gain enthalpy, and electronegativity (Pauling, Mulliken, and Alfred-Rochow scales: Definition, methods of determination, trends in periodic table, and applications in predicting and explaining chemical behavior).

Acids and Bases: Arrhenius, Brønsted-Lowry, Lux-Flood and Lewis concepts of acids and bases. Factors affecting strengths of Lewis acids and bases, Classification of acids and bases as hard and soft, Pearsons HSAB concept, acid-base strength and hardness and softness, symbiosis, application of HSAB theory.

(8 Lectures)

Unit – IV: Chemistry of s- and p- Block Elements

s-Block Elements: General characteristic properties, complexes of alkali metals, comparative study of hydrides, oxides, hydroxides, halides, carbonates and bicarbonates of group I and II, Diagonal relationship, biological role of alkali and alkaline earth metals.

p-Block Elements: General characteristic properties, comparative study (including diagonal relationship and inert pair effect) of groups 13-17 (B, C, N, O, F) elements and group trends of compounds like hydrides, oxides, halides, and oxy acids; preparation properties and structure, of diborane, borazine, alkalimetalborohydrides, fullerenes, silicates and silicones, inter-halogens and polyhalides.

Chemistry of Noble Gases: Isolation and separation of noble gases from air, chemical properties of noble gases, chemistry of xenon, structure and bonding in xenon compounds.

(10 Lectures)

Unit – V: Chemistry of *d*- Block Elements

d-Block Elements: Characteristic properties of *d*-block elements. Properties of the elements of the first transition series, their binary compounds and complexes illustrating relative stability of their oxidation states, coordination number and geometry. Comparative treatment with their 3d-analogues in respect of ionic radii, oxidation states and stereochemistry.

(7 Lectures)

Recommended Books/References:

- G. M. Barrow: *Physical Chemistry* Tata McGraw-Hill, **2007**.
- G. W. Castellan: *Physical Chemistry* 4th Ed. Narosa, **2004**.
- J. C. Kotz, P. M. Treichel, J. R. Townsend, *General Chemistry*, Cengage Learning India Pvt. Ltd.: New Delhi, **2009**.
- B. H. Mahan: *University Chemistry*, 3rd Edn. Narosa, **1998**.
- R. H. Petrucci, *General Chemistry*, 5th Edn., Macmillan Publishing Co.: New York, **1985**.

- E. S. Gilreath, *Fundamental Concepts of Inorganic Chemistry*, McGraw Hill Edu. Pvt. Ltd.
- R. Sarkar (Part-I & II), *General & Inorganic Chemistry*, Central.
- R. L. Dutta (Part-I & II), Inorganic Chemistry, The New Book Stall.
- J. D. Lee: *A New Concise Inorganic Chemistry*, E.L.B.S.
- F.A. Cotton & G. Wilkinson: *Basic Inorganic Chemistry*, John Wiley.
- D. F. Shriver and P. W. Atkins: *Inorganic Chemistry*, Oxford University Press.
- Gary Wulfsberg: *Inorganic Chemistry*, Viva Books Pvt. Ltd.

CYUCMNL1: Fundamental Chemistry-III (Lab)

Credit 1 (30 Hours)

Section – A: Physical Chemistry

Chemical Kinetics:

Study the kinetics of the following reactions:

a. Acid hydrolysis of methyl acetate with hydrochloric acid.
b. Saponification of ethyl acetate.
c. Compare the strengths of HCl and H_2SO_4 by studying kinetics of hydrolysis of methyl acetate

Conductance

a) Determination of cell constant
b) Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid.
c) Perform the following conductometric titrations:
   i. Strong acid vs. strong base
   ii. Weak acid vs. strong base

Section – B: Inorganic Chemistry

Semi-micro qualitative analysis using H_2S of mixtures- not more than four ionic species (two anions and two cations and excluding insoluble salts) out of the following:

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^{2-}, $S_2O_3^{2-}$, NO_3^{-}, NO_2^{-},Cl^{-}, Br^{-}, I^{-},SO_4^{2-}, PO_4^{3-}, BO_3^{3-}, $C_2O_4^{2-}$, F^{-}

(Spot tests should be carried out wherever feasible)

Reference Books:

- B.D. Khosla: *Senior Practical Physical Chemistry*, R. Chand & Co.
- A.I. Vogel, *Qualitative Inorganic Analysis*, Prentice Hall, 7th Edn.
- A.I. Vogel, *Quantitative Chemical Analysis*, Prentice Hall, 6th Edn.
- A. K. Nad, B. Mahapatra and A. Ghosal, *An Advanced Course in Practical Chemistry*, New Central Book Agency Priv. Ltd, **2011**
- V. K. Ahluwalia, S. Dhingra& A. Gulati, *College Practical Chemistry*, University Press, Delhi.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		3	1	1		1	3	2	3	1	3
CO2	2	1	2		3	1	1		1	3	2	3	1	3
CO3	2	2	3		2	2	2		1	2	3	1	1	3
CO4	3	1	2		3	2	1		1	3	3	3	1	2
CO5	3	1	2		3	1	1		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
IV	Minor (Level 3)	CYUDMNT1	Fundamental Chemistry-IV	Theory 3 (45 Lectures)
		CYUDMNL1	Fundamental Chemistry-IV (Lab)	Practical: 1 (30 Hours)

CYUDMNT1: Fundamental Chemistry-IV

Level 3, Credit 3 (45 Lectures)

Course Outcomes:

After completing this course, learners will be able to understand:

1. Introduction about analytical instruments and understanding about limitations and flexibility.
2. Know about volumetric titrations and chemical reactions.
3. Explain the chromatographic techniques and importance of solvents.
4. Explain fundamentals and crystal field theory for coordination complexes
5. Explain metal-carbon bond formations and stability of organometallic compounds

Section – A: Analytical Chemistry

Unit – I: Introduction

Introduction to Analytical Chemistry and its interdisciplinary nature. Balances, burettes, volumetric flasks, pipettes, calibration of tools, sampling. Errors and Statistics: significant figures, rounding off, accuracy and precision, determinate and indeterminate errors, standard deviation, propagation of errors, confidence limit, test of significance, rejection of a result.

(5 Lectures)

Unit – II: Volumetric Titration

Standard solution, primary standard and secondary standard, titration, end point, indicator, concentration of standard solution- moles, Normality, molarity, Molality, parts per million(PPM), volumetric calculation, acid base titration and use of indicators, titration curves for strong acid vs strong base, weak acid with strong base, weak base with strong acid, theory of acid base indicator, Redox titration- titration of Mohr salt against $KMnO_4$, Titration of Oxalic acid against $KMnO_4$, Titration of $FeSO_4$ against $K_2Cr_2O_7$.

(10 Lectures)

Unit – III: Chromatography

Chromatographic Techniques: classification, theory of chromatographic separation, distribution coefficient, retention, sorption, efficiency and resolution. - Column, ion exchange, paper, TLC & HPTLC chromatography etc.

Solvent Extraction: Distribution Coefficient, distribution ratio, percent extracted, solvent extraction of metals ions, extraction of ion association complex, extraction of metal chelates, multiple batch extraction and applications.

Ion-exchange: Column, ion-exchange chromatography etc. Determination of ion exchange capacity of anion / cation exchange resin (using batch procedure if use of column is not feasible).
Gas Chromatography: retention time or volume, capacity ratio, partition coefficient, theoretical plate and number, separation efficiency and resolution, instrumentation and application.

(10 Lectures)

Section – B: Inorganic Chemistry

Unit – IV: Coordination Compounds

Werner's coordination theory and its experimental verification, effective atomic number concept, chelats, nomenclature of co-ordination compounds, isomerism in coordination compounds.
Crystal Field Theory: Crystal field effect, octahedral symmetry. Crystal field stabilization energy (CFSE), Crystal field effects for weak and strong fields. Tetrahedral symmetry. Factors affecting the magnitude of D. Spectrochemical series. Comparison of CFSE for O_h and T_d complexes, Tetragonal distortion of octahedral geometry. Jahn-Teller distortion, Square planar coordination.

(10 Lectures)

Unit – V: Organometallics

Definition and Classification with appropriate examples based on nature of metal-carbon bond (ionic, s, p and multicentre bonds). Structures of methyl lithium, Zeiss salt and ferrocene. EAN rule as applied to carbonyls. Preparation, structure, bonding and properties of mononuclear and polynuclear carbonyls of 3d metals. p-acceptor behaviour of carbon monoxide. Synergic effects (VB approach)- (MO diagram of CO can be referred to for synergic effect to IR frequencies).

(10 Lectures)

Recommended Books/References:

- Skoog, D.A.; West, D.M. & Holler, F.J. *Fundamentals of Analytical Chemistry 6thEd.*, Saunders College Publishing, Fort Worth, **1992**.
- Dean, J. A. *Analytical Chemistry Notebook*, McGraw Hill.
- Vogel, A. I. *Vogel's Qualitative Inorganic Analysis 7thEd.*, Prentice Hall.
- Vogel, A. I. Vogel's *Quantitative Chemical Analysis 6thEd.*, Prentice Hall.
- J. D. Lee: *A New Concise Inorganic Chemistry*, E.L.B.S.
- F.A. Cotton & G. Wilkinson: *Basic Inorganic Chemistry*, John Wiley.
- D. F. Shriver and P. W. Atkins: *Inorganic Chemistry*, Oxford University Press.
- R. L. Dutta (Part-I & II), *Inorganic Chemistry*, The New Book Stall.
- Gary Wulfsberg: *Inorganic Chemistry*, Viva Books Pvt. Ltd.

CYUDMNL1: Fundamental Chemistry-IV (Lab)

Credit 1 (30 Hours)

Section – A: Analytical Chemistry

1. Estimation of the amount of nickel present in a given solution as bis(dimethylglyoximato) nickel(II) or aluminium as oxinate in a given solution gravimetrically.
2. Estimation of (i) Mg^{2+} or (ii) Zn^{2+} by complexometric titrations using EDTA.
3. Estimation of total hardness of a given sample of water by complexometric titration.
4. To draw calibration curve (absorbance at λ_{max} vs. concentration) for various concentrations of a given coloured compound and estimate the concentration of the same in a given solution.
5. Determination of the composition of the Fe^{3+} - alicylic acid complex / Fe^{2+} - phenanthroline complex in solution by Job's method.

Section – B: Inorganic Chemistry

1. Separation of mixtures by chromatography: Measure the R_f value in each case. (Combination of two ions to be given)
2. Binary mixture of nickel and cobalt, copper and nickel, zinc and magnesium, iron and copper; aluminium and nickel.
3. Preparation of any two of the following complexes:
   (a) tetraaammine copper (II) sulphate
   (b) tetraamminecarbonatocobalt (III) nitrate
   (c) potassiumtrioxalatochromate (III)
   (d) potassiumtrioxalatoferrate (III)
   (e) sodiumhexanitritocabaltate (III)
   (f) prussin blue

Reference Books:

- Skoog, D.A.; West, D.M. & Holler, F.J. *Fundamentals of Analytical Chemistry 6thEd.*, Saunders College Publishing, Fort Worth, **1992**.
- Dean, J. A. *Analytical Chemistry Notebook*, McGraw Hill.
- Vogel, A. I. *Vogel's Qualitative Inorganic Analysis 7thEd.*, Prentice Hall.
- B.D. Khosla, *Senior Practical Physical Chemistry*, R. Chand & Co.
- K. Nad, B. Mahapatra and A. Ghosal, *An Advanced Course in Practical Chemistry*, New Central Book Agency Priv. Ltd, **2011**.
- V. K. Ahluwalia, S. Dhingra& A. Gulati, *College Practical Chemistry,* University Press, Delhi.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		3	1	1		1	3	2	3	1	3
CO2	3	1	2		3	1	1		1	3	2	3	1	3
CO3	2	1	1		2	1	2		2	2	1	2	2	3
CO4	3	2	2		3	2	1		1	2	3	3	1	2
CO5	3	1	2		3	1	1		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
V	Minor (Level 4)	CYUEMNT1	Fundamental Chemistry-V	Theory 3 (45 Lectures)
		CYUEMNL1	Fundamental Chemistry-V (Lab)	Practical: 1 (30 Hours)

CYUEMNT1: Fundamental Chemistry-V

Level 4, Credit 3 (45 Lectures)

Course Outcomes:

After completing this course, learners will be able to understand:

1. An exposure to lab safety and work environment.
2. An experience about work ethics and moral values in science.
3. Structures of carbohydrates and reactions.
4. Synthesis of amino acids and peptides, including their structures
5. The basics of proteins and nucleic acids

Unit – I: Safety Measures in Chemical Laboratory and Solution Preparation

Introduction to the chemical laboratory: general guidelines, cleanness, reagents, glassware, and equipment; safety symbols and regulations in chemical laboratory. Materials Safety Data Sheet (MSDS). Globally CAS registry number. Global overview of chemical regulations in India. Fundamentals units of measure.

Analytical balance and weights: general purpose chemical balance, electronic balance, analytical weight box and classification, calibration of weights and handling of electronic balance. Handling of laboratory apparatus and hazardous chemicals. Calibration of glassware (pipette, burette, etc.).

Types of solutions: mole and mole concept, equivalent weight, formula weight. Expression of concentration, molarity (M), molality (m), mole fraction, normality (N); weight, volume, and weight-to-volume ratios; parts per million (ppm), parts per billion (ppb).

(9 Lectures)

Unit – II: Treatment of Experimental Data

Significant figures, accuracy and precision in calculations. Uncertainties (error) in Data and Results, classification of errors, minimizations of errors, distribution of random errors, propagation of error. Reliability of Results, Confidence Interval, Rejection of data (t-test, F-test, and Q-test), Mean and Standard Deviations, Correlation and Regression,

Use of Computer: Excel spreadsheet, data entry and manipulation, formula entry and addressing, significance test, Graph plotting, curve fitting (linear and non-linear), and its analysis (including origin software).
Microsoft PowerPoint presentation, Molecule design and its properties determination using computational softwares, Introduction of various computational softwares for chemical sciences.

(10 Lectures)

Unit – III: Carbohydrates

Classification of carbohydrates, reducing and non-reducing sugars, and General Properties, Glucose and Fructose, their open chain structure. Epimers, mutarotation and anomers, Determination of configuration of monosaccharides, absolute configuration of Glucose and Fructose, Mutarotation, ascending and descending in monosaccharides. Structure of disacharrides (sucrose, cellobiose, maltose, lactose) and polysacharrides (starch and cellulose) excluding their structure elucidation.

(8 Lectures)

Unit – IV: Amino Acids and Peptides

Preparation of Amino Acids: Strecker synthesis using Gabriel's phthalimide synthesis. Zwitterion, Isoelectric point and Electrophoresis.

Reactions of Amino acids: ester of –COOH group, acetylation of $–NH_2$group, complexation with Cu^{2+} ions, ninhydrin test.

Overview of Primary, Secondary, Tertiary and Quaternary structure of proteins. Determination of primary structure of peptides, determination of N-terminal amino acid (by DNFB and Edman method) and C–terminal amino acid (by thiohydantoin and with carboxypeptidase enzyme). Synthesis of simple peptides (up to dipeptides) by N-protection (t-butyloxycarbonyl and phthaloyl) & C-activating groups and Merrifield solid phase synthesis.

(10 Lectures)

Unit – V: Proteins and Nucleic Acids

Components of Nucleic acids: Adenine, guanine, thymine and Cytosine (Structure only), other components of nucleic acids, Nucleosides and nucleotides (nomenclature), Structure of polynucleotides; Structure of DNA (Watson-Crick model) and RNA (types of RNA), Genetic Code, Biological roles of DNA and RNA: Replication, Transcription and Translation.

(8 Lectures)

Recommended Books/References:

- P. Atkins, J. d. Paula and K. James, *Physical Chemistry*, 11th Ed., Oxford University Press, **2018**.
- K. L. Kapoor, *A Text Book of Physical Chemistry: Applications of Thermodynamics, Vol. 3*, 5th Ed., McGraw-Hill, **2015**.
- B. R. Puri, L. R. Sharma and M. S. Pathania, *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing Co., **2018**.
- D. R. Crow, *Principles and Applications of Electrochemistry*, 4th Ed., Blackie Academic & Professional, **1994**.
- S. Chand. Morrison, R. T. & Boyd, R. N., *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. *Organic Chemistry* (*Volume 1*), Dorling Kindersley (India) Pvt. Ltd.

(Pearson Education).

- Finar, I. L. *Organic Chemistry* (*Volume 2)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Nelson, D. L. & Cox, M. M. *Lehninger's Principles of Biochemistry 7thEd.,* W. H. Freeman.

CYUEMNL1: Fundamental Chemistry-V (Lab)

Credit 1 (30 Hours)

1. Calibration of weights and glassware.
2. Preparation of solutions for given concentrations.
3. Programming of computer applications.
4. Graph plotting with data provided.
5. pH metry.
6. pH metric titration of (i) strong acid *versus* strong base, (ii) weak acid *versus* strong base.
7. Determination of the concentration of glycine solution by formylation method.
8. Titration curve of glycine.
9. Action of salivary amylase on starch.
10. Effect of temperature on the action of salivary amylase on starch.
11. Determination of the saponification value of an oil/fat.
12. Determination of the iodine value of an oil/fat.
13. Differentiation between a reducing/nonreducing sugar.
14. Extraction of DNA from onion/ cauliflower.

Reference Books:

- J. Elias, *A Collection of Interesting General Chemistry Experiments*, Revised Ed., University Press, **2007**.
- A. M. Halern and G. C. McBane, *Experimental Physical Chemistry: A Laboratory Textbook*, 3rd Ed., W. H. Freeman and Company, **2006**.
- S. K. Maity and N. K. Ghosh, *Physical Chemistry Practical*, NCBA, **2015**.
- B.D. Khosla, *Senior Practical Physical Chemistry*, R. Chand & Co.
- A. K. Nad, B. Mahapatra and A. Ghosal, *An Advanced Course in Practical Chemistry*, New Central Book Agency Priv. Ltd, **2011**.
- V. K. Ahluwalia, S. Dhingra& A. Gulati, *College Practical Chemistry*, University Press, Delhi.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	1		3	2	2		1	3	2	3	1	3
CO2	3	1	2		3	1	1		1	3	2	3	2	3
CO3	3	1	2		2	1	1		1	3	1	3	1	3
CO4	3	1	2		3	2	1		1	3	3	3	1	2
CO5	2	1	2		3	1	1		1	2	2	2	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VI	Minor (Level 4)	CYUFMNT1	Fundamentals of Spectroscopy	Theory 3 (45 Lectures)
		CYUFMNL1	Fundamentals of Spectroscopy (Lab)	Practical: 1 (30 Hours)

CYUFMNT1: Fundamentals of Spectroscopy

Level 4, Credit 3 (45 Lectures)

Course Outcomes:

After completing this course, students will be able to understand:

1. Quantum mechanics versus classical mechanics, Postulates of quantum mechanics and its applications in spectroscopy.
2. Understanding and basic working principle of UV-spectroscopy.
3. Schrödinger equation for H-like atoms, four quantum numbers, introduction to Schrödinger equation to two or more electron systems.
4. Basics of Infrared spectroscopy, UV-Visible spectroscopy and Raman spectroscopy.
5. Principal and applications of Raman spectroscopy.

Unit – I: Quantum Chemistry and Spectroscopy – I

A review of quantum mechanics versus classical mechanics, (black body radiation, photoelectric effect, Compton's effect), wave nature of electron; wave particle duality; Heisenberg's uncertainty principle. Postulates of quantum mechanics, quantum mechanical operators. Free particle. Particle in a 1-D box, quantization, normalization of wave functions, concept of zero-point energy.

Spectroscopy and its importance in chemistry. Wave-particle duality. Link between spectroscopy and quantum chemistry. Electromagnetic radiation and its interaction with matter. Type of spectroscopies. Difference between atomic and molecular spectra. Born-Oppenheimer approximation: Separation of molecular energies into translational, rotational, vibrational and electronic components.

Electronic Spectroscopy: Electronic excited states. Free Electron model and its application to electronic spectra of polyenes.

(10 Lectures)

Unit-II: UV-Visible Spectrometry

Basic principles of instrumentation, principles of quantitative analysis using estimation of metal ions from aqueous solution, Determination of composition of metal complexes using Job's method of continuous variation and mole ratio method. Color and constitution, chromophores, auxochromes, bathochromic and hypsochromic shifts.

(10 Lectures)

Unit – III: Quantum Chemistry and Spectroscopy – II

Rotational Motion: Schrödinger equation of a rigid rotator and brief discussion of its results (solution not required). Quantization of rotational energy levels. Microwave (pure rotational) spectra of diatomic molecules. Selection rules. Structural information derived from rotational spectroscopy.

(9 Lectures)

Unit – IV: Quantum Chemistry and Spectroscopy – III

Vibrational Motion: Schrödinger equation of a simple harmonic oscillator and brief discussion of its results (solution not required). Quantization of vibrational energy levels. Selection rules, IR spectra of diatomic molecules. Structural information derived from vibrational spectra. Vibrations of polyatomic molecules. Group frequencies. Effect of hydrogen bonding (inter- and intramolecular) and substitution on vibrational frequencies.

(8 Lectures)

Unit – V: Raman Spectroscopy

Introduction to Raman spectra, Light Scattering: Rayleigh scattering (elastic scattering) and Raman scattering (inelastic scattering), Stokes and anti-Stokes scattering, Molecular Vibrations.

(8 Lectures)

Recommended Books/References:

- P. Atkins, J. d. Paula and K. James, *Physical Chemistry*, 11th Ed., Oxford University Press, **2018**.
- C. N. Banwell and E. M. McCash, *Fundamentals of Molecular Spectroscopy*, 4th Ed., Tata McGraw-Hill, **1996**.
- A. Chandra, *Introductory Quantum Chemistry*, 4th Ed., McGraw Hill Education, **2017**.
- T. Engel and P. Reid, *Quantum Chemistry and Spectroscopy*, 5th Ed., Pearson, **2011**.
- K. L. Kapoor, *A Text Book of Physical Chemistry: Quantum Chemistry and Molecular Spectroscopy, Vol. 4*, 5th Ed., McGraw-Hill, **2015**.
- I. N. Levine, *Quantum Chemistry*, 7th Ed., Pearson, **2014**.
- D. A. McQuarrie and J. D. Simon, *Physical Chemistry: A Molecular Approach*, Viva Book Private Limited, **2005**.
- Mendham, J., A. I. Vogel's *Quantitative Chemical Analysis* 6th Ed., Pearson, **2009**.
- Willard, H.H. et al., *Instrumental Methods of Analysis*, 7th Ed. Wardsworth Publishing California, USA, **1988**.
- Christian, G.D, *Analytical Chemistry*, 6th Ed. John Wiley & Sons, New York, **2004**.
- Harris, D.C.: *Exploring Chemical Analysis*, 9th Ed. New York, W.H. Freeman, **2016**.
- Skoog, D.A. Holler F.J. & Nieman, *T.A. Principles of Instrumental Analysis*, Saunder College Publications, **1998**.
- Mikes, O. Laboratory *Handbook of Chromatographic & Allied Methods*, Elles Harwood *John Wiley*, **1979**.
- Ditts, R.V. *Analytical Chemistry; Methods of separation*, van Nostrand, **1974**.

- Khopkar, S. M., *Basic Concepts of Analytical Chemistry*, New Age (Second edition), **1998**.
- Skoog D.A., Holler F.J., Nieman T.A., *Principles of instrumental analysis*, 5th Edn., Brooks & Cole, **1997**.

CYUFMNL1: Fundamentals of Spectroscopy (Lab)

Credit 1 (30 Hours)

1. Computational Experiments:

- Learning chemistry through computers: List the open source and commercial software packages for computational simulation.
- ArgustLab/Gaussian Software:
  - ✓ Single point energy, geometry optimization and population analysis.
  - ✓ Optimize the geometry of CO_2, H_2O, NH_3, CH_4, C_2H_6, C_2H_4, C_2H_2, etc.
  - ✓ Predict the various properties of CO_2 using Gaussian, employing HF/3-21G method.
  - ✓ Compare the C–C band length in optimized C_2H_6, C_2H_4, and C_2H_2. Also visualize the molecular orbitals, electron density, and electrostatic potential map.
  - ✓ (a) Calculate the optimized structure of CO_2 and compute vibrational frequencies. (b) Plot the structure of IR and Raman active mode in CO_2. (c) compute HOMO-LUMO energy gap in CO_2.
  - ✓ Perform conformational analysis of butane.
  - ✓ Determine the enthalpy of isomerization of *cis*- and *trans*-2-butene.

2. UV/Visible spectroscopy:
- Study the 200-500 nm absorbance spectra of $KMnO_4$ and $K_2Cr_2O_7$ (in 0.1 M H_2SO_4) and determine the λ_{max} values. Calculate the energies of the two transitions in different units (J molecule^{-1}, kJ mol^{-1}, cm^{-1}, eV).
- Study the pH-dependence of the UV-Vis spectrum (200-500 nm) of $K_2Cr_2O_7$.
- 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.

3. Colorimetry:
- Verify Lambert-Beer's law and determine the concentration of $CuSO_4$/$KMnO_4$/$K_2Cr_2O_7$ in a solution of unknown concentration.
- Determine the concentrations of $KMnO_4$ and $K_2Cr_2O_7$ in a mixture.

4. Structural characterization of compounds by infrared spectroscopy.

Note: *Experiments may be added/ deleted subject to availability of time and facilities.*

Reference Books:

- D. C. Young, *Computational Chemistry: A Practical Guide for Applying Techniques to Real-World Problems*, John Wiley, **2001**.
- D. W. Rogers, *Computational Chemistry Using the PC*, Ed: 3rd, John Wiley, **2003**.
- C. J. Cramer, *Essentials of Computational Chemistry Theories and Models*, Ed: 2nd, John Wiley, **2004**.
- R. Leach, *Molecular Modelling: Principle and Applications*, Longman, **2001**.
- Mendham, J., A. I. Vogel's *Quantitative Chemical Analysis 6th Ed., Pearson*, **2009**.
- 2Willard, H.H. et al.: *Instrumental Methods of Analysis*, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, **1988**.
- Christian, G.D. *Analytical Chemistry*, 6th Ed. John Wiley & Sons, New York, **2004**.
- Harris, D.C. *Exploring Chemical Analysis*, 9th Ed. New York, W.H. Freeman, **2016**.
- Khopkar, S.M. *Basic Concepts of Analytical Chemistry.* New Age International Publisher, **2009**.
- Skoog, D.A. Holler F.J. and Nieman, T.A. *Principles of Instrumental Analysis,* Cengage Learning India Edition.
- Mikes, O. & Chalmers, R.A. *Laboratory Handbook of Chromatographic & Allied Methods,* Elles Harwood Ltd. London.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	2		1	1	1		2	3	2	3	1	3
CO2	3	1	2		3	2	1		1	3	2	3	2	3
CO3	3	1	2		3	1	1		1	3	2	3	1	3
CO4	3	1	2		3	1	1		1	2	3	3	1	2
CO5	2	1	3		3	1	2		1	3	2	2	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VII	Minor (Level 5)	CYUGMNT1	Nanomaterials: Synthesis, Characterization, and Applications	Theory 3 (45 Lectures)
		CYUGMNL1	Nanomaterials: Synthesis, Characterization, and Applications (Lab)	Practical: 1 (30 Hours)

CYUGMNT1: Nanomaterials: Synthesis, Characterization, and Applications

Level 5, Credit 3 (45 Lectures)

Course Outcomes:

Learners shall be able to understand the following upon completion of the course:

1. Fundamental principles of nanotechnology.
2. Variety of comely used nanomaterials, ZnO, TiO_2, Ag nanoparticles, etc.
3. Structural and morphological characterization techniques of nanomaterials.
4. Wet chemical synthesis strategies of nanomaterials.
5. Recent applications based on nanomaterials.

Unit – I: Nanoscience and Nanotechnology

Introduction: Underlying physical principles of nanotechnology: *Nanostructured Materials: Size is Everything*. Fundamental physicochemical principles, size and dimensionality effects; quantum confinement; properties dependent on density of states; central importance of nanoscale morphology. Societal aspects of nanotechnology: health, environment, hype and reality.

Type of Nanostructures: Definition of a nano system; one dimensional (1D), two dimensional (2D), three dimensional (3D) nanostructured materials; quantum dots; quantum wire, and core/shell structures.

(8 Lectures)

Unit – II: Some Important Nanomaterials

Variety of inorganic (traditional to advanced) nanomaterials, Importance of Structural/refractory, Electronic and Bio-materials, Oxide superconductors and novel materials. Nanocrystalline/amorphous solids.

(7 Lectures)

Unit – III: Characterization Techniques

X-ray diffraction, electron microscopy (SEM, TEM, AFM), thermal techniques (TG, DTA, DSC), spectroscopic techniques (IR, UV-VIS), XPS.

(12 Lectures)

Unit – IV: Chemical Routes Preparation Techniques

Chemical Routes for Synthesis of Nanomaterials: Chemical precipitation and co-precipitation; sol-gel synthesis; microemulsions or reverse micelles; solvothermal synthesis; thermolysis routes, microwave heating synthesis biomimetic and electrochemical approaches; sonochemical synthesis; photochemical synthesis; synthesis in supercritical fluids.

(8 Lectures)

Unit – V: Applications of Nanomaterials

Journal paper presentation from any recent work of metal, oxide, nitride, sulfide, etc., -based nano-systems.

(10 Lectures)

Recommended Books/References:

- G. Cao, *Nanostructures and nanomaterials synthesis, properties and applications*, Imperial College Press, London, **2004**.
- G. L. Hornyak, J. J. Moore, H. F. Tibbals and J. Dutta, *Fundamentals of Nanotechnology*, 1st Ed., CRC Press, **2008**.
- T. Pradeep, *A textbook of Nanoscience and Nanotechnology*, MsGraw-Hill Education, **2015**.
- T. Pradeep, *NANO: The Essentials: Understanding Nanoscience and Nanotechnology*, 1st Ed., McGraw Hill Education, **2017**.
- B. D. Cullity, *Elements of x-ray diffraction*, 2nd Ed., Addison-Wesley Publishing Company Inc, California, **1978**.
- J. I. Goldstein, D. E. Newbury, J. R. Michael, N. W. M. Ritchie, J. H. J. Scott and D. C. Joy, *Scanning Electron Microscopy and X-Ray Microanalysis*, 4th Ed., Springer, New York, **2018**.
- D. B. Williams and C. B. Carter, *Transmission electron microscopy: a textbook for materials science*, Plenum Press, New York, **1996**.

CYUGMNL1: Nanomaterials: Synthesis, Characterization, and Applications (Lab)

Credit 1 (30 Hours)

- Verification of the Beer-Lambert law using gold/silver nanoparticles.
- Preparation and characterization of nanomaterials by bottom-up with special reference to wet chemical strategies (sol-gel, hydrothermal, co-precipitation, solid-state chemistry, *etc*.)
- Synthesis and characterization of mixed metal oxide (bimetallic and oxides)
- Studies of catalytic conversion (e.g. *p*-nitrophenol to *p*-aminophenol) using nanoparticles.
- Determination of the band gap of semiconductor nanomaterials.
- Study of photocatalytic dye degradation by using nanomaterials.

Note: *Some others experiment based on the application of nanomaterials may be carried out in the class if permit.*

Recommended Books:

- G. E. J. Poinern, *A Laboratory Course in Nanoscience and Nanotechnology*, CRC Press, **2015**.
- T. Pradeep, *A textbook of Nanoscience and Nanotechnology*, MsGraw-Hill Education, **2015**.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	1	2		2	1	1		2	3	2	3	1	3
CO2	3	2	2		3	2	1		1	3	2	3	2	3
CO3	3	1	2		3	1	1		1	3	2	3	1	3
CO4	3	1	2		3	1	1		1	2	1	2	1	2
CO5	3	1	1		3	1	2		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VIII	**Minor (Level 5)**	CYUHMNT1	Instrumental Methods of Analysis	**Theory 3 (45 Lectures)**
			Instrumental Methods of Analysis (Tutorial)	**Tutorial: 1 (15 Hours)**

CYUHMNT1: Instrumental Methods of Analysis

Level 5, Theory Credit 3 (45 Lectures)
Tutorial Credit 1 (15 Hours)

Course Outcomes:

Learners shall be able to understand the following upon completion of the course:

1. Fundamental principles of molecular spectroscopy and various spectroscopy techniques.
2. Fundamental principles of atomic spectroscopy.
3. Various thermal analytical methods to determine stability and thermodynamic nature of the molecules.
4. Fundamental principles and introduction of instruments related to chromatographic techniques.
5. Introduction of analytic tools related to electrochemical techniques.

Unit – I: Molecular Spectroscopy

Nature of electromagnetic radiation, electromagnetic spectrum, atomic, molecular and vibrational energy levels, basic instrumentation- source of radiation, monochromator, sample cells, absorber, detector, UV-Vis detector, photomultiplier, IR detector, display and recorder, single and double beam spectrophotometer, Beer Lambert law, deviation from beers law, ultraviolet and visible spectroscopy, Fluorescence and phosphorescence spectrophotometer, Fourier transform infrared spectrometer and Raman spectrometer, instrumentation, techniques and application.

(10 Lectures)

Unit – II: Atomic Spectroscopy

Flame emission spectrometry, atomic absorption spectroscopy- principle, instrumentation, Source in AAS – Hollow cathode lamp, electrode less discharge lamp, burners, nature and property of flame, interference in AAS, difference between AAS and FES, ICP.

(8 Lectures)

Unit – III: Thermal Analysis

Types of thermal method, Thermogam, thermogravimetric analysis (TGA), differential thermal analysis (DTA), differential scanning calorimetry (DSC), schematic diagram for TGA and DTA instruments and their working principle, factors affecting thermogram like geometry of sample holder, furnace atmosphere, heating rate, particle size, packing of sample, weight of sample, analysis of metals or oxide in mixture, application of TGA and DTA.

(7 Lectures)

Unit – IV: Chromatography

Principles of chromatographic separation, classification of Chromatographic Techniques: adsorption, partition, ion exchange and size exclusion chromatography, theory of chromatographic separation, distribution coefficient, retention time, sorption, theory of column efficiency and resolution, separation factor, retention factor. – working principle and application of Column chromatography, ion exchange chromatography, paper chromatography, thin layer chromatography (TLC) & HPTLC.

(10 Lectures)

Unit – V: Electroanalytical Techniques

Electrochemical cells, current potential relationship, mass transfer by migration, convection and diffusion, Electrogravimetry, voltammetry, polarography, reference electrode, working electrode, auxiliary electrode, dropping mercury electrode, current potential curve, limiting current, coulometry, conductometry methods, instrumentation, techniques and application. Amperometric titration, effect of electroactive and reagent on amperometric curve and its advantage, rotating platinum electrode, biamperometric titration and its advantage, fluorimetry and phosphorimetry.

(10 Lectures)

Recommended Books/References:

- Arthur I. Vogel: *A Test book of Quantitative Inorganic Analysis* (Rev. by G.H. Jeffery and others) 5th Ed. The English Language Book Society of Longman .
- Hobert H. Willard et al: *Instrumental Methods of Analysis*, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, **1988**.
- Gary D. Christian: *Analytical Chemistry*, 6th Ed. John Wiley & Sons, New York, **2004**.
- C. Daniel Harris: *Exploring Chemical Analysis*, Ed. New York, W.H. Freeman, **2001**.
- S. M. Khopkar: *Basic Concepts of Analytical Chemistry*, New Age, International Publisher, **2009**.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		2	1	1		2	3	2	3	1	3
CO2	3	1	3		3	2	1		1	2	1	3	2	3
CO3	2	1	2		3	1	1		1	3	2	3	1	3
CO4	3	2	2		3	1	1		1	2	3	3	1	2
CO5	3	1	2		3	1	1		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
VIII	Minor (Level 5)	CYUHMNT2	Introduction of Bioorganic Chemistry	Theory 3 (45 Lectures)
		CYUHMNL2	Introduction of Bioorganic Chemistry (Lab)	Practical: 1 (30 Hours)

CYUHMNT2: Introduction of Bioorganic Chemistry

Level 5, Credit 3 (45 Lectures)

Course Outcomes:

Learners shall be able to understand the following upon completion of the course:

1. Carbohydrates structures and reactions, degradation of monosaccharides.
2. Alkaloids, terpenes isolation, structural elucidation.
3. Photochemistry of carbonyl compounds and olefins.
4. Amino acids, peptide bonds, protein structure, deficiency diseases, oxygen uptake proteins.
5. Enzyme function, kinetics, hemoglobin, transport mechanisms, physiological roles of vitamins and hormones.

Unit – I: Carbohydrates

Introduction, monosaccharadies, glycoside bond formation, mutarotation. Reactions of aldoses and ketoses (oxidation and reductions). Killiani synthesis, Osazone formation. Glucose-structure (including cyclic structure), Fructose (reactions only). Degradation of monosaccharaides: Ruff degradation.

(10 Lectures)

Unit – II: Chemistry of Natural Products

A study of the following compounds involving their isolation, structure elucidation and synthesis: Alkaloids- Hofmann exhaustive methylation, nicotine; Terpenes- Isoprene rule, citral.

(10 Lectures)

Unit – III: Photochemistry

Principles of photochemistry, photochemical reactions of carbonyl compounds and olefins.

(5 Lectures)

Unit – IV: Amino acids, Peptides and Proteins

Amino acids – Importance, Preparative methods, physical properties, dipolar nature, chemical reactions and configuration. Concept of unnatural amino acids.

Peptides: Peptide-linkage, peptide synthesis and structure of polypeptides. Proteins: General characteristics and primary, secondary and tertiary structure. Common deficiency diseases. Oxygen uptake proteins: Hemerythrin and hemocyanin

(10 Lectures)

Unit – V: Enzymes, Proteins, Vitamins and Hormones

Introduction, classification, formation and function of enzymes, co-enzymes, cofactors (elementary idea); Enzyme kinetics, TON and TOF, Enzyme inhibitors. Hemoglobin: Oxygen and carbon dioxide transport by hemoglobin. Carbonic anhydrase and superoxide dismutase. Chemical constitution and physiological functions of vitamins A, B2 (Riboflavin), C (Ascorbic acid); Thyroxin and estrone.

(10 Lectures)

Recommended Books/References:

- "Organic Chemistry", R. T. Morrison and R. N. Boyd, *6th Edition*, Prentice-Hall of India (P) Ltd., New Delhi, **1992**.
- "Organic Chemistry", S. M. Mukherji , S. P. Singh, and R. P. Kapoor, *1st Edition* (1985), , New Age International (P) Ltd. Publishers, New Delhi, 5th Reprint, **1999**.
- "Organic Chemistry", I. L. Finar, *Vol. II, 5th Edition, Reprinted in 1996,* ELBS and Longman Ltd., New Delhi, **1975**.
- "Biochemistry" L. Stryer, *5th edition*, Freeman & Co New York, **2002**.
- "Principles of Biochemistry" D. L. Nelson M.M. Cox, Lehninger, *3rd edition*, McMillan North Publication, **2002**.
- L. Stryer, Biochemistry, *5th Edition*, Freeman &Co. New York, **2002**.
- D.L. Nelson and M.M. Cox, Lehninger *Principles of Biochemistry 3rd Edition*, McMillan North Publication, **2002**.
- D. Voet, J. G. Voet, *Biochemistry 3rd Edition*, Wiley International Publication, **2004**.
- I. Bertini, H. B. Gray, S. J. Lippard, J.S. Valentine, *1st South Asian Edn.,* Viva Books Pvt. Limited, New Delhi, **1998**.
- M. B. Smith, *Organic Synthesis,* Mc Graw Hill Inc, New York, **1998**.

CYUHMNL2: Introduction of Bioorganic Chemistry (Lab)

Credit 1 (30 Hours)

A. Identification and estimation of the following:

1. Carbohydrates – qualitative and quantitative.
2. Lipids – qualitative.
3. Proteins – qualitative.
4. Isolation of protein.
5. Determination of protein by the Biuret reaction.

B. Qualitative analysis:

Unknown organic compounds containing monofunctional groups (carbohydrates, aryl halides, aromatic hydrocarbons, nitro compounds, amines and amides) and simple bifunctional groups, for e.g. salicylic acid, cinnamic acid, nitrophenols etc.

C. Identification by Spectroscopy:

Simple organic compounds by IR spectroscopy and NMR spectroscopy (Spectra to be provided).

Recommended Books:

- T.G. Cooper: *Tool of Biochemistry*.
- Keith Wilson and John Walker: *Practical Biochemistry*.
- Alan H Gowenlock: *Varley's Practical Clinical Biochemistry*.
- Thomas M. Devlin: *Textbook of Biochemistry*.
- Jeremy M. Berg, John L Tymoczko, Lubert Stryer: *Biochemistry*.
- G. P. Talwar and M Srivastava: *Textbook of Biochemistry and Human Biology*.
- A.L. Lehninger: Biochemistry. O. Mikes, R.A. Chalmers: *Laboratory Handbook of Chromatographic Methods*

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		1	2	1		2	3	2	3	1	3
CO2	3	1	2		3	1	1		1	3	2	3	1	3
CO3	3	1	2		3	1	1		1	3	2	3	1	3
CO4	3	2	2		3	1	1		1	3	3	3	1	2
CO5	2	1	3		3	1	2		1	2	2	2	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

Multidisciplinary Courses (MDC)

Semester	Nature of Course	Course Code	Name of the course	Credits
I/II	**MDC (Level 1)**		Conceptual Understanding of Physical Science-I	**Theory 2 (30 Lectures) Tutorial 1 (15 Hours)**

: Conceptual Understanding of Physical Science-I

Level 1, Theory 2 (30 Lectures)

Tutorial 1 (15 Hours)

Course Outcomes:

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

1. Understand the importance of chemistry in daily life
2. Importance and impact of the measurement term of quantity and dimensions
3. Basic understanding of the law of motion
4. Understand the basics of power, energy, kinetic and potential energies
5. Fundamentals of gravity.

Unit – I: Chemistry in daily life

Organic molecules in daily life: Chemistry of carbohydrates, amino acids, lipids, fats, soaps, detergents: General structure, source, applications, detection and analysis

General introduction to pesticides (natural and synthetic), benefits and adverse effects, synthesis and technical manufacture and uses of representative pesticides in the following classes: Organochlorines (DDT); Quinones (Chloranil).

Chemical constitution and physiological functions of vitamins A, vitamin C (Ascorbic acid).

15 lectures

Unit – II: Measurement

Physical quantities and dimensions of physical quantities, dimensional analysis and its applications.

1 Lecture

Unit – III: Kinematics

Motion in a straight line: Position-time graph, speed and velocity. Uniform and non-uniform motion, average speed and instantaneous velocity. Uniformly accelerated motion, velocity time and position-time graphs, and relations for uniformly accelerated motion (graphical treatment), Scalar and Vector products of Vectors.

3 Lectures

Unit – IV: Laws of Motion

Intuitive concept of force. Inertia, Newton's first law of motion; momentum and Newton's second law of motion; impulse; Newton's third law of motion. Law of conservation of linear momentum and its applications.

3 Lectures

Unit – V: Work, Energy and Power

Work done by a constant force and a variable force; kinetic energy, work-energy theorem, power. Notion of potential energy, potential energy of a spring, conservative forces; conservation of mechanical energy (kinetic and potential energies); non-conservative forces.

4 Lectures

Unit – VI: Gravitation

Kepler's laws of planetary motion. The universal law of gravitation. Acceleration due to gravity and its variation with altitude and depth. Gravitational potential energy; gravitational potential. Escape velocity.

5 Lectures

Reference:

- "Organic Chemistry", I. L. Finar, Vol. I & II, 5th Edition (1975), Reprinted in 1996, ELBS and Longman Ltd., New Delhi.
- "Biochemistry" L. Stryer, 5th edition (2002) Freeman & Co New York.
- "Principles of Biochemistry" D. L. Nelson, M.M. Cox, Lehninger, 3rd edition (2002) McMillan North Publication.
- R. Cremlyn: Pesticides, John Wiley
- Mechanics, J.C. Upadhyaya, 2017, Ram Prasad Publications, Agra.
- Classical Mechanics, 2014, J.C. Upadhyaya, Himalaya Publishing House.
- NCERT: Physics Part-I

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2	2	3	1	1	2	1	3	2	3	2	3
CO2	2	3	2	2	2	3	3	1	1	3	2	3	1	2
CO3	3	1	2	1	3	1	1	3	1	3	2	2	1	3
CO4	3	2	2	2	3	1	1	3	1	2	2	3	1	3
CO5	3	1	2	1	3	1	1	3	1	3	1	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
I/II/III	**MDC (Level 1)**	MDCCY01	Chemistry in Everyday Life	**Theory 2 (30 Lectures) Tutorial 1 (15 Hours)**

MDCCY01: Chemistry in Everyday Life

Level 1, Theory 2 (30 Lectures)

Tutorial 1 (15 Hours)

Course Outcomes:

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

1. Understand the chemical processes involved in daily life
2. Know the respiration process in terms of chemistry
3. Understand chemicals hazardous for health
4. Understand chemical structures of various vitamins
5. Understand the role of minerals in important biological processes.

Unit – I: Respiration and Energy Production in Human Body

Respiration, Respiratory enzymes, brief outline of hemoglobin and myoglobin, oxygen transport mechanism in body, co-operativity, Respiration in lower animals, hemocyanine, hemerythrine. Energy production in body, ATP; enzyme responsible for food digestion, mechanism of food digestion, active site of cytochrome c-oxidase.

(6 Lectures)

Unit – II: Chemical Aspects of Some Common Health Hazards

Anemia, sickle cell anemia, leukemia, blood pressure irregulation, blood sugar, arthritis, carbon monoxide poisoning in mines, cyanide poisoning, fluorosis etc.

(5 Lectures)

Unit – III: Vitamins and minerals

Need for vitamin in body, types of vitamins, water soluble and fat-soluble vitamins, Vitamin B- 12, vitamin C (Cyanocobalamine), D, Vitamin K. Role of minerals in body, iodine deficiency andremedy.

(5 Lectures)

Unit – IV: Significance of Radical chemistry in Living System

Radical production in environment, superoxide and peroxide, health impact, action of radicals, cell mutation, diseases caused by free radical, cancer, radical quencher, anti-oxidants, natural anti-oxidants like vegetables, beverages like tea and coffee, fruits.Radical destroying enzymes: superoxide dismutase, catalase, peroxidase, mechanism of action.

(6 Lectures)

Unit – V: Chemistry of Materials

Soaps and Detergents – their action, Biofuels – production of biofuels and its utility as alternative fuel source, Fibers: natural fibers, cotton, wool, silk, rayon, artificial fibers,

polyamides, acrylic acid, PVC, PVA; Examples of natural biodegradable polymers, cellulose, cellulose acetate, cellophane, soy protein, corn, zein protein, wheat gluten protein, synthetic biodegradable polymers. Use of polymeric materials in daily life.

(8 Lectures)

Recommended Books/References:

- Kaim W, *Bioinorganic Chemistry*, Vol 4, Brigitte Scwederski, Wiley,**1994**.
- Crichton R. H., *Biological Inorganic Chemistry – An Introduction*, Elsevier, **2008**.
- Berg J. M., Tymoczeko J. L., Stryer L. *Biochemistry*, W. H. Freeman, **2008**.
- Bertini, I., Gray, H. B., Lippard, S. J. and Valentine, J. S., *Bioinorganic Chemistry.* University Science Books, **1994**.
- Lippard S., Berg J. M., *Principles of Bioinorganic Chemistry*, University Science Books **1994**.
- V. R. Gowariker, N. V. Viswanathan, J. Sreedhar, *Polymer science*, New Age International.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		3	1	1		1	3	2	3	1	3
CO2	3	3	2		2	3	3		1	3	3	3	1	3
CO3	3	1	2		3	1	1		1	3	2	3	1	3
CO4	3	2	2		3	1	1		1	3	2	3	1	3
CO5	3	1	2		3	1	1		1	3	1	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
I/II/III	**MDC (Level 1)**	MDCCY02	Good Laboratory Practices	**Theory 3 (45 Lectures)**

MDCCY02: Good Laboratory Practices

Level 1, Credit 3 (45 Lectures)

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

1. Demonstrate essential practical skills required in scientific experiments, with a solid understanding of good laboratory practices.
2. Identify and analyze contemporary research problems in chemistry and evaluate possible solutions.
3. Utilize standard laboratory procedures and safety protocols while performing chemical experiments.
4. Apply appropriate analytical techniques to investigate the properties and structures of chemical compounds and salts.
5. Interpret experimental data accurately and draw meaningful conclusions based on laboratory findings.

Unit – I: Fundamentals of Laboratory Practices
Importance and scope of Good Laboratory Practices (GLP), Lab conduct and ethics, Interpretation of reagent bottle labels (hazard symbols, expiry, concentrations), Basic safety measures in handling chemicals, Introduction to toxic chemicals and safe disposal methods.

(07 Lectures)

Unit – II: Solution Chemistry and Laboratory Calculations
Molarity, molality, normality: definitions and calculations, Preparation of solutions and dilutions, Percentage, molar, molal, and normal solutions, Common laboratory calculations in chemistry labs, Use and calibration of micropipettes.

(10 Lectures)

Unit – III: Instrumental Techniques in Laboratory Work
Use of analytical balances and calibration, Operation of pH meter, conductivity meter, and potentiometer, Rotary evaporator: working principle and applications, Safety and maintenance of laboratory instruments, Use of purified water in laboratory experiments.

(09 Lectures)

Unit – IV: Laboratory Handling and Material Preparation
Cleaning and drying of glassware, Handling of samples and reagents, Crystallization techniques: preparation of crystals from salts, Preparation and application of dyes in lab experiments, SOPs for common lab processes.

(08 Lectures)

Unit – V: Advanced Laboratory Procedures and Demonstrations
Sol-gel synthesis: principle, procedure, and demonstration, Lab notebook maintenance and data recording, Quality assurance through proper documentation, Ethical issues and error prevention in

experimental work, Demonstration-based learning and hands-on evaluations

(11 Lectures)

Recommended Books/References:

- J. P. Seiler, *Good Laboratory Practices: the why and how*. 2nd Ed Springer-Verlag Berlinand Heidelberg GmbH & Co. **2005**.
- W. Y. Garner, M. S. Barge, P. J. Ussary, *Good Laboratory Practice Standards: Application for field and Laboratory studies*. WileyVCH, **1992**.
- Bunn, G. P. (Ed.). (2023). *Good Laboratory Practice for Nonclinical Studies*. CRC Press; 1st ed.
- Doneski, L., Roos, D., & Dong, M. W. (2023). "Good Laboratory Practice (GLP): An Overview for the Analytical Chemist." *LCGC North America*, 41(6), 381–385.
- OECD (2021). *Second Edition: Quality Assurance and GLP* and *GLP Data Integrity*. OECD Series on Principles of Good Laboratory Practice and Compliance Monitoring.
- Patil-Dongare, T. (2021). *Good Laboratory Practices and Compliance Monitoring*. BSP Books/PharmaMed Press; 1st ed.
- Weinberg, S. (2024). *Good Laboratory Practice Regulations*, Revised & Expanded (4th ed.). Taylor & Francis.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		3	1	1	2	1	3	2	3	2	3
CO2	3	3	2		2	3	3	1	1	3	3	3	1	3
CO3	3	1	2		3	1	1	3	1	3	2	3	1	3
CO4	3	2	2		3	1	1	3	1	2	2	3	1	3
CO5	3	1	2		3	1	1	3	1	3	1	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
I/II/III	**MDC (Level 1)**	MDCCY03	Chemistry of Food, Nutrition, and Preservation	**Theory 2 (30 Lectures) Tutorial 1 (15 Hours)**

MDCCY03: Chemistry of Food, Nutrition, and Preservation

Level 1, Theory 2 (30 Lectures)

Tutorial 1 (15 Hours)

Course Outcomes:

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

1. To know about the basics of human physiological system
2. To learn about nutrition and its importance
3. To learn about the food science
4. To learn about food preservation and its utility
5. To learn about the Quantitative estimation and nutritional assessment data

Unit – I

Basic of human physiological system and food science: Digestive System: Structure and functions of G.I. tract, Process of digestion and absorption of food, Structure and functions of liver, gallbladder and pancreas. Basic concept on Food, Nutrition and Nutrients (Nutrition, Malnutrition and Health: Scope of Nutrition.), Classification of Food, Classification of Nutrients.

(10 Lectures)

Unit – II

Nutrition: Dietary fibers (composition, properties and Minerals and trace elements (biochemical and physiological role, bioavailability and requirement with examples), Vitamins (examples, biochemical and physiological requirements, deficiency and excesses), Water (requirement, water balance), basic idea about community nutrition (objective, importance of various programmes).

(10 Lectures)

Unit – III

Food preservation: definition, objectives and principles of food preservation. Different methods of food preservation. Preserved Products: Jam, Jelly, Marmalade, Sauces, Pickles, Squashes, Syrups-types, composition and manufacture, selection, cost, storage, uses and nutritional aspects, Food Standards: ISI, Agmark, FPO, MPO, PFA, FSSAI.

(10 Lectures)

Recommended Books/References:

- Sri Lakshmi B(2017): Nutrition Science,6th Multicolour Ed. New Age International (P)Ltd.
- Roday S (2012): Food Science and Nutrition, 2nd Ed. Oxford UniversityPress.
- Mann J and Truswell S(2017) : Essentials of Human Nutrition, 5th Ed. Oxford University Press.
- Wilson K and Walker J(2000): Principles and Techniques of Practical Biochemistry, 5th Ed. Oxford UniversityPress.
- Sadasivan S and Manikam K(2007): Biochemical Methods, 3rd Ed. New Age International (P) Ltd.
- Oser B. L. (1965). Hawk's Physiological Chemistry, 14th Ed. McGraw-HillBook.
- Gopalan C, Rama Sastri BV and Balasubramanian S.C. (2016): Nutritive value of Indian Foods, Indian Council of MedicalResearch.
- Subalakshmi, G and Udipi, SA(2006):Food processing and preservation, 1st Ed. New Age International(P)Ltd.
- Srilakshmi B(2018): Food Science, 7th Colour Ed. New Age International (P) Ltd.
- Potter NN and Hotchkiss JH(1999): Food science,5th Ed ,Spinger.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		3	1	1	2	1	3	2	3	2	3
CO2	3	3	1		2	3	2	1	2	3	3	2	1	3
CO3	3	1	2		3	1	1	3	1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

Skills Enhancement Course (SEC)

Semester	Nature of Course	Course Code	Name of the course	Credits
I/II/III	**SEC (Level 1)**	SECCY01	Science Communication and Popularization	**Theory 2 (30 Lectures) Tutorial 1 (15 Hours)**

SECCY01: Science Communication and Popularization

Level 1, Theory 2 (30 Lectures)

Tutorial 1 (15 Hours)

Course Outcomes:

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

1. Identify the need and role of science communication in human development
2. utilize visual media science communication for creating scripts and documentaries
3. Contribute in science popularization through internet communication and public sensitization
4. Outreach Talks and Public Sensitization

Unit – I: Print Science Communication

Need for Science Journalism: Science has potential for breaking news, impact on Human life, impact on technology. Role of science and technology in human development. Framing policies at national and international levels. Writing and communicating popular articles effectively, case studies of celebrated works of science communicators including Cosmos by Carl Sagan, works of Bill Bryson, Richard Dawkins, Richard Feynman, Isaac Asimov, Carl Zimmer and Matt Riddley, importance for communication through regional languages.

(10 Lectures)

Unit – II: Visual Media Science Communication

Science outreach through visual media: Creating science documentaries, creating the outline and expanding, scripts, citing authentic sources, case study: Famous documentaries of Carl Sagan, David Attenborough and Prof. Yashpal

(8 Lectures)

Unit – III: Internet Science Communication

Science outreach through internet: social media, Websites, Blogs, Youtube, Podcast etc.

(7 Lectures)

Unit – IV: Science Outreach Talks and Public Sensitization

Tactics for providing a charismatic and effective public talk, use of metaphors, speaking in context, Science outreach for biodiversity conservation sensitization of public

(5 Lectures)

Recommended Books/References:

- Selected works of Carl Sagan, works of Bill Bryson, Richard Dawkins, Richard Feynman, Isaac Asimov, Carl Zimmer and Matt Riddley.

- Gigante, E. Marie (2018). Introducing Science Through Images: Cases of Visual Popularization (Studies in Rhetoric/Communication), University of South Carolina Press.

Course Outcomes and their mapping with Programme Outcomes

PO CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		3	1	1		1	3	2	3	1	3
CO2	2	2	2		3	1	3		1	2	2	3	1	2
CO3	3	1	2		3	1	1		1	3	2	3	1	3
CO4	3	1	2		3	1	1		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
I/II/III	**SEC (Level 1)**	SECCY02	Fermentation Science and Technology	**Theory 3 (45 Lectures)**

SECCY02: Fermentation Science and Technology

Level 1, Credit 3 (45 Lectures)

Course Outcomes:

After completing this course, the learner will be able to:

1. Describe and implement standard procedures for the maintenance of microbial cultures.
2. Apply techniques for the long-term preservation of microorganisms to ensure viability and purity.
3. Examine the principles and types of fermentation technology used in industrial microbiology. Apply fermentation strategies for the efficient production of microbial metabolites and bioproducts.
4. Demonstrate experimental skills in the microbial production of industrial enzymes such as amylase and protease.
5. Execute and evaluate downstream processing methods for the recovery and purification of microbial bioproducts.

Unit – I: Fundamentals of Microbial Fermentation

Introduction to fermentation and its historical background, Preparation and sterilization of fermentation media, Isolation and improvement of industrially significant microorganisms, Types of fermenters and their components, Preparation and inoculation of microbial cultures.

(08 Lectures)

Unit – II: Microbial Growth Kinetics and Metabolite Production

Growth curve phases and kinetic models, Maintenance and preservation techniques of microorganisms, Primary vs. secondary metabolites, Metabolic regulation and strategies for overproduction, Product formation kinetics.

(09 Lectures)

Unit – III: Fermentation Strategies and Bioprocess Modes

Principles of fermentation: Submerged, solid-state, batch, fed-batch, and continuous culture, Selection and scale-up of fermentation processes, Aeration, agitation, pH, and temperature control, Bioprocess monitoring and instrumentation, Fermentation data interpretation and troubleshooting.

(10 Lectures)

Unit – IV: Microbial Production of Industrial Products

Production of industrially relevant products: Alcohols (ethanol, wine, beer), Acids (citric acid, gluconic acid), Amino acids (lysine, glutamic acid), Antibiotics (penicillin, streptomycin), Role of microbial strain selection and media optimization.

(08 Lectures)

Unit – V: Microbial Enzyme Production and Downstream Processing

Microbial production of enzymes: Amylase and Protease, Strategies for enzyme overproduction and secretion, Bioproduct recovery techniques: filtration, centrifugation, precipitation, Enzyme purification basics, Applications of microbial enzymes in industry.

(10 Lectures)

Recommended Books/References:

- Waites M.J. (2008). Industrial Microbiology: An Introduction, 7th Edition, Blackwell Science, London, UK.
- Prescott S.C., Dunn C.G., Reed G. (1982). Prescott & Dunn's Industrial Microbiology, 4th Edition, AVI Pub. Co., USA.
- Reed G. (2004). Prescott & Dunn's industrial microbiology, 4th Edition, AVI Pub. Co., USA.
- JR Casida L.E. (2015). Industrial Microbiology, 3rd Edition, New Age International (P) Limited Publishers, New Delhi, India.
- Waites M.J., Morgan N.L., Rockey J.S. and Higton G. (2001) Industrial Microbiology: An Introduction. 1st Edition, Blackwell Science, London, UK.
- Pelczar M.J., Chan E.C.S. and Krieg N.R. (2003) Microbiology. 5th Edition, Tata McGraw-Hill Publishing Company Limited, New Delhi.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		3	1	1		1	3	2	3	1	3
CO2	2	2	2		3	1	2		2	3	2	2	1	3
CO3	3	1	2		3	1	1		1	3	2	3	1	3
CO4	3	1	2		3	3	1		1	1	2	3	1	3
CO5	3	1	2		3	1	1		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
I/II/III	**SEC (Level 1)**	SECCY03	Environmental Impact Analysis	**Theory 2 (30 Lectures) Tutorial 1 (15 Hours)**

SECCY03: Environmental Impact Analysis

Level 1, Theory 2 (30 Lectures)

Tutorial 1 (15 Hours)

Course outcomes:

After completing this course, the learner will be able to;

1. Have a critical understanding of environmental impact
2. Learn important steps of EIA process
3. Interpret the environmental appraisal and procedures in India.
4. Environmental factors of different environmental resources

Unit – I: Origin and Development

Purpose and aim, core values and principles, History of EIA development, Environmental Management Plan, Environmental Impact Statement, Scope of EIA in Project planning and Implementation.

(10 Lectures)

Unit – II: EIA Process

Components of EIA, EIA Methodology- Screening, Scoping, Baseline data, Impact Identification, Prediction, Evaluation and Mitigation, Appendices and Forms of Application, Techniques of Assessment-Cost-benefit Analysis, Matrices, Checklist, Overlays, Impact on Environmental component: air, noise, water, land, biological, social and environmental factors. EIA Document.

(10 Lectures)

Unit – III: Main Participants in EIAP Process

Role of Project proponent, environmental consultant, PCBs, PCCs, public and IAA. Public participation.

(5 Lectures)

Unit – IV: Environmental Appraisal and Procedures in India and EIA

Methodology, indicators and mitigation, Environmental Audit of different environmental resources, Risk Analysis, Strategic environmental assessment, ecological impact assessment: legislation.

(5 Lectures)

Tutorials

Credit 1 (15 Hours)

1. Prepare a Matrix of every environmental existing resource of your college or your ostel/mohalla or any defined area and evaluate each component using established methods and make audit analysis.
2. Prepare a case report of Environmental impact of any area underdevelopment.

Recommended Books/References:

- Kulkarni V and Ramachandra TV, (2006). Environmental Management, Capital Pub. Co. New Delhi.
- Petts, J. (2005) Handbook of Environmental Impact Assessment- Volume 1 and 2. Blackwell Publishers, UK.
- Glasson, J. Therivel, R. and Chadwick, (2006) A. Introduction to Environmental Impact Assessment. Routledge, London.
- Canter, W. L. (1995) Environmental Impact Assessment, McGraw-Hill Science/ Engineering/ Math, New York;
- Morris, P. and Therivel, R. (1995) Methods of Environmental Impact Assessment, UCL Press, London;
- Petts, J. (1999) (ed) Handbook of Environmental Impact Assessment, volume 1 and 2, Blackwell Science, Oxford;
- Therivel, R. and Partidario, M. R. (1996) (eds) The Practice of Strategic Environmental Assessment, Earthscan, London;
- Vanclay, F. and Bronstein, D. A. (1995) (eds) Environmental and Social Impact Assessment, Wiley & Sons, Chichester.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		3	1	1		2	3	2	2	1	3
CO2	3	2	2		3	1	1		1	2	2	3	1	3
CO3	2	1	3		3	2	1		1	3	2	3	1	3
CO4	3	1	2		3	1	1		1	3	2	3	1	2
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

Value Added Course (VAC)

Semester	Nature of Course	Course Code	Name of the course	Credits
I/II	**VAC (Level 1)**	VACCY01	Efficient Technologies for Food Processing and Shelf-Life Extension	**Theory 2 (30 Lectures)**

VACCY01: Efficient Technologies for Food Processing and Shelf-Life Extension

Level 1, Credit 2 (30 Lectures)

Course Outcomes:

After completing this course, the learner will be able to:

1. Understand the food processing and technology.
2. Aware of the skills required to be a professional food technologist.
3. Qualifications required for specific careers in the industry.
4. Know the advanced techniques of food packing.

Unit – I: Introduction

Food Constituents & Functions, Quality and Safety Aspects of Food, Factors Affecting Quality during Processing and Storage, Role of Water in Food and its Shelf Life.

(5 Lectures)

Unit – II: Technologies in Food Preservation:

Principles of Food Preservation, Traditional Food Preservation Technologies, High Pressure Processing of Food, Membrane Technology, Food Irradiation, Hurdle Technology.

(8 Lectures)

Unit – III: Food Quality enhancement and analysis:

Rancidity, Natural Antioxidants, Ozonation of Food Grains, Food Fortification: Iron Fortified Rice (IFR), Nutri Dal and Fortified Noodles, Hyper Spectral Imaging for Quality Analysis of Food Grains, Non-Destructive Methods for Analysis of Grain Quality, Detection of Spoilage in Grains using Biosensors.

(10 Lectures)

Unit – IV: Advanced Techniques in Food Packing:

Nano encapsulation, Nano-emulsions, Nanoparticles/active packaging, Nanoclays in packaging, Nanocomposites in packaging, Nanosensors in plastic film packages/ Intelligent packaging, Color changing labels, etc.

(7 Lectures)

Recommended Books/References:

- Food Processing Technology by P. J. Fellows, Woodhead publishing ltd.
- Food Science by N.N. Potter, CBS publishing.
- Physical principles of Food Preservation. Vol. II by M. Karel, O.R. Fenema and D.B. Lurd, Maroel, Dekker Inc. New York.
- The technology of food preservation by N.W. Desrosier and J.N. Desrosier, CBS publishing

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		3	1	1		1	3	2	3	1	3
CO2	3	1	2		3	1	3		1	2	2	2	2	2
CO3	3	1	2		3	1	1		1	3	2	3	1	3
CO4	3	1	2		3	1	1		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
I/II	VAC **(Level 1)**	VACCY02	Polymer Chemistry	**Theory 2 (30 Lectures)**

VACCY02: Polymer Chemistry

Level 1, Credit 2 (30 Lectures)

Course Outcomes:
After completing this course, the learner will be able to:

1. Students will learn about polymer structure and try to understand how the polymer is important in daily life.
2. Students will be able to classify the polymer material that is harmful and the one that is not harmful.
3. They will know different categories of plastics and their impact on the environment.
4. They will know about the process and technology used in the production of industrially important polymer articles/plastics/ rubber/foam.

Unit 1:
Introduction: History of polymer, Concept of macromolecules, Synthetic and Biopolymers Classification and Types of polymers.

(7 Lecture)

Unit 2
Polymer processing and technology: Additives, Processing of polymers, molding, calendaring, Foaming, Brief overview of rubber and fiber technology.

(7 Lecture)

Unit 3
Polymer properties and applications: Examples of natural, synthetic, industrial polymers and its preparation and properties, applications of polymers in medicine, agriculture and daily life.

(8 Lecture)

Unit 4
Plastics: Types of Plastics, Properties and use of plastics, microplastics, recyclization of plastics, impact of polymers/plastics on environment.

(8 Lecture)

Recommended Books/References:

- F. W. Billmayer, Jr., *Text Book of Polymer Science*, 3rd Edition (1984), Willey-Interscience, New York.
- G. Odian, P. W. Atkins, *Physical Chemistry*, 6th Edition, Oxford University Press, New York.
- G. Odian, *Principles of Polymerization*, 3rd edition (1991) John Wiley, Singapore

- P.Bahadur and N.V. Sastry, Principle of Polymer Sciences , Narosa Publishing House, New Delhi (2002)
- V.R. Gowarikar, N.V. Vishwanathan, J. Shreedhar , *Polymer Sciences*, Wiley Eastern, New Delhi (1986)

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	1	2	3	1	1	1	1	3	2	3	1	3
CO2	2	1	2	1	3	1	1	2	1	2	2	2	2	3
CO3	3	2	2	2	2	1	2	1	1	3	3	3	1	3
CO4	3	1	2	2	3	1	1	1	1	3	2	3	1	2
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
I/II	VAC **(Level 1)**	VACCY03	Ancient Indian Chemistry in Modern Perspective	**Theory 2 (30 Lectures)**

VACCY03: Ancient Indian Chemistry in Modern Perspective

Level 1, Credit 2 (30 Lectures)

Course Outcomes:

After completing this course, the learner will be able to:

1. Understand Ayurveda and Charak Sanhita
2. Aware of the Indian Knowledge System focusing on Indian Chemistry.
3. Know about various rasas and their uses.
4. Know the contribution of the Indian scientist to Ancient Indian Chemistry.

Unit – I: General Aspects of Ayurveda

(a) Chemical Techniques in ancient India: general Introduction

(b) Contribution of ancient Indian scientists in chemistry, e.g., metallurgy, dyes, pigments, cosmetics, Ayurveda, Charak Sanhita.

(5 Lectures)

Unit – II: Tradition of Indian Chemistry

Knowledge Tradition of Indian Chemistry. Ancient Indian chemists and their works: Nagarjuna, Vagbhata, Govindacharyn, Yashodhara, Ramchandra, Somadeva, etc.

(7 Lectures)

Unit – III: Rasas

Introductory idea about rasas, Main rasa: Maharas, Uparas, Commonras; Ratna, dhatu, poison, alkali, acid, salt, lauhabhasma. Maharasas: Abram, Vaikrant, Bhasik Vimala. Shilaiatu. Sasak, Chapala. Uprasas: Gandhak, Garik, Kashis, Suvari, Lalak, Manah, Shila, Anjana, Kankushtha. Common rasas: Koyala, Gouripashan, Navasara, Vartaka, Agnijar, Lajavarta, Giri Sindur, Hingur, Murdad, Shrangakam.

(10 Lectures)

Unit – IV: Indian Scientific Contribution

Life history and scientific contribution of Aacharya Prafulla Chandra Ray, Shanti Swaroop Bhatnagar, Asima Chatterjee in the context of ancient and Medieval India

(8 Lectures)

Recommended Books/References:

- Scientific Knowledge in Sanskrit Literature – Nirmal Trikha
- Indian Astronomy: An Introduction – S. Balachandra Rao
- Ancient Indian Sciences – B. Seal
- Science in Ancient India (Science of the Past) – Melissa Stewert
- A History of Hindu Chemistry: from the Earliest Times to the Middle of the Sixteenth Century, A.D. Hardcover – 1 December 2010 by P. C. Ray (Author)

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2	2	3	1	1	1	1	3	2	3	1	3
CO2	3	1	2	1	3	1	1	2	1	3	2	2	1	3
CO3	3	1	2	2	3	1	1	1	1	3	2	3	1	3
CO4	3	1	2	2	3	1	1	1	1	3	2	3	1	2
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

Vocational Course (VOC)

Semester	Nature of Course	Course Code	Name of the course	Credits
II/III/IV/V/VI	VOC (Level 2)	VOCCYT01	Green Water Technology	Theory 1 (15 Lectures)
		VOCCYL01	Green Water Technology (Lab)	Practical: 3 (90 Hours)

VOCCYT01: Green Water Technology

Level 2, Credit 1 (15 Lectures)

Course Outcomes:

Course Outcome 1:
- Outcome 1.1: Introduction to various types of water samples.
- Outcome 1.2: Sampling of various types of water sample.
- Outcome 1.3: factors affecting the quality and stability of water sample.

Course Outcome 2:
- Outcome 2.1 Determination of physical and chemical properties of water samples.
- Outcome 2.2: Importance of potable water and its necessity for life.
- Outcome 2.3: Introduction to water pollutions and their impact on environment.

Course Outcome 3:
- Outcome 3.1: Different water pollutants and their effect on flora and fauna.
- Outcome 3.2: introduction of water treatment technologies.
- Outcome 3.3: Introduction of Sorbents of Phyto and animal origin.

Course Outcome 4:
- Outcome 4.1: Introduction of composite materials for polluted water treatment.
- Outcome 4.2: Introduction of natural polymer based composite material.
- Outcome 4.3: Various methods used for addressing water pollution problems.

Unit – I:

Distribution of water on earth, Types of water, Water quality as given by W.H.O., Indian Standard specification laid down for Potable water. Sampling and testing of various water bodies. Factors affecting quality and stability of particular water bodies. What is natural water.

(3 Lectures)

Unit – II:

Determination of Physical and chemical properties of water. What are D.O., B.O.D. and C.O.D. What are Soft and Hard water. What are their effects on flora and fauna. What is Potable water, why water is necessary for life. What is water pollution and how environment is affected by the polluted water.

(4 Lectures)

Unit – III

Study of different water pollutants and their effects on flora and fauna. Brief introduction of the following water treatment technology: Osmosis, Reverse Osmosis, Resins for Cationic and Anionic exchanges, Sorbents of Phyto & Animal origin.

(4 Lectures)

Unit – IV

Some knowledge on Composite materials. What are natural polymer based composite materials. Different methods of using such composite materials in addressing polluted water. How they are environment friendly.

(4 Lectures)

Recommended Books/References:

- Senior Practical Physical Chemistry, B. D. Khosla, R. Chand & Co. Chemistry Practical, O. P. Pandey, D.N. Bajpai, S. Giri, S. Chand.

VOCCYL01: Green Water Technology (Lab)

Level 2, Credit 3 (90 Hours)

LIST OF EXPERIMENTS

1. Determination of BOD of Water sample.
2. Determination of COD of Water sample.
3. Determination of pH of Water samples.
4. Determination of Temporary Hardness of Water.
5. Determination of Total Hardness of Water.
6. Determination of TDS of Water Sample.
7. Determination of Metal Ions in Water Samples.
8. Determination of Turbidity of Water samples.
9. Determination of Chloride Contents in Water Samples by Using Argentometric Titration Method.
10. Determination of N and P in Water Samples.

Recommended Books:

- Vogel's Qualitative Inorganic Analysis, A. I. Vogel, Prentice Hall.
- Vogel's textbook of chemical quantitative analysis, Longman Scientific
- Comprehensive Practical Organic Chemistry, V. K. Ahluwalia, & R. Aggarwal, Universities
- Press.
- Laboratory Manual of Organic Chemistry, R. K. Bansal, New Age Pub.
- Senior Practical Physical Chemistry, B. D. Khosla, R. Chand & Co. Chemistry Practical, O. P. Pandey, D.N. Bajpai, S. Giri, S. Chand.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		3	1	1		2	3	2	2	1	3
CO2	3	2	2		3	1	1		1	2	2	3	1	3
CO3	2	1	3		3	2	1		1	3	2	3	1	3
CO4	3	1	2		3	1	1		1	3	2	3	1	2
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
II/III/IV	VOC (Level 3)	VOCCYT02	Cement Chemistry	Theory 1 (15 Lectures)
		VOCCYL02	Cement Chemistry (Lab)	Practical: 3 (90 Hours)

VOCCYT02: Cement Chemistry

Level 3, Credit 1 (15 Lectures)

Course Outcomes:

Course Outcome 1:

- Outcome 1.1: Introduction and definition of Cement material
- Outcome 1.2: Chemistry of raw materials used in cement manufacturing
- Outcome 1.3: Properties of calcareous and argillaceous materials.

Course Outcomes 2

- Outcome 2.1 Selection & chemical analysis of major and minor raw materials
- Outcome 2.2: Effect of adding gypsum, auxiliary components of cement raw materials
- Outcome 2.3: Cement components and their effects

Course Outcome 3:

- Outcome 3.1: Determination of acidic oxides such as SO_3, SiO_2,
- Outcome 3.2: Determination of basic oxides such as Al_2O_3, Fe_2O_3, CaO, MgO,
- Outcome 3.3: Determination of LOI (loss on ignition),
- Outcome 3.4: determination of total carbonate and magnesium carbonate (TC and MC).

Course Outcome 4:

- Outcome 4.1: Different methods of raw mix design, two, three, four component designs,
- Outcome 4.2: Criteria for raw mix design,
- Outcome 4.3: Chemical composition of raw materials of cement clinker,
- Outcome 4.4: Potential clinker composition.

Course Outcome 5:

- Outcome 5.1: Different methods of cement manufacturing, dry process, wet process, semi dry process
- Outcome 5.2: Setting and hardening of cement, reactions during setting and hardening
- Outcome 5.3: function of gypsum, and hydration reaction of gypsum
- Outcome 5.4: ISI specification of Portland cement

Unit – I:

Cement, chemistry of raw materials used in cement manufacturing, calcareous and argillaceous materials, limestone, high grade, low grade, feed take grade, chalk, marl, clay component, iron ore, bauxite, clay, gypsum, fly ash, slag, properties of calcareous and argillaceous materials.

(3 Lectures)

Unit – II:

Selection & chemical analysis of major and minor raw materials such as CaO, alumina, iron oxide, silica, alkalis, sulfur, magnesium oxide, effect of adding gypsum, auxiliary components of cement raw materials, chlorides, fluoride. P_2O_5, cement components and their effects.

(3 Lectures)

Unit – III

Determination of acidic oxides such as SO_3, SiO_2, determination of basic oxides such as Al_2O_3, Fe_2O_3, CaO, MgO, determination of LOI (loss on ignition), determination of total carbonate and magnesium carbonate (TC and MC).

(3 Lectures)

Unit – IV

Different methods of raw mix design, two, three, four component designs, criteria for raw mix design, chemical composition of raw materials of cement clinker, quality control at the lime stone quarry, potential clinker composition.

(3 Lectures)

Unit – V

Different methods of cement manufacturing, dry process, wet process, semi dry process, their advantages and disadvantages, block diagram of dry process and wet process, Setting and hardening of cement, reactions during setting and hardening, sequence of changes during setting and hardening of cement (block diagram), function of gypsum, and hydration reaction of gypsum. Setting and hardening of blended Portland cements. ISI specification of Portland cement.

(3 Lectures)

Recommended Books/References:

- Introduction to Colloid & Surface Chemistry, Duncan J. Shaw, 4th Edition, Butterworth, **1992**.
- Chemistry of Cement and Concrete, Peter C. Hewlett, 4th Edition, Elsevier Science & Technology Books, **2004**.
- Special Inorganic Cements, Ivan Odler, E&FN Spon (Taylor & Francis Group), 2000.
- Alkali activated materials: state-of-the-art report, RILEM TC 224-AAM (Vol. 13), J. L. Provis and J.S. Van Deventer, Eds., Springer Science & Business Media, **2013**.
- Lothenbach, B. and Winnefeld, F., **2006**. Thermodynamic modelling of the hydration of Portland cement. *Cement and Concrete Research*, 36 (2), pp.209-226.
- Gartner, E.M. and Macphee, D.E., **2011**. A physico-chemical basis for novel cementitious binders. Cement and Concrete Research, 41(7), pp.736-749.
- Gartner, E.M. and Jennings, H.M., **1987**. Thermodynamics of calcium silicate hydrates and their solutions. Journal of the American Ceramic Society, 70(10), pp.743-749.

VOCCYL02: Cement Chemistry (Lab)

Level 3, Credit 3 (90 Hours)

LIST OF EXPERIMENTS

S. No.	Title of Experiments
1.	Determination of acidic oxides(SO_3,SiO_2).
2.	Determination of Basic oxides (Al_2O_3,Fe_2O_3,CaO, MgO).
3.	Determination of loss on ignition.
7.	Determination of Compressive strength.
8.	Determination of fineness by sieving.
9.	Determination of Insoluble residue.
10.	Determination of soundness by Le Chtalier's expansion.
11.	Determination of drying shrinkage.
12.	Determination of calcium content in cement.
13.	Industrial visit
14.	Any other related experiments available in the laboratory/ industry in proximity.

Recommended Books:

- Vogel's Qualitative Inorganic Analysis, A. I. Vogel, Prentice Hall.
- Vogel's textbook of chemical quantitative analysis, Longman Scientific
- Cement Chemistry, H.F.W. Taylor, 2nd Edition, Thomas Telford, **1997**.
- Textbook of Engineering Chemistry by SS Dara and SS Umare, Publisher S Chand, **2024**.
- Engineering Chemistry by Jain and Jain Publisher: Dhanpat Rai Publishing Company, **2015**.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2		3	1	1		1	3	2	3	1	3
CO2	2	2	1		2	1	2		2	3	2	2	1	3
CO3	2	1	2		3	1	1		1	3	2	2	2	3
CO4	3	1	2		3	3	2		1	1	2	3	1	2
CO5	3	1	3		3	1	1		1	3	2	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
II/III/IV/V/IV	**VOC (Level 3)**	VOCCYT03	Drug Discovery and Pharmaceutical Chemistry	**Theory 1 (15 Lectures)**
		VOCCYL03	Drug Discovery and Pharmaceutical Chemistry (Lab)	**Practical: 3 (90 h)**

VOCCYT03: Drug Discovery and Pharmaceutical Chemistry

Level 2, Credit 1 (15 Lectures)

Course Outcomes:

1. Understand the basics about drug designing, limitations, and the scope of designing a new drug.
2. Scope of chemistry to develop the new drug, and a basic understanding of regulatory guidelines for drug development.
3. Basic analytical tools to confirm the pharmaceutical molecule and correlate chemical structure with biological systems

Unit – I:

Focuses on the principles and applications of the discovery of new drug molecules. Introduction to Drug Discovery, Physicochemical Principles, Enzymes as targets of drug design: Drug-like properties, Lead Discovery and Optimization: identifying and optimizing lead compounds from natural, semi-synthetic, and synthetic sources.

(5 Lectures)

Unit – II:

Theoretical Structural Activity Relationship (SAR): Studies the relationship between the chemical structure of a drug and its biological activity, Targets and Mechanisms of Action, Prodrugs and Drug Metabolism, Computational Drug Design, Synthetic Strategies in Drug Design, Analytical Techniques.

(5 Lectures)

Unit – III:

Stereochemistry in drug design and concept of Pharmacophore; Impact and importance of metals in drug development, Cost Effectiveness and drug screening, Enzyme kinetics, inhibition, rational design of enzyme Inhibitors; Receptors as targets of drug design; In vitro ADME and In vivo Pharmacokinetics; Animal Models and Clinical trials; Intellectual property, Role of regulatory bodies. Case studies related to drug development (Anticancer, antiparasitic and antibiotics etc).

(5 Lectures)

Recommended Books:

1. Textbook of Drug Design and Discovery, Povl Krogsgaard-Larsen, Tommy Liljefors and, 3rd Ed Taylor Francis 2005
2. Drugs From Discovery to Approval Rick Ng 3rd Ed John Wiley and Sons 2015
3. Basic Principles of Drug Discovery and Development Benjamin E Blass 1st Ed Academic Press 2015
4. Textbook of Drug Design and Discovery, Edited by Kristian Stromgaard, Povl Krogsgaard-Larsen, Ulf Madsen. 4th Ed., CRC Press 2015
5. "An Introduction to Medicinal Chemistry" by Graham Patrick
6. "The Organic Chemistry of Drug Design and Drug Action" by Richard Silverman
7. "Drug Discovery and Development" by Raymond Hill

VOCCYL03: Drug Discovery and Pharmaceutical Chemistry (Lab)

Level 2, Credit 3 (90 Hours)

LIST OF EXPERIMENTS

1. Introduction of the Laboratory Safety
2. To the Knowledge About the Basic Glassware are Used in the Laboratory
3. To Knowledge About the Laboratory Techniques of Recrystallization
4. To Obtain Pure Components from a Mixture of Organic Compounds Using Steam Distillation
5. To Determine and Report the Melting Point of the Given Sample Naphthalene and Benzoic Acid
6. To Determine and Report the Boiling Point of the Given Sample (Benzaldehyde and Benzene)
7. To Determine and Report the Solubility Behavior of the Given Sample
8. Derivative Preparations
    - 8.1 Acid to Amide
    - 8.2 Phenol to Benzoate
    - 8.3 Ketone to Oxime
9. Synthesis of Aspirin (Acetylsalicylic Acid)
10. Synthesis of Oil of Wintergreen
11. Synthesis of Aniline from Nitrobenzene
12. Synthesis of Phenytoin
13. Synthesis of Paracetamol
14. Synthesis of Hippuric Acid
15. Synthesis and Characterization of Benzocaine

Recommended Books:

- Vogel's Qualitative Inorganic Analysis, A. I. Vogel, Prentice Hall.
- Practical Lab Manual of Pharmaceutical Organic Chemistry-I, IP Innovative Publication Pvt. Ltd. by Dr Shivendra Kumar Dwivedi,

- chromextension://efaidnbmnnnibpcajpcglclefindmkaj/https://jru.edu.in/studentcorner/lab-manual/bpharm/2nd-sem/Lab%20Manual%20-%20%20Pharmaceutical%20Organic%20Chemistry.pdf

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	2	2	2	3	1	2	1	2	3	2	2	1	3
CO2	3	1	2	1	3	1	1	1	1	3	2	3	1	2
CO3	3	1	2	2	3	3	1	1	1	1	1	3	1	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Course Structure Under NEP-2020

4-Years B.Sc.-Chemistry

Online Courses

Sem.	Courses	Course Code	Name of the Courses	Page No.
III Jul-25	**Online (SWAYAM)**	CYUCMJT3M	MOOC_Introductory Organic Chemistry II - Course	MOOC1
	Offline	CYUCMJL3	Introductory Organic Chemistry II (Lab) (Offline)	MOOC3
V Jul-25	**Online (SWAYAM)**	CYUCMJT1M	MOOC_Advanced Transition Metal Chemistry - Course	MOOC5
	Offline	CYUCMJL01	Advanced Transition Metal Chemistry (Lab)	MOOC7

Semester	Nature of Course	Course Code	Name of the course	Credits
III Jul-2025	**Major (Level 3)**	CYUCMJT3M	Introductory Organic Chemistry II - Course	Theory 2 (8 Weeks) SWAYAM
		CYUCMJL3	Introductory Organic Chemistry II (Lab)	Tutorial 1 (15 Hours) Practical: 1 (30 Hours)

CYUCMJT3M: Introductory Organic Chemistry II

ABOUT THE COURSE:

This course focuses on organic chemistry, the chemistry of carbon and carbon compounds. Stemming from the Introductory Organic Chemistry I, this course builds important concepts in chemistry of organic compounds and their reactions. This course will cover important functional groups such as carboxylic acid and derivatives, carbonyl compounds, enols and enolates etc. Other important topics include rearrangement reactions, conjugate additions and stereochemistry of addition reactions. In short, welcome to a course explaining the molecular basis of chemistry around you.

INTENDED AUDIENCE : Second and third year B.Sc. students; first year M.Sc. students
PREREQUISITES : Introductory Organic Chemistry I is a prerequisite. This course has content for several competitive exams as well.

Summary

Course Status :	Upcoming
Course Type :	Core
Language for course content :	English
Duration :	8 weeks
Category :	Chemistry
Credit Points :	2
Level :	Undergraduate/Postgraduate
Start Date :	21 Jul 2025
End Date :	12 Sep 2025
Enrollment Ends :	18 Aug 2025
Exam Registration Ends :	29 Aug 2025

Exam Date :	20 Sep 2025 IST
NCrF Level *:*	4.5 — 8.0

Course Outcome:

After completing this course, the learner will be able to:

1. Demonstrate a detailed understanding of electrophilic and nucleophilic aromatic substitution mechanisms, including directing effects and reactivity patterns of mono- and poly-substituted benzenes.
2. Interpret and predict the outcomes of carbonyl chemistry, including nucleophilic additions to aldehydes and ketones, and explain the electronic and steric influences on reactivity.
3. Analyze complex multi-step reaction sequences involving enols and enolates, with emphasis on Aldol, Claisen, and related C–C bond-forming reactions, using mechanistic reasoning.
4. Apply NMR spectroscopy (^{1}H and ^{13}C) as a structural elucidation tool to identify organic compounds and track chemical transformations involving aromatic and carbonyl compounds.
5. Evaluate and propose mechanisms for molecular rearrangements and named organic reactions (e.g., Beckmann, Baeyer–Villiger, Fries, Pinacol–Pinacolone), demonstrating the ability to solve mechanistic and synthetic challenges.

Course layout

Week-1: Electrophilic Aromatic Substitution and NMR
Week-2: Electrophilic/Nucleophilic Aromatic Substitution of Substituted Benzene
Week-3:Carbonyl Chemistry and Addition to Carbonyl Groups
Week-4: Carboxylic acids and their Derivatives
Week-5: Enols and Enolates: Aldol reactions
Week-6: Enols and Enolates: Aldol and related reactions
Week-7: Conjugate Additions, Acylation of Enol/enolates
Week-8: Rearrangements and Named Reactions

Books and references

- J. Clayden, N. Greeves, S. Warren, Organic Chemistry, 2nd edition, Oxford Unviersity Press, New Delhi, 2012.
- R. T. Morrison, R. N. Boyd, Organic Chemistry, 6th edition, Prentice-Hall, New Delhi,1992.
- P. Y. Bruice, K. J. R. Prasad, Essential Organic Chemistry, 1st edition, Pearson Education, New Delhi, 2008.

Instructor bio

Prof. Harinath Chakrapani

IISER Pune

Prof. Harinath Chakrapani completed his undergraduate and post-graduate studies in Chemistry from Loyola College and Indian Institute of Technology Madras, respectively. He moved to Duke University, USA to pursue his doctoral studies and after post-doctoral research stints at Wake Forest University and the National Cancer Institute, USA, he joined IISER Pune in July 2009 and is currently Associate Professor. His research interests are in organic chemistry and chemical biology. His laboratory works on developing new tools to study effects of oxidative stress responses in cells and antibiotic resistance. He has over eight years of teaching experience at IISER Pune.

Prof. Neeraja Dashaputre

Prof. Neeraja Dashaputre completed her undergraduate studies in chemical technology from Institute of Chemical Technology, Mumbai. After which, she obtained a doctoral degree in organic chemistry at University of Maryland, USA. She worked as a faculty at Claremont University post her doctoral studies. She joined IISER Pune in July 2016 and is currently Assistant Professor. Her research interests are in pedagogy development for teaching chemistry. She has over five years of teaching experience in India, and USA.

CYUCMJL3: Introductory Organic Chemistry II (Lab)

Practical 1 (30 Lectures)
Tutorial 1 (15 Lectures)

Inorganic Chemistry

1. Preparation of tetraaminecopper(II) sulfate, [Cu(NH3)4H2O]SO4.
2. Preparation of *cis*- and *trans*- potassium dioxalatodiaquachromate(III) complex.
3. Preparation of potassium trioxalatoferrate(III) complex.

Organic Chemistry

1. Functional group detection of organic compounds containing carboxylic acid & sulphonic acid.
2. Functional group detection of organic compounds containing aliphatic alcohol & aromatic alcohol.
3. Functional group detection of organic compounds containing aldehyde & ketone.

Note: Experiments may be added/deleted subject to availability of time and facilities.

Recommended Books:

- Marr and Rockett, *Practical Inorganic Chemistry*, John Wiley & Son, **1972**.
- Vogel's *Qualitative Inorganic Analysis*, Revised by G. Svehla. Pearson Education, **2002**.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2	2	3	1	1	1	1	2	2	3	1	3
CO2	2	1	3	1	3	2	1	2	1	3	2	2	1	3
CO3	3	2	2	2	2	1	2	1	1	3	2	3	1	3
CO4	3	1	2	2	3	1	1	1	1	3	2	3	1	2
CO5	3	2	1	3	2	1	1	1	2	2	3	2	2	1
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

Semester	Nature of Course	Course Code	Name of the course	Credits
V Jul-2025	Major (Level 4)	CYUCMJT1M	Advanced Transition Metal Chemistry - Course	Theory 3 (12 Weeks) SWAYAM
		CYUCMJL01	Advanced Transition Metal Chemistry (Lab)	Tutorial 1 (15 Hours) Practical: 1 (30 Hours)

CYUCMJT1M: Advanced Transition Metal Chemistry

ABOUT THE COURSE:

This course on "Chemistry of Transition Metals" focuses mainly on coordination chemistry, classification of ligands with special emphasis on structure and bonding concepts. 18 Electron rule and its importance in coordination and organometallic compounds. Reactions such as oxidative addition and reductive elimination, important in catalysis, are discussed in detail. Metal-ligand and metal-metal multiple bonding, trans effect in square planar complexes are also included in the discussion.

PRE-REQUISITES: 12th Grade Chemistry Knowledge.

INTENDED AUDIENCE: All UG, PG, PhD students, college lecturers and all chemistry researchers.

INDUSTRY SUPPORT: This course is very useful for those working in pharmaceutical industries. This course will become one of most popular courses in Chemistry.

Summary

Course Status :	Upcoming
Course Type :	Core
Language for course content :	English
Duration :	12 weeks
Category :	Chemistry
Credit Points :	3
Level :	Undergraduate/Postgraduate
Start Date :	21 Jul 2025
End Date :	10 Oct 2025
Enrollment Ends :	28 Jul 2025

Exam Registration Ends :	15 Aug 2025
Exam Date :	25 Oct 2025 IST
NCrF Level *:*	4.5 — 8.0

Note: This exam date is subject to change based on seat availability. You can check final exam date on your hall ticket.

Course Outcome:

After completing this course, the learner will be able to:

1. Understand the structure, bonding, and reactivity of transition metal complexes
2. Their role in catalysis and biological systems
3. Apply the concepts like VSEPR, MOT, and CFT to analyze coordination complexes
4. Understand electronic spectra and magnetic properties and
5. Interpret reaction mechanisms.

Course layout:

Week 1: General introduction to Periodic Table and introduction to Transition Elements
Week 2: Coordination chemistry
Week 3: Bonding concepts
Week 4: Bonding concepts continued
Week 5: 18 electron rule
Week 6: Metal-Metal multiple bonding
Week 7: Classification of ligands
Week 8: Classification of Ligands
Week 9: Preparatory methods/Trans Effect/Methods of characterization of metal complexes
Week 10: Oxidative addition and reductive elimination reactions
Week 11: Important applications of transition elements and their complexes
Week 12: Revision and conclusions

Books and References:

- Advanced Inorganic Chemistry, 6th edition, 1999, F. A. Cotton, G. Wilkinson, C. A. Murillo, M. Bochmann, John Wiley and Sons, New York.
- Inorganic Chemistry, 3rd Edition, 1999, D. F. Shriver, P. W. Atkins, Oxford University Press, Oxford.
- Inorg. Chemistry 2nd, 3rd or 4th Edition, C. E. Housecroft and A. G. sharpe, Pearson, Prentice Hall.

Instructor bio

Prof. M. S. Balakrishna

IIT Bombay

Prof. M.S. Balkrishna Joined the department of chemistry in 1996. Taught Transition metal chemistry, coordination chemistry, interpretative molecular spectroscopy, organometallic chemistry of main group elements to UG, PG and Ph.D. scholars. Research interests: Main group and transition metal chemistry, organophosphorus chemistry, homogeneous catalysis and biological applications of copper(I) complexes. Published 210 research papers, five book chapters, edited a book on copper(I) complexes of phosphines (Elsevier) and has delivered more than 500 invited lectures. Balakrishna has supervised 23 PhD students, several M.Sc. students and postdoctoral fellows.

CYUCMJL01: Advanced Transition Metal Chemistry (Lab)

Practical 1 (30 Lectures)
Tutorial 1 (15 Lectures)

Oxidation-Reduction Titrimetric Analysis:

1. Standardization of $KMnO_4$ standard oxalic acid solution.
2. Estimation of Fe(II) using standardized $KMnO_4$ solution.
3. Estimation of carbonate and bicarbonate present together in a mixture
4. Estimation of acetic acid in commercial Vinegar.
5. Estimation of Fe(III) using standard $K_2Cr_2O_7$ solution.
6. Estimation of Fe(II) and Fe(III) in a given mixture using standard $K_2Cr_2O_7$ solution.
7. Estimation of Fe(II) and Cu(II) in a given mixture.

Qualitative Semi-Micro Analysis:

Objective: Analysis of mixtures containing three radicals, with an emphasis on understanding the chemistry behind different reactions.

Cation Radicals: Ni^{2+}, Cu^{2+}, Zn^{2+}, Pb^{2+}, Cd^{2+}, Bi^{3+}, Sn^{2+}/Sn^{4+}, As^{3+}/As^{5+}, $Sb^{3+/5+}$, NH_4^+, Mg^{2+}
Anion Radicals: PO_4^{3-}, AsO_4^{3-}, BO_3^{3-}, CrO_4^{2-} / $Cr_2O_7^{2-}$, $Fe(CN)_6^{4-}$, $Fe(CN)_6^{3-}$
Insoluble Materials: Al_2O_3(ig), Fe_2O_3(ig), Cr_2O_3(ig), SnO_2, $SrSO_4$, $BaSO_4$, CaF_2, $PbSO_4$

Recommended Books:

- *Vogel's Qualitative Inorganic Analysis*, Revised by G. Svehla Pearson Education, **2002**.
- Marr & Rockett, *Practical Inorganic Chemistry*. John Wiley & Sons, **1972**.
- Mendham, J., A. I. Vogel's *Quantitative Chemical Analysis*, 6th Ed., Pearson, **2009**.

Course Outcomes and their mapping with Programme Outcomes

PO / CO	PO									PSO				
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2	2	3	1	1	1	2	3	1	3	2	3
CO2	3	1	3	1	3	2	2	2	1	3	2	2	1	3
CO3	2	1	2	2	2	1	1	1	1	3	2	3	1	3
CO4	3	1	2	2	3	1	1	1	1	3	2	3	1	2
CO5	3	2	1	3	2	1	1	1	1	2	3	2	2	3
Weightage: 1-Sightly; 2-Moderately; 3-Strongly														

ORDINANCE No. 97

04 Years UG programme with Multiple Entry-Exit Options

Under National Education Policy 2020

(as per the Curriculum and Credit framework for Undergraduate Programmes by UGC, New Delhi)

(Ordinance prepared as per the provisions given in Statute 28(1) (b) of The Central Universities Act, 2009)

---

1. TITLE AND COMMENCEMENT:

1.1. The Ordinance shall be called as Ordinance governing the award of 04 Years UG programme with Multiple Entry-Exit Options.

1.2. This ordinance will come into force from the Academic Session 2023-24 and shall replace the existing ordinance.

1.3. The ordinance shall govern the 04 years undergraduate programmes offered by School of Physical Science, Life Sciences, Natural Science, Interdisciplinary Science, Social Science, Arts, Management and Commerce, Mathematical and Computational Science barring the programmes recognized and regulated by any regulatory body.

2. DEFINITION & KEY WORDS:

2.1. "*Vishwavidyalaya"* or "*University*" means Guru Ghasidas Vishwavidyalaya (A Central University established by the Central Universities Act, 2009 No. 25 of 2009) located at Koni, Bilaspur, Chhattisgarh;

2.2. "*Student*" means one who has been admitted in the UG programme of this University through Common University Entrance Test (CUET) or by any other procedure notified by the University from time to time;

2.3. *"Academic Year" means t*wo consecutive (one odd and one even) semesters;

2.4. *"Semester*"means an academic session spread over 15-18 weeks of teaching work with minimum 90 teaching days. The odd semester may normally be scheduled from July to December and even semester from January to June.

2.5. *"Summer term"* means the period during the summer vacation between the even and odd semesters. The students especially those who wish to exit after the $2^{nd}/4^{th}$ semesters of study should carry out internship/apprenticeship/ work-based vocational education in summer term period.

2.6. *"Course*" means "*papers*" through different modes of delivery and is a component of a programme as detailed out in the respective program structure;

2.7. *"Flexibility for courses"* means courses across various branches of UG available for students to learn. A program that provides choice for students to select courses from the prescribed (Major, Minor, Multi-disciplinary, Ability enhancement, Skill enhancement,

Value added etc.)courses as per the guidelines issued by UGC/regulatory bodies where ever applicable and as approved by the appropriate bodies of the University;

2.8. *"Credit*" means a unit by which the course work is measured. It determines the number of hours of instructions required per week. One credit is equivalent to one hour of lecture/tutorial per week or two hours of seminar/internship/studio activity/practical/lab work/field work/community engagement/community service/project etc. per week. The number of credits for each course shall be defined in the respective examination scheme;

2.9. *"Credit Point*" means the product of grade point and number of credits for a course;

2.10. *"Grade Point*" means a numerical weight allotted to each letter grade on a 10 point scale or as prescribed by the UGC/University from time to time;

2.11. *"Letter Grade*" means an index of the performance of students in a course. Grades are denoted by letters O, A+, A, B+, B, C, P, F, and Ab;

2.12. *"Semester Grade Point Average* (*SGPA*)" means a measure of performance of a student in a semester of program. It is the ratio of total credit points (sum of product of number of credits with grade points in all courses of a semester) and the total credits of all courses during the semester. It shall be expressed up to two decimal places;

2.13. *"Cumulative Grade Point Average* (C*GPA*)" means a measure of cumulative performance of a student till a semester/ at the end of program. It is the ratio of total credit points (sum of product of number of credits in a semester with respective SGPA) and the total credits till that semester. It shall be expressed up to two decimal places;

2.14. *"Grade Card"* means a certificate based on the grades earned. Grade certificate shall be issued to all registered students after every semester. The grade certificate will contain the course details (code, title, number of credits, grade secured) along with SGPA of the semester and CGPA earned till that semester. The semester grade certificate shall also reflect the cumulative total of marks obtained by the student till that semesters out of maximum marks allocated for which the grades of the program were evaluated. However, the final result will be based on the grades/CGPA;

2.15. "*Transcript"* means a certificate issued to all enrolled students in a programme after successful completion of the programme. It contains the SGPA of all semesters and the CGPA;

2.16. "Promotion" means a student will be promoted to the next semester till final semester and will be allowed to pursue the courses of programme and he will be awarded certificate/diploma/degree/Hons/Hons with Research after clearing all the courses/internship (if any) of the programme within the maximum period of the programme.

2.17. "Internship" means that the student will gain the working experience in the actual work situation either in firms/industry/organization/individuals (Maestros) etc. or training in labs with faculty in their own or other HEIs/research institutions.

2.18. "ABC Credit Transfer" means transfer of credits earned by the student from other HEI or through MOOCs for such courses which were offered by the department in a semester of

the programme within 40% maximum limit for awarding a certificate/diploma/degree/Hons/Hons with Research either through ABC portal or any other mechanism notified by the University.

2.19. "Equivalence Committee" means a committee notified by the University to consider the equivalence of courses in case of a student entering in to the programme through lateral entry after exiting the same programme or other programme from other HEI.

2.20. Degree awarding for lateral entry students will be from that institute where students earned maximum credits in core courses.

2.21. Vocational courses shall be defined as courses from the pool of vocational courses notified by the University or chosen from the pool of such courses from the accredited vocational University / Institute or from MOOCs on SWAYAM platform or any such blended mode platform notified by the University.

3. Entry – Exit options and award of CERTIFICATE, DIPLOMA, DEGREE AND THEIR DURATION:

3.1. "UG (Honours)" program shall be of eight semesters (four academic years) and those students who secure 75 % marks and above in first six semesters in aggregate and are inclined towards research may opt "UG (Honours with research)". The 4-year undergraduate programs have multiple entry-exit options and the re-entry may be allowed within a period of three years from the session in which student exits. However, the maximum stipulated period to complete the undergraduate program will be seven consecutive academic years. The student after successful completion of the eight semesters of the programme shall be awarded degree of UG (Honors) or UG (Honours with research) as the case may be. If a student is unable to clear all the semesters of the program within the maximum duration (as specified above), he/she will automatically exit from the program.

3.2. If a student wish to exit the "UG (Honours)" after completion of the (first/second) year(s) and secured (40/80) credits respectively and completed one vocational course/Internship of 4 credits during the summer vacation of first or second year will be awarded "UG Certificate/UG Diploma".

3.3. If a student wish to exit after completion of three years and secures 120 credits and fulfils minimum credit requirements distributed over all type of courses will be awarded "UG in Major discipline".

3.4. The maximum total duration shall include the period of absence, withdrawn and different kinds of leave permissible to a student but it shall exclude the period of rustication/suspension/or any other penalty period imposed by the University.

4. NUMBER OF SEATS

Number of seats in each program will be as approved and notified by the Academic Council of the University and as advertised for admission to the program.

5. ADMISSION PROCEDURE AND ELLIGIBILITY

5.1. Admission to the UG programme of this University will be through Common University Entrance Test (CUET) or by any other procedure notified by the University from time to time. The minimum qualification for admission to the specific programme will be as notified by the university from time to time.

5.2. Reservation and relaxation in minimum eligibility for admission for OBC/SC/ST/ EWS/PwD (Person with Disability) and Kashmiri migrant candidates, as specified by Government of India/UGC and notified by the university shall be followed.

5.3. Either foreign nationals residing in India or abroad or Indian nationals residing abroad may be admitted to the programme according to the policy guidelines laid down by the Government of India/ University from time to time as per the number of seats available for this category. These seats will be supernumerary and shall be advertised separately in addition to the seats approved for each program.

6. ENROLMENT IN THE UNIVERSITY

Every student admitted to the programme shall be enrolled before appearing in the first semester examination through the procedure prescribed by the competent authority from time to time.

7. TYPES OF COURSES

The UG programme will consist of the following categories of the courses:

(i) Major (core) : 80 credits;
(ii) Minor : 32 credits
(iii) Multidisciplinary : 09 credits
(iv) Ability enhancement : 08 credits
(v) Skills enhancement : 09 credits
(vi) Value added courses (VAC) and internship (Int.) : 10 (if VAC of 6 credit then Int. will be of 4 credits; if VAC is of 8 credits then Int. will be of 2 credits)
(vii) Research project/dissertation : 12 credits (for the UG (Honours with research)) or 12 credits (5 credit major + 5 credit minor + 2 seminar for UG (Honours))

The nature and number of courses mentioned above may be changed as per the university notification from time to time.

7.1. Major and minor courses:

Major discipline is the discipline or subject in which degree will be awarded. The major course will provide in-depth study of particular subject or discipline and will carry 50% of total credits required for awarding the degree.

Minor discipline helps a student to gain a broader understanding beyond the major discipline. The minor courses will be of 32 credits from two disciplines including 12 credits for vocational

courses to be chosen from the pool of vocational courses, which are to be studied compulsorily by a candidate as a core requirement.

7.1.1 A major course offered in a discipline/subject may be treated as a minor by other discipline/subject and vice versa.

7.1.2 The student may be allowed to change major within the broad discipline and may declare the choice of minor and vocational course at the end of first year/second semester. However, change of such major discipline is subject to the seat restrictions as notified by University and on the basis of CGPA merit of first two semesters.

7.2. **Multidisciplinary/AEC/SEC:**

Generally, three basic courses may be chosen each from a pool of courses offered by the University in different categories of multidisciplinary, AE, SE, VA courses.

7.2.1 **Multidisciplinary courses:** These courses may expand the horizon of intellectual experience of the students across different disciplines. A student has to opt three introductory level courses from the broad disciplines which were not taken by the student at the higher secondary level in the proposed major and minor steam courses. A student of 4-year UG (Honours) or 4-year UG (Honours with research) programmay opt the multidisciplinary courses from the following broad disciplines:

i. Natural &Physical Sciences:

ii. Humanities and Social Sciences:

iii. Commerce and Management:

iv. Mathematical and Computational:

v. Library, Information and Media Science:

Students will not be allowed to choose multidisciplinary courses as mentioned above from those broad disciplines, which they have studied at 10+2 level.

7.2.2 **Ability Enhancement Courses (AEC):** The student will opt the one AEC course of 2 credits in each semester from pool of University AEC courses in the first four consecutive semesters to achieve competency in Modern Indian Languages (MIL) and in English Language with emphasis on communication skill including writing skill, discussions, debate and other linguistic skills.

7.2.3 **Skills Enhancement Course (SEC):** These courses may be chosen from a pool of courses designed to provide practical skills, soft skills etc. to enhance the employability of students. The student will opt the one SEC course of each 3 credits in first three semesters of the program.

7.3 **Value added courses (VAC) common to all:**

7.3.1 The student will study the four value added courses which will be common to all students invariably. Each value added course will be of 2 credits and the student

will opt any two courses given below in first semester and then remaining in the second semester:

(i) **Understanding India:** To inculcate the deeper understanding of modern India with historical perspective, Indian knowledge system, constitutional values, freedom struggle etc. to make the students a responsible democratic citizen.

(ii) **Environmental education:** The student will learn knowledge, skill, attitude and values for conservation of environment for sustainable living.

(iii) **Digital and technological solutions:** Students shall get the knowledge of front runner technologies such as artificial intelligence, machine learning, big-data analysis, 3-D machining, drone technologies and deep learning.

(iv) **Health & Wellness/Yoga/Sports/Fitness:** The student will acquire physical, emotional, intellectual, social, spiritual quotient. The activities may be organized outside of the regular classes.

7.3.2 The students may get chance to opt other VA Courses as offered by the University time to time which may be relevant for any specific discipline or common to all.

7.4 **Summer Internship/Apprenticeship:**

Internship will be mandatory component of the course. The student may be inducted in actual work situation either in firm/industry/organization etc. or training in labs with faculty in their own or other HEIs/research institutions.

7.5 Research Project/Dissertation:

An elective course designed to acquire special/advanced knowledge, such as supplement study/support study to a project work, and a candidate studies such a course on his own with an advisory support by a teacher/faculty member is called dissertation/project. The student who is eligible and opted UG (Honours with research) will take up research project. The research outcomes will be published in peer-reviewed journal/patented/presented in conferences or seminars/defended in open seminar to secure 12 credits.

8. Level of courses: There will be 5 level of courses on the basis of learning outcome and difficulty levels distributed across semesters in ascending order. Level-1 (0-99), Level-2 (100-199), Level-3 (200-299), Level-4 (300-399), Level-5 (400-499) courses shall be pre-requisite, introductory, intermediate, higher level, and advanced courses respectively.

9. Course Structure:

9.1 The Board of Studies of each department will decide the course structure and syllabus for a specific programme.

9.2 An undergraduate degree with Honours in a discipline such as UG (Honours with research) with single major will be awarded with the following course structure as per the UGC guidelines-

17 Major papers in the discipline: 2 (level-2); 5(level-3); 6(level-4); 4(level-5)

08 Minor papers: 2 (level-2); 2(level-3); 2(level-4); 2(level-5)

03 Multidisciplinary: 3 courses from broad disciplines

04 AEC courses; 03 SEC courses; 4 VAC courses; Internship and Research Project

9.3 The credit of the courses given in the following table:

Course	**Credits distribution Theory + Practical/Tutorial (L+P+T or L+P or L+T)**	
	UG (Honours with research)	**UG (Honours)**
I. Major Course* Theory (17/18 Papers) Practical / Tutorial (17/18 Papers) *The schemes of major courses and pedagogy can be decided by the respective Board of Studies subject to the total core credits remains same. The structure should be such that experiential learning should be enhanced maximum upto 50%, however, it is not mandatory.	Total 80	Total 85
II. Minor Courses (including 12 credits vocational)	32	37
III. Multidisciplinary courses	9	9
IV. Ability Enhancement Courses	8	8
V. Skill Enhancement Courses	9	9

VI. Value added courses	8	8
VII. Internship	2	2
VIII. Research Project/Seminar	Research Project/Dissertation of 12 Credits	Seminar 02 Credits
Total Credit	**160**	**160**

9.4 STRUCTURE OF COURSES

Semester	Courses	Number of courses	Level	Credits	Total Credits
I	Major	1	2	4	20
	Minor	1	2	4	
	Multidisciplinary	1	1	3	
	AEC	1	1	2	
	SEC	1	1	3	
	VAC	2	1	2 + 2	
II	Major	1	2	4	20
	Minor	1	2	4	
	Multidisciplinary	1	1	3	
	AEC	1	1	2	
	SEC	1	1	3	
	VAC	2	1	2 + 2	
The student must complete the 4 credit vocational course/Internship during summer term to get UG Certificate if he wish to exit the program after first 2 semesters.					
	Major	2	3	8	
	Minor	1	3	4	

III	Multidisciplinary	1	1	3	20
	AEC	1	1	2	
	SEC	1	1	3	
IV	Major	3	3	14	20
	Minor	1	3	4	
	AEC	1	1	2	
The student must complete the 4 credit vocational course/Internship either after first year or second year during summer term to get UG Diploma if he wish to exit the program after first 4 semesters.					
V	Major	3	4	15	21
	Minor	1	4	4	
	Internship	-	-	2	
VI	Major	3	4	15	19
	Minor	1	4	4	
The students wish to exit after six semester upon securing 120 credits will be awarded UG degree in relevant subject/discipline					
After sixth semester, there will be two steams :(I) UG (Honours with research) and (II) UG (Honours). The students who will secure 75% and above may opt for UG (Honours with research).					
(I) Course structure for UG (Honours with research)					
VII	Major	3	5	15	19
	Minor	1	5	4	
VIII	Major	1	5	5	21
	Minor	1	5	4	
	Research project/dissertation	-	-	12	

(II) Course structure for the UG (Honours)					
VII	Major	3	5	15	20
	Minor	1	5	4	
	Seminar	-	-	1	
VIII	Major	2	5	10	20
	Minor	2	5	8	
	Seminar	-	-	2	

10. ATTENDANCE AND ELIGIBILITY TO APPEAR IN THE EXAMINATION

A student must have a minimum attendance of 75% of the total number of classes held during the semester including lectures, practicals /tutorials etc., for appearing in the end semester examination. However, Students having attendance more than or equal to 65% and less than 75% shall apply for condonation to the respective Dean of school through the Head of Department. The Dean of School may condone aforesaid shortage in attendance after due consideration of one or more of the following reasons:

(a) Participation in NCC/NSS Camps, duly supported by a certificate from the Commanding Officer;

(b) Participation in University Team(s)/Games or Inter-state or Inter-University tournament(s) duly supported by a certificate from appropriate authority of the University;

(c) Participation in educational excursion conducted on working days certified by the Dean or Head of the department. These excursions shall not include those organized for the class as a whole;

(d) Participation in any of co-curricular activities organized by the Institute/Department/School, duly certified by competent authority;

(e) Prolonged illness duly certified by the Registered Medical Practitioner;

(f) Any other cogent reason up to the satisfaction of the Head of Department/ Dean.

The application must be supported by such documents as considered to be fit for granting such condonation.

11. MEDIUM OF INSTRUCTION

The medium of instructions in general shall be English or Hindi except for language courses. However, University may notify the medium of instruction for a specific programme, and in such cases the medium of instruction shall be as notified by the university. Regardless of the medium of instructions for a programme students will be allowed to answer the semester/internal examinations in Hindi.

12. EXAMINATION AND EVALUATION

12.1. The academic performance of a candidate shall be evaluated in respect of the courses of study prescribed for each semester through the evaluation. The evaluation of students admitted in any of these programmes shall decide the grade and shall be based on
(a) End Semester Examinations (summative assessment), and (b) Continuous Internal Assessment (Formative assessment).

12.2. Out of the total marks, 70% shall be allotted for the end semester examinations and 30% shall be allotted to continuous internal assessments during the semester. The scheme of internal assessment shall be as notified from time to time by the university in the academic calendar.

12.3. The end semester examinations will be held on such dates as may be notified by the appropriate authority of the University.

12.4. The minimum percentage of marks to pass the courses in each semester shall be 40% in each paper (course) comprising internal assessment and end semester examination.

12.5. All programmes shall have a specified number of credits in each semester. The number of credits along with grade points that the student has satisfactorily cleared shall measure the performance of the student. Satisfactory progress of a student is subject to his/ her maintaining a minimum Cumulative Grade Point Average (CGPA), as well as minimum grades in different courses of the programme as given in table-1 which a student if obtains as mentioned above in 9.4 is eligible for the award of appropriate Certificate/Diploma/Degree as the case may be.

Calculation of Semester Grade Point Average (SGPA) and Cumulative Grade Point Average (CGPA):

i. The SGPA is the ratio of sum of the product of the number of credits with the grade points scored by a student in all the courses taken by a student and the sum of the number of credits of all the courses undergone by a student, i.e

$$\mathbf{SGPA\ (S_i) = \Sigma(C_i \times G_i) / \Sigma C_i}$$

where, C_i is the number of credits of the ith course and G_i is the grade point scored by the student in the ith course.

ii. The CGPA is also calculated in the same manner taking into account all the courses undergone by a student over all the semesters of a programme, i.e.

$$\mathbf{CGPA = \Sigma(C_i \times S_i) / \Sigma\ C_i}$$

where, S_i is the SGPA of the ith semester and C_i is the total number of credits in that semester.

iii. The SGPA and CGPA shall be rounded off to 2 decimal points and reported in the transcripts.

Grading System: The grading system, as detailed here under in Table 1 shall be applicable for each course:

Table - 1: Award of Grades Based on Absolute Marks on a 10 point scale

Range of % of marks	Grade points	Letter Grade	GRADE
> 90-≤ 100	10	O	Outstanding
>80- ≤ 90	9	A+	Excellent
>70- ≤80	8	A	Very Good
>60- ≤70	7	B+	Good
>50- ≤60	6	B	Above Average
>40- ≤50	5	C	Average
= 40	4	P	Pass
0- <40	0	F	Fail
Absent	0	Ab	Fail

Description

(i) Letter grades **O, A+, A, B+, B, C,** and **P** in a course mean that the student has passed that course.

(ii) The grade **F** and **Ab** denote **FAIL**; a student fails in the course due to poor performance or non-appearance/incomplete appearance in the examination of the course. A student has to appear at subsequent examination(s), if provided under the ordinances in all such courses, until a passing grade is obtained.

Declaration of Semester Examination Results

Semester examination results will have in the followings categories:

(i) **Pass**: those students who have passed in all courses of the semester examination.

(ii) **Promoted:** Any student admitted in a programme having duly filled in examination

form forwarded by the HoD concerned shall be promoted in the next semester, subject to the eligibility for appearing in the end semester examination.

Backlog: ln any semester a student can opt maximum 40 credits to appear in the end semester examination including those of current semester as well as of previous semesters backlog. The backlog of even semester courses will be cleared with even semester examinations and odd semester courses will be cleared with odd semester examinations. Accordingly, the backlog credits will be opted. The maximum duration in which a student can clear the backlog is the maximum duration of that programme as notified by the University from time to time.

(iii) **Withheld:** those who have cleared all courses in the last semester, but not cleared the backlog courses of the program, the result of the last semester will be *Withheld* till clearing of all backlog courses subject to not crossing maximum duration of the program as defined in the ordinance.

(iv) **Fail:** The student fails to clear all courses in last semester will be categorized as *Fail*. He/she will be given ATKT chance after declaration of last semester result subject to not crossing maximum duration of the program as defined in the ordinance.

13. DECLARATION OF DIVISION:

A student who has passed in all the courses of all Semesters and obtained at least CGPA of 4.00 with fulfilling other requirement mentioned in the ordinance shall be declared as '**Passed**'. The division will be awarded after successful completion of second, fourth, sixth, and eight semester as the case may be for awarding of certificate, diploma, degree, degree (honours) or degree (honours with research) according to the following criteria:

(i) First Division with distinction	:	CGPA $\geq$ 7.50
(ii) First Division	:	CGPA $\geq$ 6.00, but < 7.50
(iii) Second Division	:	CGPA $\geq$ 4.00, but <6.00

14. TRANSCRIPT:

Based on the above Letter grades, grade points and SGPA and CGPA, the Vishwavidyalaya shall issue the transcript indicating the performance in all semesters after successful completion of second, fourth, sixth, and eight semester as the case may be for awarding of certificate, diploma, degree, degree (honours) or degree (honours with research).

15. CONVERSION TO PERCENTAGE:

The conversion formula for converting CGPA to the corresponding Percentage (P) of Marks will be as follows:

$$\mathbf{P = 10 \times CGPA}$$

16. RANKING

Ranking of top 10 candidates in each program will be declared by the university on the basis of their percentage of marks. Only such candidates who complete successfully all courses of the programme in single attempt without using entry-exit option in the program shall be considered for declaration of ranks, medals etc.

17. Re-admission:

1.1 A student of First Year (Semester I/II) of a programme (enrolled in the University) found not eligible to appear in the End-Semester Examination of Odd or Even Semester of the programme due to shortage of attendance ***less than 75%*** shall be permitted to take re-admission to the First Semester of the same programme in the following academic year.

17.2 Students of III Semester onwards, disallowed to appear in the End- Semester Examination due to shortage of attendance (< 75%) shall be permitted to take re-admission in the following academic year in the same semester.

18. Interpretation of Ordinance

In any matter of interpretation of the provisions of this ordinance, the matter shall be referred to Vice-Chancellor who is the chairman of Academic Council and his/her decision shall be final.

19. POWER TO REMOVE DIFFICULTIES

If any question arises related to the matters not covered in these provisions, the relevant provisions made in appropriate Act/Statute/Ordinance/Regulations/Rules/Notifications issued by the university, will prevail.

Minutes of BoS Meeting

Department of Chemistry

Guru Ghasidas Vishwavidyalaya, Bilaspur, Chhattisgarh

Date: August 01, 2025

As per the notification **(313/BOS/Chem/2025/Bilaspur, dated July 28, 2025)**, a meeting of the Board of Studies (BoS) for the Department of Chemistry was convened on August 01, 2025, at 02:00 pm in the Conference Hall of the Department of Chemistry.

The following BoS members were present at the meeting:

1.	Prof. Khemchand Dewangan	–	Chairman
2.	Prof. Samar K. Das	–	External Subject Expert
3.	Mrs. Pushpa Ambrose	–	Expert from Industry
4.	Prof. G. K. Patra	–	Member
5.	Prof. Sunil K. Singh	–	Member
6.	Prof. Charu Arora	–	Member
7.	Prof. Ashish K. Singh	–	Member
8.	Prof. Manorama	–	Member
9.	Dr. Santosh S. Thakur	–	Member
10.	Dr. Suryabhan Singh	–	Member

In this meeting, **the Scheme and Syllabus of the 04-Years Undergraduate (UG) Programme in Chemistry under the NEP-2020** were thoroughly discussed, and suggestions made by members (both external and internal) were considered and incorporated. Each paper of the 4-Years UG Course was thoroughly modified and restructured as per GGV **ORDINANCE No. 97** of the 04-Years UG program with Multiple Entry-Exit Options. The scheme and syllabus of 04-Years UG course are attached (Annexure-I), which would be submitted to the Vishwavidyalaya authority for approval.

Signature of BoS Members:

Prof. Khemchand Dewangan (Chairman)	**Prof. Samar K. Das (External Subject Expert)**	**Mrs. Pushpa Ambrose (Expert from Industry)**
Prof. G. K. Patra (Member)	Prof. Sunil K. Singh (Member)	Prof. Charu Arora (Member)
Prof. Ashish K. Singh (Member)	Prof. Manorama (Member)	Dr. Santosh S. Thakur (Member)
Dr. Suryabhan Singh (Member)		