P. D. E. A's
Prof. Ramkrishna More Arts, Commerce and Science
College Akurdi Pune-411044

Affiliated to

Savitribai Phule Pune University [SPPU]

B.Sc. Chemistry / B.Sc. Honors Chemistry

(Three Years B. Sc. and Four Years B. Sc. Honors Program)

Choice Based Credit System [CBCS]
Under
Autonomy and NEP-2023/24 Pattern

Syllabus

M. Sc.-I Chemistry

From Academic Year
2026-2027

Board of Studies in Chemistry

Preamble: Department of Chemistry

- **Programs Offered in the Department :**
  - B.Sc. Chemistry, (started 1995-96)
  - M.Sc. Analytical Chemistry (started 2006-07
  - M. Phi. Chemistry (started 2014-15
  - Ph. D. Chemistry (started 2021-22)
- **Teaching Faculty:**
  - Doctorate- with SET/NET 05
  - Doctorate 01
  - NET/SET Qualified- 04
- **Sophisticated Instruments available in the Department:**
  - High Performance Liquid Chromatography [HPLC]
  - Thermogravimetric Analyser [TGA]
  - Atomic Absorption spectrometer [AAS}
  - UV- Visible spectrophotometer
- **Innovations in Research:**
  - Instruments designed and constructed by faculty with the help of students –
    1. High Temperature DC Conductivity
    2. Photo catalytic reactor
    3. Gas sensor
    4. Pellet Maker
- **Innovations in Teaching & Learning Methods: -**
  1. Use of Models and simulation prepared by faculty in Excel, MS-Office on HPLC
  2. Models to show Symmetric Operation on Molecules
  3. Simulations
  4. Google Classroom

Rules and Regulations

1. **National Credit Framework (NCrF):** For creditisation and integration of all higher education qualifications leading to a certificate/ diploma/ degree with multiple entry and exit options, college will refer to National Credit Framework (NCrF) which encompasses the qualification frameworks for higher education, vocational and skill education and school education, namely National Higher Education Qualification Framework (NHEQF), National Skills Qualification Framework (NSQF) and National School Education Qualification Framework (NSEQF) respectively.

2. **Structure of Four years multidisciplinary UG Programme and Five Years Integrated Multidisciplinary Master's Degree Programmes with Multiple Entry and Exit Options at Different Levels:**

   (i) Students will have the flexibility to enter four years multidisciplinary Under Graduate Programme in odd semesters and exit a programme after the successful completion of even semesters as per their future career needs.

   (ii) Students will get a Certificate after a One year programme (minimum 40 Credits), a Diploma after two years (minimum 80 Credits), a Bachelor's degree after three years (minimum 120 Credits), and a Bachelor's degree with Research or Honours after Four years (minimum 160 Credits).

3. Qualification Type and Credit Requirements of Four Years Multidisciplinary Degree Programme with Multiple Entry and Exit Options

(i) Details of qualifications, minimum credit requirements, exit credit courses, year and semester are as under:

Levels	Qualification Title	Credit Requirements		Semester	Year
		Minimum	Maximum		
4.5	UG Certificate	40	44	2	1
5.0	UG Diploma	80	88	4	2
5.5	Three Years Bachelor's degree	120	132	6	3
6.0	Bachelor's degree Honour's with Major	160	176	8	4
	Bachelor's degree Honour's with Major	160	176	8	4
7.0	Master's Degree	200	220	10	5
8.0	Ph. D.	----	-----	-----	----

(ii) An exit 6-credit bridge course(s) lasting two months, including at least 6-credit job specific internship/apprenticeship that will help the graduates acquire job-ready competencies required to enter the workforce will be an additional requirement for the award of the undergraduate Certificate/ Diploma/ three year Bachelor's Degree.

(iii) On exit, the students will have the option to re-enter the programme in the college, or in a different higher education institution. Re-entry at various levels for lateral entrants in academic programmes should be based on the earned and valid credits as deposited and accumulated in the Academic Bank of Credits (ABC) through Registered Higher Education Institutions (RHEI) and proficiency test records.

(iv) Eligibility for admission to the fourth year of four-year **Honours with Research Degree Programmes** as per UGC guidelines: Minimum CGPA of 7.5 or minimum 75% at three-year degree.

(v) PG curriculum, as illustrated below, have flexibility a) One-year Post-Graduate Diploma (PGD), b) Two year Post-graduate Programme and c) 5 Years Master's degree programmes with multiple Entry and Exit options at different levels.

(a) Post-Graduate Diploma (PGD): Programme duration- One year (2 semesters) after any bachelor's degree, min. 40 credits

(i) UGC: 1-Year (2 semesters) Post-Graduate Diploma (PGD) after 3-years Bachelor's degree: Level 6.0

(ii) UGC: 1-Year (2 semesters) PGD after 4 years Bachelor's degree (Honors/ Research): Level 6.5

(b) Master's Degree:

(i) UGC: 2-Years (four semesters) Master's Degree after obtaining a 3-years Bachelor's degree, Minimum 40 credits/year, second year devoted entirely to research, PG – 2nd year: Level 6.5

OR

(i) 1-Year (two semesters) Master's Degree after obtaining a 4-year Bachelor's degree (Honours/Research): Minimum 40 credits: Level 6.5

(c) Level 8 represents Ph. D. Research Degree.

(d) A 5-year Integrated Bachelor's and Master's programme shall have a minimum of 220 credits.

(e) Master's and doctoral programmes, while providing rigorous research-based specialization, should also provide opportunities for multidisciplinary work, in academia, government, research institutions, and industry.

4. Lateral Entry/ Re-entry at higher Levels after exit from lower levels of four years multidisciplinary UG degree programme:

(i) The credit points earned and accumulated shall be used to determine the eligibility for taking admission to various programs at multiple levels, subject to fulfilment of the broad principles laid down under NCrF. Students who leave with a Certification, Diploma, or a Basic Bachelor's Degree will be eligible to re-enter the programme at the exit level to complete or progress to the next level through lateral entry mode. Depending upon the academic and physical facilities available, the State Universities/ Autonomous Colleges (Higher Education Institutions or HEI) may earmark specific seats/ intake for lateral entry into the second year/ third year/ fourth year of a four years multidisciplinary UG degree programme as approved by Professional Standard Setting Bodies (PSSB/Govt. of Maharashtra/ statutory council of affiliating University plus any consequential vacancies caused by exits to an ongoing programme (four-year Degree Programme and Integrated Master's or second year Master's). Lateral entry or Re-entry is open to those students if he/she has either –

(a) successfully completed the first year/second year/third year of the particular four years multidisciplinary degree programme in any ABC registered HEI with valid credits in ABC and re-entering into the second year/third year/fourth year, respectively of the same four years degree programme of any ABC registered HEI, within stipulated/ permissible period of years as decided by Statutory Councils of that HEI

OR

(b) Already successfully completed a multidisciplinary four-year first-degree programme and is desirous of and academically capable of pursuing another multidisciplinary four years first-degree programme in an allied subject.

(ii) A student will be allowed to enter/re-enter only at the odd semester. Re-entry at various levels for lateral entrants in academic programmes should be based on the earned and valid credits as deposited and accumulated in Academic Bank of Credits (ABC) through Registered Higher Education Institutions (RHEI) and proficiency test records. However, in terms of the admission eligibility requirements, the student shall belong to the same faculty/ discipline in terms of Major Subject i.e., the Major subject of his earlier Programme and the Major subject of the new Programme for which he is seeking admission must be from the same faculty/discipline. Reservation for lateral entry will be executed as per the Government of Maharashtra norms.

5. Distribution of Credits across Multidisciplinary Four Years Degree Programme:

(i) Four-year multidisciplinary degree programme with Honours/ Specialization Degree will have Internship and Core /Major Courses with a minimum of 22 credits per sem. in the Fourth Year.

(ii) Four-year multidisciplinary degree programme with Research will have Research Projects, Seminars, Dissertations and Internships with a minimum of 22 credits per Sem. in the Fourth Year.

(iii) Students shall select a 'Major or Core Subject/ Discipline' and a '**Minor Subject/Discipline' from the lists of various Subject Combinations and Options provided the Colleges.** In general, for the four years multidisciplinary bachelor's degree programme, the distribution of credits will be as follows:

(a) Disciplinary/interdisciplinary Major/ Core Subject (minimum of 68 credits)- Mandatory and Elective Courses

(b) Disciplinary/interdisciplinary Minor Subject (maximum of 22 credits)

(c) Skill based/Vocational studies corresponding to the Major/ Core Subject (8 credits)

(d) Field projects/internship/apprenticeship/community engagement and service corresponding to the Major/ Core Subject (14-22 credits) with a maximum of six credits per Semester

(e) Generic/ Open Electives through Baskets of Elective Courses (12 credits),

(f) Ability Enhancement Courses including Languages, Literature and Environmental Studies (12 credits),

(g) In-built modules on the Indian Knowledge System (IKS) in Major/ Core Subject at Level 4.5 – 2 credits

(h) Value-based Education, Life Skills and Professional Ethics: Co-curricular Courses such as Sports and Culture, NSS/NCC and Fine/ Applied/Visual Arts (8 credits).

Student can earn some credits (SEC/VSC/GE/OE) in the form of online from-

(i) The National Skills Qualifications Framework (NSQF) organizes qualifications for Vocational and Skill Courses in a series of 8 levels based on professional knowledge, professional skills, core skills and responsibilities, in the increasing order of complexity and competency.

(ii) University Grants Commission (Credit Framework For Online Learning Courses through Study Webs of Active-Learning for Young Aspiring Minds) Regulations, 2021, **permits up to 40 per cent of the total courses being offered in a particular programme in a semester through the Online Learning Courses offered through the Study Webs of Active-Learning for Young Aspiring Minds (SWAYAM) platform**.

6. Examination and Assessment Process:

(i) The basic principle of the credit framework is that credits are a function of the successful completion of a program of study/ vocational education/ training and assessment. No credit can be earned by the student unless the student is assessed for the achievement of the desired competencies and outcome of a program.

(ii) Exit options are provided with certification, diploma and basic Bachelor's degrees to the students at the end of the second, fourth and sixth semesters of a four years multidisciplinary degree programme. Students will receive a Bachelor's degree with Honours/ Research on successfully completing of all eight semesters of the UG Program either at a stretch or with opted exits and re-entries.

(iii) For the smooth success of four-year multidisciplinary degree programme with multiple entry and exit systems, the examination mode will be based on the combination of innovative trends in formative (informal and formal tests administered during the learning process) and summative (evaluation of students learning at the end of an instructional unit) examination modes. This is in line with the UGC Report on 'Evaluation Reforms in Higher Educational Institutions (2019)'.

(iv) Evaluation of each students in each course will be done as follows

a. Each theory may be 2 or 4 credits and practical course will be of 2 credits. 2 credit course examination will be of 50 mark and for 4 credits 100 marks.

b. Internal evaluation 40% weightage

c. External evaluation 60% weightage

d. Students should secure 40% marks in each type of evaluation for successful completion of a course.

(v) Evaluation Pattern.

a. Internal evaluation – Question paper should be designed so that evaluation of CO, PO, PSO can be performed. Internal evaluation should include written tests, seminars, orals, poster presentation, open book challenging tests, surprise test, objective test on whole syllabus of the course (at least 40 questions of objective type must be designed), etc. for 5 marks at least three different types technique must be utilized.

b. External Evaluation - Question paper should be designed so that evaluation of CO, PO, PSO can be performed. External evaluation will be done at the end of semester. Time for examination - 2 credits 2 hour time and 4 credit 3 hour time.

7. Declaration of Results:

(i) Declaration of result is based on the Semester Grade Point Average (SGPA) earned towards the end of each semester or the Cumulative Grade Point Average (CGPA) earned at the completion of all eight semesters of the programme and the corresponding overall alpha-sign or letter grades as given in Table 2. If some candidates exit at the completion of the first, second or third year of the four years Undergraduate Programmes, with Certificate, Diploma or Basic Degree, respectively, then the results of successful candidates at the end of the second, fourth or sixth semesters shall also be classified on the basis of the CGPA obtained in

the two, four, six or eight semesters, respectively. Successful candidates at the end of the tenth semester of the integrated Master's Degree Programmes shall also be classified on the basis of CGPA obtained in the ten semesters of the Programmes. Likewise, the successful candidates of one year or two semesters Master's Degree Programme are also classified on the basis of the CGPA of two semesters of the Master's Degree Programme.

Table-2: Grades on degree certificate/mark sheet will be assigned to the students as per the following table

Semester GPA/ Program CGPA Semester/Program	% of Marks	Alpha-Sign / Letter Grade Result
9.00-10.00	90-100	O (outstanding)
8.00 - <9.00	80.00 – <90.00	A+ (Excellent)
7.00 - <8.00	70.00-<80.00	A (Very Good)
6.00 - <7.00	60.00-<70.00	B+ (Good)
5.50 - <6.00	55.00-<60.00	B (Above Average)
5.00 - <5.50	50.00-<55.00	C (Average)
4.00 - <5.00	40.00-<50.00	P (Pass)
Below 4.00	< 40	F (Fail)
Ab	----------	Absent

(ii) A student obtaining Grade F shall be considered failed and will be required to reappear in the examination. For non-credit courses 'Satisfactory' or "Unsatisfactory' shall be indicated instead of the letter grade and this will not be counted for the computation of SGPA/CGPA.

8. Award of Major and Minor Degree:

(i) A student pursuing four-year multidisciplinary UG programme will be awarded an appropriate Honours/ Research degree in Major/ Core Subject on completion of VIII Semester with the minimum of 176 credits if he secures in that Subject at least 50% of the total credits for that programme. He shall thus study the specific number of Mandatory Core Courses, Core Electives, Vocational and Skill Courses and Field projects/ Internships connected to Core Subjects in eight semesters so as to cover at least 50% of the total credits.

(ii) In case of Research Degree, a student shall pursue research project and write dissertation in that Major in the VII and VIII semesters.

On the basis of above rules and regulations under NEP-2020 following course frame work is adopted by the Prof. Ramkrishna More Arts, Commerce and Science College, Akurdi, Pune-411044 for the completing of four years honours degree in Major and Minor subjects.

9. Distribution of Credits across Four Years Degree Programmes:

In general, for the four years' bachelor's degree programme, the distribution of credits will be as follows:

(a) Major (Core) Subject comprising Mandatory and Elective Courses:

i. Minimum 50% of total credits corresponding to Three/Four - year UG Degree- Mandatory Courses offered in all Four years;

ii. 2 credit course on Major Specific IKS shall be included under Major;

iii. Elective courses of Major will be offered in the third and/or final year.

iv. Vocational Skill Courses, Internship/ Apprenticeship, Field Projects, Research Projects connected to Major first to fourth year.

(b) Minor Subject: 18-20 Credits

i. The Minor subjects may be from the different disciplines of the same faculty of DSC Major (Core) or they can be from different faculty altogether.

ii. The credits of Minor subjects shall be completed in the first three years of UG Programme.

(c) Generic/ Open Elective Courses (OE): 10-12 credits

i. It is to be offered in I and/or II year

ii. Faculty-wise baskets of OE shall be prepared by University/ Autonomous Colleges.
iii. OE is to be chosen compulsorily from faculty other than that of the Major.

(d) Vocational and Skill Enhancement Courses (VSEC): 14-16 credits

Vocational Skill Courses (VSC): 8-10 credits, including Hands on Training corresponding to the Major and/or Minor Subject:
i. To be offered in first to three years;
ii. Wherever applicable vocational courses will include skills based on advanced laboratory practicals of Major

 # Skill Enhancement Courses (SEC): 06 credits
i. To be offered in I and II year;
ii. To be selected from the basket of Skill Courses approved by University/ Autonomous Colleges

(e) Ability Enhancement Courses (AEC), Indian Knowledge System (IKS) and Value Education Courses (VEC): 14 Credits

- **AEC: 08 credits**

i. To be offered in I and II year
ii. English: 04 Credits
iii. Modern Indian Language: 04 credits
iv. To be offered from the Basket approved by the College;
The focus for both languages should be on linguistic and communication skills.

o IKS: 2 Credits
i. To be offered in I Year
ii. Courses on IKS to be selected from the basket of IKS courses approved by the Colleges

o VEC: 04 Credits
i. To be offered in I year
ii. Value Education Courses (VEC) Environmental Science Education (Compulsory), Understanding India, and Digital and Technological Solutions.

(f) Field Projects/ Internship/ Apprenticeship/ Community Engagement and Service corresponding to the Major (Core) Subject, Co-curricular Courses (CC) and Research Project

o Internship/Apprenticeship corresponding to the Major (Core) Subject: 8 Credits

o Field Projects/Community Engagement and Service corresponding to the Major (Core) Subject: minimum 4-6 credits
To be offered in II, and III years of UG Degree Programmes.

o Co-curricular Courses (CC) such as Health and Wellness, Yoga education sports, and fitness, Cultural Activities, NSS/NCC and Fine/ Applied/ Visual/ Performing Arts: 8 credits. To be offered in I and/or II year

o Research Projects: 10 to 12 credits
To be offered in the final year for 4-year Honours with Research UG Degree

The UGC Regulations, 2021 permit up to 40% of the total courses being offered in a particular programme in a semester through the Online Learning Courses offered through the SWAYAM platform and/or other State Level Common Platforms which can be developed in due course with the participation of different Universities/ HEIs.

Abbreviations: Generic/ Open Electives: **GE**/**OE**; Vocational Skill and Skill Enhancement Courses: **VSEC**; Vocational Skill Courses: **VSC**; Skill Enhancement Courses**: SEC**; Ability Enhancement Courses: **AEC**; Indian Knowledge System: **IKS**; Value Education Courses: **VEC; OJT**: On Job Training: Internship/ Apprenticeship; Field projects: **FP**; Community engagement and service: **CEP**; Co-curricular Courses: **CC**; Research Methodology**-RM**; Research Project: **RP** Note: The Credit Distribution Table given above is illustrative only. The Universities/ Autonomous Colleges may suitably modify within the broader framework of credit distribution across six verticals.

Definitions:

1. One semester = 15 weeks

2. 1-credit theory = 15 hours i.e. for 1 credit, 1 hour per week teaching is to be performed.

15 hours of 1-credit are splinted as 12 hours actual teaching + 3 hours Tutorial (practice problem solving sessions, repeated discussion on difficult topics, discussion on student's difficulties, questions discussion and internal evaluation)

3. 1-credit practical = 30 hours. Thus, 1 credit practical = 2 contact hours in laboratory per week. 30 hours splinted as 24 hours actual table work and 6 hours for journal competition, oral on each practical and other internal evaluation.

4. Each theory course of any type (major, minor, VSC, VEC, OE/GE, VEC, SEC, CC, etc.) **is of 2 credits**.

a. Theory per semester: Contact hours per credi t= 15h (12 teaching + 3 tutorials include problem solving sessions, repeated discussion on difficult topics, solution difficulty, questions discussion and internal evaluation).

b. Each course will be of two or four modules, one module = 15 hours

c. Each module may consist of one or more than one chapter.

5. Each practical course of any course is of 2 credits = 60 hours per semester

a. Each laboratory sessions will be of 4 hours.

b. Minimum 12 laboratory sessions of 4 hour should be conducted in one semester. This time include completion practical report of the session.

10. Eligibility Criterion for Admission: As per rules of SPPU and Government of Maharashtra

a. First Year UG: 12^{th} Science pass

b. First Year PG: B. Sc. Chemistry / B. Sc. Industrial Chemistry / B. Sc Nanochemistry / B. Sc. Forensic Science

c. Second Year UG: student who secured 50% credit in first year UG or Diploma holder in any branch of Engineering or Pharmacy.

d. Third Year UG: student who passed first year UG and secured 50% credit in second year UG. / Diploma Engineering/ Pharmacy

e. Fourth Year UG (honours): Eligibility for admission to the fourth year of four-year **Honours with Major and minor / Research Degree Programmes** as per UGC guidelines: Minimum CGPA of 7.5 or minimum 75% at three-year degree.

P. D. E. A's.

Prof. Ramkrishna More College, Akurdi, Pune 411044

Graduate and Honors Degree Course Framework under Autonomy as per NEP-2020; Pattern-2023; With Major Chemistry

Level / Difficulty	Sem	Subject-1	Subject-2	GE/OE	SEC	IKS	AEC	VEC	CC	Total
Certificate										
4.5 / 100	I	4T + 2P/T	4T + 2P/T	2T	2T/P	2T (General)	2T	2T	0	22
	II	4T + 2P/T	4T + 2P/T	2T/P	2T/P	0	2T	2T	2T/P	22
Exit option: Award of UG Certificate in Major with 44 credits and an additional 4 credits core NSQF course/ Internship OR Continue with Major and Minor **Continue option:** Student will select one subject among the (subject 1, subject 2 and subject 3) as major and another as minor and third subject will be dropped.										
Diploma										
Level / Difficulty	**Sem**	**Credits Related to Major**				**Subject-2**	**GE/OE**	**SEC**	**IKS**	**AEC**	**VEC**	**CC**	**Total**
		Major Core	**Major Elective**	**VSC**	**FP / CEP / OJT**								
5.0 / 200	III	4T + 2P/T	0	2T/P	2 FP	2T+ 2T/P	2T	0	2T (Major Specific)	2T	0	2	22
	IV	4T + 2P/T	0	2T/P	2 CEP	2T + 2P/T	2T/P	2T/P	0	2T	0	2	22
Exit option: Award of UG Diploma in Major and Minor with 88 credits and an additional 4 credits core NSQF course/ Internship OR Continue with Major and Minor													
Three years Graduation Degree													
5.5 /300	V	8T + 4P/T	4T + 2P/T	2T/P	2 FP/RP	0	0	0	0	0	0	0	22
	VI	8T + 4P/T	2T + 2P/T	2T/P	4 OJT	0	0	0	0	0	0	0	22
	Total Credits	**48**	**10**	**8**	**10**	**20**	**8**	**6**	**4**	**8**	**4**	**6**	**132**
Four Years Graduate Degree with Honours (Major and Minor subjects)													
6.0 /400	VII	10T + 4P/T	2T + 2P/T	0	0	4T+P RM	0	0	0	0	0	0	22
	VIII	10T + 4P/T	2T + 2P/T	0	4 OJT	0	0	0	0	0	0	0	22
	Total Credits	**76**	**18**	**8**	**14**	**24**	**8**	**6**	**4**	**8**	**4**	**6**	**176**
Four Years Graduate Degree with Honours (Research)													
6.0 /400	VII	8T + 2P/T	2T + 2P/T	0	4 RP	4T+P RM	0	0	0	0	0	0	22
	VIII	10T + 2P/T	2T + 2P/T	0	6 RP	0	0	0	0	0	0	0	22
	Total Credits	**68**	**18**	**8**	**22**	**24**	**8**	**6**	**4**	**8**	**4**	**6**	**176**

M. Sc. Part I

NEP-2020; Academic Year 2026-27

Course Type	Code	Title of the Paper	Credits
Semester-I			
Major	CHMAT-511	Thermodynamics and Chemical Kinetics	2
Major	CHMAT-512	Molecular Symmetry and Group Theory	2
Major	CHMAT-513	Organic Stereochemistry and Aromaticity	2
Major	CHMAT-514	Bioinorganic Chemistry	2
Major	CHMAT-515	Rearrangement, Oxidation and Reduction Reactions	2
Major	CHMAP-516	Practical Physical Chemistry –I	2
Major	CHMAP-517	Practical Organic Chemistry –I	2
Major Elective (Any one)	CHMET-511A	Solid State Chemistry-II	2
	CHMET-511B	Nuclear Chemistry	2
Major Elective (Any one)	CHMEP-512A	Practical Inorganic Chemistry -I	2
	CHMEP-512B	Practical Inorganic Chemistry -I	2
Minor	CHRMT-511	Research Methodology in Chemistry	2
Minor	CHRMP-512	Practical Research Methodology	2
Extra Credits	PGHRT-511	Human Rights-I	2
Semester-II			
Major	CHMAT-521	Quantum Chemistry and Bonding Theories.	2
Major	CHMAT-522	Ligand Field Theory	2
Major	CHMAT-523	Physical Methods for Material Characterization	2
Major	CHMAT-524	Advanced Organic Molecular Spectroscopy	2
Major	CHMAT-525	Photochemistry and Pericyclic Reactions	2
Major	CHMAP-526	Practical Inorganic Chemistry –II	2
Major	CHMAP-527	Practical Organic Chemistry –II	2
Major Elective (Any One)	CHMET-521A	Electro Analytical Chemistry	2
	CHMET-521B	Chemistry of main group elements	2
Major Elective (Any One)	CHMEP-522A	Practical Electrochemistry	2
	CHMEP-522B	Practical on Main Group Element	2
Minor	CHOJP-521	On Job Training	4
Extra Credits	PGHRT-521	Human Right-II	2
Extra Credits	PGCRT-521	Cyber Security-I	2

Program Outcomes

PO-1: **Disciplinary knowledge and skill:** A graduate student is expected to be capable of demonstrating comprehensive knowledge and understanding both theoretical and practical fundamental concepts in all disciplines of Chemistry. Further, the student will be capable of applying modern technologies, handling advanced instruments and Chemistry related soft-wares for chemical analysis, characterization of materials and in separation technology.

PO-2: **Skilled communicator:** The course curriculum incorporates basics and advanced training in order to make a graduate student capable of expressing the subject through technical writing as well as through oral presentation.

PO-3: **Critical thinker and problem solver:** The course curriculum also includes components that can be helpful to graduate students to develop critical thinking and to design, carry out, record and analyze the results of chemical reactions. Students will be able to think and apply evidence based comparative chemistry approach to explain chemical synthesis and analysis.

PO-4: **Sense of inquiry:** It is expected that the course curriculum will develop an inquisitive characteristics among the students through appropriate questions, planning and reporting experimental investigation.

PO-5: **Team player:** The course curriculum has been designed to provide opportunity to act as team player by contributing in laboratory, field based situation and industry.

PO-6: **Skilled project manager:** The course curriculum has been designed in such a manner as to enabling a graduate student to become a skilled project manager by acquiring knowledge about chemistry project management, writing, planning, study of ethical standards and rules and regulations pertaining to scientific project operation.

PO-7: **Digitally literate:** The course curriculum has been so designed to impart a good working knowledge in understanding and carrying out data analysis, use of library search tools, use of chemical simulation software and related computational work.

PO-8: **Ethical awareness:** A graduate student requires understanding and developing ethical awareness or reasoning which is adequately provided through the course curriculum. Students CO-2: To know how to handle the technical devices for presenting research works. can also create an awareness of the impact of chemistry on the environment, society, and also make development outside the scientific community.

PO-9: **Environmental Awareness:** As an inhabitant of this green planet a Chemistry graduate student should have many social responsibilities. The course curriculum is designed to teach a Chemistry graduate student to follow the green routes for the synthesis of chemical compounds and also find out new greener routes for sustainable development. The course also helps them to understand the causes of environmental pollution and thereby applying environmental friendly policies instead of environmentally hazard ones in every aspect.

PO-10: **Analytical skill development and job opportunity:** The course curriculum is designed in such a way that Chemistry graduate students can handle many Chemistry based software, modern instruments and advanced technologies to synthesize, characterize and analyze the chemical compounds very skillfully. Such a wonderful practice in the graduate level will bring a good opportunity to the students for getting job in industries besides academic and administrative works. Programme.

Semester-I

CHMAT 511

Thermodynamics and Chemical Kinetics, [2 Credits, 30 L]

Chapter No.	Name of the Chapter	Lectures Assigned
Module-I	Fundamental Concepts of Kinetics	5 L
	Kinetics of More Complex Systems	4 L
	Techniques and Methods	4 L
	Enzyme Catalysis	2 L
Module-II	Thermodynamics	5 L
	Change of State	4 L
	Molecular Thermodynamics	6 L

Chapter-1: Fundamental Concepts of Kinetics [5 L]

Rates of Reactions, Dependence of Rates on Concentration, First-Order, Second-Order, Zero-Order, N^{th}-Order Reaction, Cautions on Treating Kinetic Data, Effect of Temperature, Some Common Reaction Mechanisms, Direct Combination, Chain Mechanisms, Substitution Reactions, Catalysis, ***Reference-1****: 1-30*

Chapter-2: Kinetics of More Complex Systems [4 L]

Second-Order Reaction, First-Order in Two Components, Third-Order Reactions, Reversible Reactions, Effect of Temperature, ***Reference-1****: 36-45; 58-64; 69-75*

Chapter-3: Techniques and Methods [4 L]

Calculating Rate Constants, The Method of Half-Lives, Initial Rates, The Logarithmic Method, Flow Techniques, Relaxation Techniques, Tracer Methods, Kinetic Isotope Effects, ***Reference-1:*** 79-89; 94 to 107

Chapter-4: Enzyme Catalysis [2 L]

Introduction, Enzyme Action, Kinetics of Reactions Catalysed by Enzymes, Michaelis–Menten Analysis, Lineweaver–Burk and Eadie Analyses. ***Reference-1*****:** 205 -224

Chapter-5: Thermodynamics [05 L]

State function, path function, exact differential and inexact differential, internal energy and enthalpy, temperature dependent internal energy and enthalpy, reversible and irreversible adiabatic expansion. The entropy of irreversible changes, the Helmholtz and Gibbs function, Entropy and entropy change in an ideal gas with temperature and pressure, Clausius inequality, chemical potential, chemical potential of a substance in a mixture. ***Ref****-2-3; Relevant pages*

Chapter-6: Change of State [04 L]

Partial molar quantities, methods for determination of molar quantities, ideal solutions, Raoult's and Henery's law, Thermodynamics of Gibbs function of mixing, colligative properties: Elevation in boiling point, depression in freezing point and osmosis. ***Ref****-2-3: Relevant pages*

Chapter-7: Molecular Thermodynamics [06 L]

Molecular energy levels, Boltzmann distribution law, partition functions and ensembles, translational, rotational and vibrational partition function of diatomic molecule, obtaining energy, heat capacity, entropy and equilibrium constants from partition functions, Maxwell- Boltzmann, Fermi-Dirac and Bose-Einstein statistics. ***Ref-2-3****; Relevant pages*

Reference-1: Principles of Chemical Kinetics, James E. House Second Edition, Elsevier
Reference-2: Atkins Physical Chemistry by P. W. Atkin and De Paul, 11th Ed. Oxford
Reference-3: Physical Chemistry by T. Engel and P. Reid

Course Outcomes: At the end of course, student should able to -

CO-1: Define / recall the terms in thermodynamics and chemical kinetics included in syllabus.

CO-2: Can evaluate various thermodynamic parameters, rate, order and molecularity of the chemical reactions from given experimental data.

CO-3: Explain /discuss terms in thermodynamics and chemical kinetics included in syllabus.

CO-4: Differentiates / compare/ relate among or between the terms such as enthalpy, internal energy, entropy; exact differential and inexact differential; Maxwell- Boltzmann, Fermi-Dirac and Bose-Einstein statistics; Raoult's and Henery's law; molecularity and order; first, second and third order reactions; different methods of evaluating order of reactions; different mechanisms of reactions, etc.

CO-5: Derive equations for enthalpy, Boltzmann distribution law, partition functions constant, Raoult's and Henery's law; half life of first, second and third order reactions. Graphical representation of the same.

CO-6: Apply knowledge of thermodynamics and chemical kinetics to given reaction to predict order, molecularity and mechanism.

CHMAT 512
Molecular Symmetry and its Applications[2-Credits, 30 L]

Chapter No.	Name of the Chapter	Lectures Assigned
Module-I	Molecular Symmetry and Symmetry Groups	10 L
	Symmetry Group	05 L
Module-II	Representations of Matrix	08 L
	Symmetry Adapted Linear Combinations (SALCs)	07 L

Chapter-1: Molecular Symmetry and Symmetry Groups (10L)

Symmetry elements and operations, Symmetry planes and reflections, the inversion centre, proper axes and proper rotations, improper axes and improper rotation, products of symmetry operations, equivalent symmetry elements and equivalent atoms, general relations among symmetry elements and symmetry operations, classes of symmetry operations, symmetry elements and optical isomerism, symmetry point groups, classification of molecular point groups.

Chapter-2: Symmetry Group (05)

Defining properties of a group, group multiplication table, some examples of group, subgroups and classes.

Chapter-3: Representations of Matrix (08 L)

Matrix representation and matrix notation for geometric transformation, The Great Orthogonality theorem and its consequence, character tables (No mathematical part), wave function as basis for irreducible representations.

Chapter-4: Symmetry Adapted Linear Combinations (SALCs) (07L)

Projection operators and their use of construct SALC (Construction of SALC for sigma bonding for molecules belonging point groups: D2h, D3h D4h, C4v, Td., Oh., normalization of SALC, transformation properties of atomic orbital, MO's for sigma bonding, ABn molecules, tetrahedral AB4 and Oh AB6 cases.

References:

1) Chemical Applications of Group Theory by F. A. Cotton;
2) Symmetry and spectroscopy of molecules by K. Veera Reddy;
3) Group Theory and its Chemical Application, P.K. Bhattarchrya

Course Outcomes: At the end of course student should able to -

CO1: Define symmetry elements and symmetry operations, classes, properties of a group, group multiplication table, etc.

CO2: Classify symmetry elements, point group, Group, sub-group and classes.

CO3: Use wave function as basis for determination of irreducible representations and the Great Orthogonality theorem and its consequence.
CO4: Solve problem based on point group, matrix representation and character table
CO5: Construct character table of various point group
CO6: Justify which can take part in bonding on the basis of SALCs and point group of molecules

CHMAT 513

Organic Stereochemistry and Aromaticity, [2-Credits, 30 L]

Chapter No.	Name of the Chapter	Lectures Assigned
Module -I	Stereochemistry-I	15 L
Module -II	Stereochemistry-II	05 L
	Aromaticity	10 L

Chapter-1: Stereochemistry-I (15 L)

a) Sterochemical principles, Interconversions of projection and perspective formulae, enantiomeric relationship, distereomeric relationship, R and S, E and Z nomenclature in C, N, S, P containing compounds, Prochiral relationship, stereospecific and stereoselective reactions, optical activity in biphenyls, spiranes, allenes, Topicity. **Ref. 1 PP. 92 to 189**

Chapter-2: Stereochemistry-II (5 L)

Conformational analysis of di, tri, tetra-substituted 5-6 membered rings and decalins. **Ref. 1 PP. 160 to 189**

Chapter-3: Aromaticity (10 L)

Aromaticity: Benzenoid and non-benzenoid compounds, Huckel's rule, antiaromaticity, Application to carbocyclic and heterocyclic systems, annulenes, azulenes, current concepts of aromaticity. **Ref. 1 PP 39 to 62**

References:

1. Advanced Organic Chemistry, Jagdamba Singh and L. D. S. Yadav, Pragati Prakashan 20th edition (2014)
2. Stereochemistry of carbon compound-by E.L. Eliel
3. Advanced Organic Chemistry (Part A) F. A. Carey and R. J. Sundberg

Course outcomes: Student will able to

CO-1: Learn Stereochemistry of organic compounds.
CO-2: Conversion of Fischer to Newmann, Newmann to Sawhorse and vice versa.
CO-3: Assign absolute configuration to given organic molecules
CO-4: Explain stereoselective and stereospecific reactions; acquire knowledge on topicity.
CO-5: Understand some fundamental aspects of organic chemistry
CO-6: Discuss the concept aromaticity, and various types of aromatic compounds.

CHMAT 514

Bioinorganic Chemistry, [2-Credits, 30 L]

Chapter No.	Name of the Chapter	Lectures Assigned
Module-I	Overview of Bioinorganic Chemistry	06 L
	Concepts of Inorganic Chemistry in Bioinorganic Chemistry	09 L
Module-II	Control and Utilization of Metal-Ion Concentration in Cells	07 L
	Biochemistry of following Elements	08 L

Chapter-1: Overview of Bioinorganic Chemistry (06 L)

What is bioinorganic chemistry, metal functions in metalloproteins: dioxygen transport, electron transfer, structural roles for metal ions, metalloenzyme functions: hydrolytic enzymes, two-electron redox enzymes, multielectron pair redox enzymes, and rearrangements, communication roles for metals in biology, interactions of metal ions and nucleic acids, metal-ion transport and storage, and metals in medicine.
Reference No.-1, page no. 1 to 16

Chapter-2: Concepts of Inorganic Chemistry in Bioinorganic Chemistry (09 L)

Thermodynamic aspects:- HSAB concept, chelate effect and Irving-William series, pKa values of coordinated ligands, Tuning of redox potential, Biopolymer effects. Kinetic aspects:- Ligand exchange rate, Substitution reactions, Electron transfer reaction, Electronic and Geometric Structures of Metal Ions in Biology, Reactions of coordinated ligands, and Concept of spontaneous self-assembly model compounds**.**
Reference No.-1, page no. 21 to 37

Chapter-3: Control and Utilization of Metal-Ion Concentration in Cells (07L)

Beneficial and toxic effects of metal ions, beneficial metal under tight regulation: (Iron): solubilisation, uptake and transport, metalloregulation of uptake and storage, the enzymes involved in mercury detoxification, metalloregulation of the mercury detoxification genes, The generation and uses of metal-ion-concentration gradients: the generation of ionic gradients, ion transport by ion channels, the acetylcholine receptor, and the voltage-gated sodium channel.
Reference No.-1, page no. 139 to 162

Chapter-4: Biochemistry of following Elements (08L)

(a) Metals at the centre of Photosynthesis: Magnesium and Manganese
(b) Electron Carriers: iron-sulphur proteins, blue copper proteins, and cytochromes.
(c) Calcium-Binding Proteins: calmodulin and Ca in Blood coagulation
Reference No.-2, Page no. 51 to 74 and 290, 184 to 192
Reference No.-1, page no. 231 to 243

References:

1. Principle of Bioinorganic Chemistry by S.J. Lippard and J. M. Berg
2. Bioinorganic Chemistry: Inorganic Elements in Chemistry of Life by W.Kaim and B. Schwederski
3. Biological Inorganic Chemistry, 2nd edition, Robert R. Crichton

Course Outcomes:

At the end of course student should able to –
CO-1: Define metalloproteins, metallo-eznymes, photosynthesis, HSAB concept, nucleic acids, metalloregulation, Biopolymer effects and acetylcholine receptor.
CO-2: Explain chelate effect and Irving-William series, pKa values of coordinated ligands, Tuning of redox potential, and Reactions of coordinated ligands.
CO-3: Describe Fe-S clusters, model compounds and spontaneous self-assembly, metals in medicine, blue copper proteins, and cytochromes, and Na/K pumps.
CO-4: Express nitrogen fixation, detoxification of mercury, structure of RNA, cis-platin, amino acids, siderophore,and calmoduline zinc finger proteins.
CO-5: Distinguish between hemoglobin and myoglobin, transferrin and ferritin, photosystem-I and photosystem-II.
CO-6: Decide role of metals in biological system, medicine, blood coagulation, oxygen storage and transport, photosynthesis and uptake and transport of iron.

CHMAT 515

Rearrangement, Oxidation and Reduction reactions, [2 Credits, 30 L]

Chapter No.	Name of the Chapter	Lectures Assigned
Module-I	Rearrangements	10 L
	Oxidizing Agent –I	05 L
Module-II	Oxidizing Agent –II	05 L
	Reducing agents	10 L

Chapter-1: Rearrangements: (10 L)
Beckmann, Hofmann, Curtius, Schmidt, Wolff, Lossen, Bayer-villiger, Sommelet, Favorskii, Pinacol-pinacolone, Benzil-benzilic acid, Fries, Tiffeneau Demjanov, Claisen, Cope Rearrangement. **Reference No.-1, page no. – Relevant pages**

Chapter-2: Oxidizing Agent –I (5 L)
Oxidising agents: CrO_3, PDC, PCC, $KMnO_4$, MnO_2; **Ref. 2 PP 1063 to 1069**

Chapter-2: Oxidizing Agent –II (5 L)
Oxidising agents: CrO_3, PDC, PCC, $KMnO_4$, MnO_2, Swern, SeO_2, $Pb(OAc)_4$, Pd-C, RuO_4, OsO_4, m-CPBA, O_3,$NaIO_4$, HIO_4, TEMPO, IBX, CAN, Dess-Martin, DDQ, Ag_2O. **Reference No.-2, page no. 1070 to 1162**

Chapter-3: Reducing agents (10 L)
Boranes and hydroboration reactions, MPV reduction and reduction with H_2/Pd-C, Raney-Ni, $NaBH_3CN$, Willkinsons catalyst, DIBAL and Wolff-Kishner reduction, Birch, Clemenson, Dissolving metal. **Reference No.-2, page no. 289 to 365**

References:

1. Name Reactions, Jie Jack Li, Third Expanded Edition, Springer
2. Advanced Organic Chemistry (Part B) C. A. Carey and R. J. Sundberg (Fifth edition) Springer
3. Organic Chemistry–by J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford)
4. Advanced Organic Chemistry, Jerry March, JOHN WILEY AND SONS.INC. 4th Edition.

Course Outcome: Student will able to

CO-1: Learn the role of various reaction intermediates like carbocation, carbanion, carbenes, radicals, and nitrenes in rearrangement reactions.
CO-2: Explain the mechanism involved in rearrangement reactions.
CO-3: Justify the product formation in rearrangement reactions.
CO-4: Appreciates the various steps involved in the molecular rearrangements.
CO-5: Understand the mechanism involved in oxidation and reduction reactions.
CO-6: Apply synthetic reagent of oxidation and reduction for solving the problems.

CHMAP 516

Practical Physical Chemistry –I [2-Credits]

Experiment-1. Statistical treatment of experimental data (calculation of mean and standard deviation for given data and least square method for calibration curve method) (compulsory)
Part-I: Chemical Kinetics: (Any three)
Experiment-2. Kinetic decomposition of diacetone alcohol by dilatometry.
Experiment-3. Determination of an order of a reaction.
Experiment-4. Brönsted primary salt effect.
Experiment-5. Kinetics of oxidation of ethanol by $K_2Cr_2O_7$
Part-II: Non-Instrumental: (Any Three)
Experiment-6. Determination of surface excess of amyl alcohol or TX-100 surfactant by Capillary rise method.
Experiment-7. Determination of molecular weight by steam distillation.
Experiment-8. Glycerol radius by viscosity.

Experiment-9. Partial Molar Volume (Polynometry) Determination of the densities of a series of solutions and to calculate the molar volumes of the components.

Part-III: Colorimetry and spectrophotometry (Any four experiments)

Experiment-10. Simultaneous determination of Ni(II) and Co(II) by spectrophotometry (Ref-1)

Experiment-11. Simulations determination of $KMnO_4$ and $K_2Cr_2O_7$ by spectrophotometry.(Ref-7)

Experiment-12. To study the adsorption of certain dyes such as methyl violet, picric acid or malachite green on charcoal. (Ref-2)

Experiment-13. To determine the indicator constant of bromocresolpuple by half height method (Ref-8)

Experiment-14. Estimation of Cu(II) by titration with Na_2 EDTA by colorimetry

Experiment-15. a. Determination of energy of n to Π* transition in acetone and study of effect of solvent on energy of this transition by recording absorbance spectra in n-hexane and water. b. To study the effect of the extended conjugation on the λmax of p-nitro phenol by recording spectrum in acidic and alkaline medium (Ref-8).

Part -IV: Radioactivity: (Any one)

Experiment-16. Estimation of Mn in tea leaves by NAA.

Experiment-17. Half-life of a radioactive nuclide and counting errors.

Experiment-18. Determination of E-max of β radiation and absorption coefficients in Al.

References:

1. Practical physical chemistry, A. Findlay, T.A. Kitchner (Longmans, Green and Co.)
2. Experiments in Physical Chemistry, J.M. Wilson, K.J. Newcombe, A.r. Denko. R.M.W. Richett(Pergamon Press)
3. Senior Practical Physical Chemistry, B.D. Khosla and V.S. Garg (R. Chand and Co., Delhi.).
4. Experimental Physical Chemistry by D. P. Shoemaker, Mc. Growhill, 7th Edition, 2003.
5. Physical chemistry by Wien (2001)
6. Advance Physical Chemistry Experiment, Gurtu and Gurtu, Pragati Publication (Meerut),
7. Experiments in Chemistry, D. V. Jahagirdar, Himalaya Publishing House
8. Practical physical Chemistry, B. Vishwanathan and P. S. Raghwan, Viva Books

Course Outcome: Student will able to

CO-1: Prepare solution of required conc. And handle laboratory equipment property.

CO-2: Perform experiment accurately and able to perform calculation.

CO-3: Explain experiment and principal of experiment in detail.

CO-4: Write / discuss results and conclusions of the experiment.

CO-5: Apply knowledge to a) design experiment for given aim or modify experiment to enhance results. b) to find out lacuna in experimental procedure.

CO-6: Solve problem/ numerical depending on given data / information.

CHMAP 517
Practical Organic Chemistry –I, [2-Credits]

Experiment-1: Introduction to Laboratory Safety: Meaning of safety signs on container of chemicals, safety handling of chemicals, MSDS sheets: Detailed explanation at least for 4 different types of substances (e.g. nitric acid, benzene, potassium dichromate, bromine, etc.), Handling of glassware's and care to be taken, handling of organic flammable as well as toxic solvents in laboratory, use of safety goggles, shoes and gloves, fire extinguisher and its use, action to be taken in accidental cases e.g. cleaning of acid spill over, use eye wash station and bath station in emergency, etc. (compulsory)

Experiment-2: Introduction to Green Chemistry (Compulsory; Ref-3 and 4)

Concept of green chemistry, twelve principals of green chemistry, applications of green chemistry for sustainable development, Atom economy, monitoring of reaction using TLC.

(Compulsory)

Experiment – 1(a):. Use of chemdraw/chemoffice/chewin/Avagadro for structure drawing and writing chemical reactions.

Experiment-1(b): Writing three-dimensional structures of simple organic molecules and their computational properties.

Experiment-2: Drawing organic structures using SMILES codes.

Any 8 experiments from 1 to 21 from following experiments

Note: Wherever necessary, 1) purification solids must be performed by crystallization or sublimation 2) TLC of products must be recorded 3) Wherever possible search for green chemistry procedures for practical 1 to 16 and practice green chemistry methods for regular practicals.

Part-I: classical organic synthesis (oxidation, reduction, nitration, N and O-acylation, condensation, etc). (Any)

Experiment-3: Alkene oxidation: preparation of adipic acid from cyclohexene. Ref-1; pp-240

Experiment-4: Synthesis of an ether: preparation of β-naphthyl methyl ether Ref-1; pp-250

Experiment-5: Auto-oxidation–reduction of aromatic aldehydes: Cannizzaro reaction Ref-1; pp-259

Experiment-6: Synthesis of α, β-unsaturated ketones: Claisen-Schmidt reaction Ref-1; pp-262

Experiment-7: Multistep synthesis of a drug: paracetamol Ref-1; pp-280

Experiment-8: Hofmann rearrangement: synthesis of 2-aminobenzoic acid (anthranilic acid) Ref-1; pp-323

Experiment-9: N-Heterocycle synthesis: producing benzo-triazol Ref-1; pp-336

Experiment-10: Synthesis of macrocycles: preparation of calix[4]pyrrole Ref-1; pp-338

Experiment-11: Methyl ketone reactivity: acetophenone oxidation with sodium hypochlorite Ref-1; pp-380

Experiment-12: Electrophilic aromatic substitution (SEAr): preparation of 4-methyl-3-nitroacetanilide from 4-methylaniline. Ref-1; Pp-382

Experiment-13: Sandmeyer reaction: 2-iodobenzoic acid synthesis Ref-1; pp-385

Experiment-14: Free-radical halogenation: 9-bromoanthracene preparation Ref-1; pp-389

Experiment-15: Alkylbenzene oxidation: reactivity of alkyl groups in aromatic compounds with $KMnO_4$ Ref-1; pp-391

Experiment-16: Reduction of a ketone alkaline solution: cyclohexanone reaction with $NaBH_4$ Ref-1; pp-439

Experiment-17: Acylation of aromatic amines: obtention of acetanilide with acetic acid and Zn Ref-1; pp-425

Experiment-18: Thiamine-catalysed benzoin condensation (Ref-2; 657)

Experimen-19: Preparation of triphenyl pyridine (ref-5, pp-366)

Experiment-20: Reduction of vanilline using $NaBH_4$ (internet source PDF)

Experiment – 21: Reduction of Nitro compounds under mild condition. (Ref: Chemical papes, 66, 8, 772-778, 2012)

Experiment – 22: Reduction of Nitro compounds under mild condition using Zn-Hydrazine. (Ref: Indian journal of chemistry, Vol42-B, 2003, 180-183)

Experiment-23: Benzoin reduction by $NaBH_4$ (internet source PDF).

Part-II: Green Chemistry Experiments (any two) (Ref-3 and 4)

Experiment- 24 : Preparation of Schiff's bases in aqueous medium.

Experiment- 25 : Preparation of dihydropyrimidinone under solvent free conditions.

Experiment- 26: Preparation of acetanilide from aniline and acetic acid using Zn dust.

References:

Reference-1: Experimental Organic Chemistry, Laboratory Manual; Joaquín Isac-García, José A. Dobado, Francisco G. Calvo-Flores, Henar Martínez-García, Academic Press is an imprint of Elsevier.

Reference-2: Macroscale and Microscale Organic Experiments, Kenneth L. Williamson, Katherine M. Masters, Cengage Learning.

Reference-3: Comprehensive Practical Organic Chemistry by V.K. Ahluwalia and Renu Aggarwal

Reference-4: Monograph on Green Chemistry Laboratory Experiments by Green Chemistry Task Force Committee, DST.

Reference-5: A Microscale Approach ***to*** Organic Laboratory Techniques, SIXTH EDITION, Donald L. Pavia, Gary M. Lampman, George S. Kriz, Randall G. Engel, **Cengage Learning**

Course Outcome: Student will able to

CO-1: Learn safety techniques and handling of chemicals.

CO-2: Purify organic compounds by techniques like recrystallization and sublimation

CO-3: Ccarrying out different types of reactions and their workup methods.

CO-4: Understand the green chemistry and role of green chemistry in pollution reduction.

CO-5: Avoid solvents and do solvent free reaction.

CO-6: Also the work-up procedure in many experiments is made more eco-friendly to environment.

CHMET 511A

Solid State Chemistry-II, [2 Credits, 30 L]

Chapter No.	Name of the Chapter	Lectures Assigned
Module-I	Bonding in Solids and Electronic Properties	04 L
	Defects and Non-Stoichiometry	08 L
	Magnetic Properties	03 L
Module-II	Superconductivity	04 L
	Synthesis of Solids	11 L

1. **Bonding in Solids and Electronic Properties (04 L)**

[Recapitulation the concepts Crystalline solids, unit cell, and types of unit cells, Introduction, Bonding in Solids—Free Electron Theory, Electronic Conductivity]

Bonding In Solids—Molecular Orbital Theory, Simple Metals, Semiconductors—Si and Ge, Photoconductivity, The *P-N* Junction—Field-Effect Transistors, Bands In Compounds—Gallium Arsenide, Bands In d-Block Compounds—Transition Metal Monoxides. **(Ref-1 pp-179-199, Ref-4).**

2. Defects and Non-Stoichiometry (08 L)

Introduction, point defects—an introduction, defects and their concentration, intrinsic defects, extrinsic defects, the concentration of defects, ionic conductivity in solids, solid electrolytes, fast-ion conductors: oxygen ion conductors, fast-ion conductors Silver Ion Conductors: α-AgI, fast-ion conductors – Oxygen ion Conductors: Stabilized Zirconias, Perovskites, sodium ion conductors – Beta Alumina, Applications: 1) fuel cells, 2) sensors, 3) electrochromic devices, non-stoichiometric compounds, introduction, non-stoichiometry in wustite, Electronic Defects in FeO, the titanium monoxide structure. (**Ref-1** pp 201 - 257, Ref-4)

3. Magnetic Properties (3 L)

Physical Properties, Behaviour of substances in a magnetic field, Effects of temperature: Curie and Curie–Weiss laws, Magnetic moments, Mechanisms of ferro- and antiferromagnetic ordering: superexchange, Some more definitions, Magnetic Materials, their Structures and Properties, Metals and alloys, Transition metal monoxides, Transition metal dioxides, Spinel's, Applications: Structure–Property Relations **(Ref-4: 445-467, Refence-1)**.

3. Superconductivity (04 L)

Introduction, Discovery, The Magnetic Properties of Superconductors, Josephson Effects, The BCS Theory of Superconductivity, High Temperature Superconductors, Theory of High Tc Superconductors, Uses of High Temperature Superconductors. **(Ref-1 pp-394 to 410, Ref-4)**

4. Synthesis, Processing and Fabrication Methods (11 L)

Introduction, Solid State Reaction or Shake 'n Bake Methods: Nucleation and growth, epitaxy and topotaxy, Practical considerations and some examples of solid state reactions, Li_4SiO_4, $YBa_2Cu_3O_{7-\delta}$, Na β/β alumina, Combustion synthesis, Mechanosynthesis, Low Temperature or Chimie Douce Methods: Alkoxide sol–gel method, Synthesis of $MgAl_2O_4$, Synthesis of silica glass, Spinning of alumina fibres, Preparation of indium tin oxide (ITO) and other coating, Fabrication of YSZ ceramics, Sol–gel method using oxyhydroxides and colloid chemistry, Synthesis of zeolites, Preparation of alumina-based abrasives and films, Citrate gel and Pechini processes, Use of homogeneous, single-source precursors, Hydrothermal and solvothermal synthesis, Microwave synthesis, Intercalation and deintercalation, Graphite intercalation compounds, Pillared clays and layered double hydroxides, Synthesis of graphene, Example of a difficult synthesis made possible by chimie douce methods: $BiFeO_3$, Gas phase Methods: Vapour-phase transport, Chemical vapour deposition, CVD, Amorphous silicon, Diamond films; Atomic layer deposition (ALD) Aerosol synthesis and spray pyrolysis. **(Ref-4 PP 187 to 226 and Ref-3).** Procedures of synthesis of some nano-materials- gold and silver nanoparticles, CdS nanoparticles, ZnO, TiO_2 and Fe_2O_3 nanoparticles and Porous Silica. (Ref-3)

References

Ref.-1: Elaine A. Moore, Lesley E. Smart - Solid State Chemistry - an Introduction. Third Ed. / Fourth Ed. CRC Press (2012)

Ref-2: C. N. R. Rao, Kanishka Biswas, Essentials of inorganic materials synthesis, Wiley, 2015

Ref-3: Nanotechnology: Principles and Practices, S. K. Kulkarni, Third Ed. Springer

Ref-4: Anthony R. West, Solid State Chemistry and its Applications Second Edition (Student Edition), Wiley.

Ref-5: Solid State Materials Chemistry, Patrick M. Woodward, Pavel Karen, John S. O. Evans, Thomas, Cambridge University Press

Course outcomes:

CO1: Explain the fundamental concepts of crystalline solids, unit cells, and bonding theories (Free Electron Theory and Molecular Orbital Theory) to interpret the electronic properties of solids.

CO2: Differentiate between simple metals, semiconductors (Si, Ge), and compound semiconductors (GaAs), and describe their conductivity, photoconductivity, and device applications such as P–N junctions and field-effect transistors.

CO3: Describe various types of defects (intrinsic and extrinsic), non-stoichiometry, and their influence on defect concentration, ionic conductivity, and the behavior of fast-ion conductors.

CO4: Analyze the structure, properties, and technological applications of solid electrolytes, fast-ion conductors (α-AgI, stabilized zirconia, perovskites, beta alumina), and non-stoichiometric compounds such as wustite (FeO).

CO5: Interpret the magnetic properties of solids by distinguishing paramagnetism, ferromagnetism, antiferromagnetism, and ferrimagnetism, including domain theory and practical magnetic materials.

CO6: Explain the principles of superconductivity (BCS theory, Josephson effects, High Tc superconductors) and evaluate various solid-state synthesis techniques, including soft-chemistry routes and nanomaterial preparation methods.

CHMET-512A

Nuclear Chemistry, [2 Credits, 30 L]

Chapter No.	Name of the Chapter	Lectures Assigned
Module-I	Radioactivity	04 L
	Elements of Radiation	06 L
	Determination of Radioactivity	04 L
Module-II	Nuclear Fission:	06 L
	Applications of Radioactivity	09 L

Chapter-1: Radioactivity [04 L]

Types of radioactive decay, general characteristics of radioactive decay, decay kinetics, general expression for the activity of a daughter nuclide, Geiger- Nuttalis law, α-decay: A problem in classical physics, Internal conversion and the Auger effect. ***Referenc-1:*** *Relevant pages*

Chapter-2: Elements of Radiation [06 L]

Chemistry: Interaction of radiation with matter, interaction of γ radiation with matter, units for measuring radiation absorption, Radiation dosimetry, Radiolysis of water, free radicals in water radiolysis, Radiolysis of some aqueous solutions. ***Referenc-1:*** *Relevant pages*

Chapter-3: Determination of Radioactivity [04 L]

Ionization Counters: Introduction, Ionization Counter, General Design of an Ionization Chamber, Current–Voltage Characteristics of the Ionization Chamber, Nature of Gas to be used in Ionization Chamber, Regions Suitable for Counting Purposes, and Pulses Due to α- and β-Particles, Relationship between Energy of Radiation and Pulse Height, Ionization Counters; **Geiger–Müller Counter**: Design of the End-Window G.M. Counter, Principle of a G.M. Counter, Liquid Geiger–Müller Counter Liquid Geiger–Müller Counter, The Assembly of the Liquid G.M. Counter, Thickness of the Window and Density Correction, Necessary Precautions While Using Liquid G.M. Counter**,** Current–Voltage Characteristics of the G.M. Counter, Dead Time of Geiger–Müller Counter, Chemically Quenched G.M. Counter, Organic Gas Quenched G.M. Counter, Limitations of Ionization Counters. ***Refence-2:*** *53 to 93 (relent part only)*

Chapter-4: Nuclear Fission: **[06 L]**

The discovery of nuclear fission, the process of nuclear fission, fission fragments and their mass distribution, charge distribution, Ionic charge of fission fragments, fission energy, fission cross-section and threshold, fission neutrons, theory of nuclear fission, Neutron evaporation and spallation. ***Referenc-1:*** *Relevant pages*

Chapter-5: Applications of Radioactivity [09 L]

Typical reaction involved in the preparation of radioisotopes, The Szillard- Chalmers reaction, Radiochemical principles in the use of tracers, Isotopes in elucidating reaction mechanism and structure determination, physic-chemical research - The solubility of a sparingly soluble substances, surface area of a powder or precipitate rates of diffusion, Analytical applications- Isotope dilution analysis, Neutron activation analysis, Radiometric titrations, Medical applications-Thyroiditis, Assessing the volume of blood in a patient, Industrial applications thickness measurements and control, friction and wear out, gamma radiography. ***Referenc-1:*** *Relevant pages*

References:

Referenc-1: Elements of Nuclear Chemistry by H.J.Arnikar, CBS Publisher

Referenc-2: Nuclear Chemistry, Second Edition, Maheshwar Sharon, Madhuri Sharon, Springer

Course Outcomes: At the end of course student should able to -
CO-1: Define and discuss the various terms in nuclear chemistry as in syllabus.

CO-2: Can evaluate / demonstrate decay kinetics of a particular nuclear reaction, age of particular sample from data, use of radioactivity in different fields of chemistry, etc.
CO-3: Explain different types of nuclear reactions and their mechanism.
CO-4: Differentiates / compare/ relate among or between various terms in nuclear chemistry as in syllabus, such as different types of decay, methods of measurement of radioactivity, types of nuclides, types of nuclear reactions, ion pair behavior in electrical field, nuclear fission and fusion, application of particular isotope in tracer application, etc.
CO-5: Apply knowledge of radioactivity in different fields of chemistry such as structure of molecule, mechanism of reaction, determination of age of sample such as rock, wood/fossil, water, and in medicine.
CO-6: Solve problem/ numerical depending on given experimental data.

CHMEP-511B

CHMEP-512B

Inorganic Chemistry Practical, [2 Credits]

Part-I: Analysis (at least two of the following) (Ref. -1)
Experiment-1. Determination of Silica and Manganese from pyrolusite ore.
Experiment-2. Determination of Aluminum and Silica from Bauxite ore.
Experiment-3. Determination of silica and iron from hematite ore.
Experiment-4. Determination of copper and iron from Chalcopyrite ore.

Part-II: Alloy Analysis (at least two of the following) (Ref. -1)
Experiment-5. Determination of tin and lead from solder alloy.
Experiment-6. Determination of iron and chromium from stainless steel alloy.
Experiment-7. Determination of copper and nickel from cupranickel alloy.

Part-III: Synthesis of solid-state materials / nano-materials **(any Four) (Ref- 2 and 3)**
Experiment-8. Synthesis of ZnO from zinc oxalate - precursor method and determine band gap by absorption spectroscopy
Experiment-9. Synthesis of Colloidal silver nanoparticles and determine band gap by absorption spectroscopy
Experiment-10. Synthesis of Fe_2O_3 nanoparticles from FeC_2O_4 (synthesis of FeC_2O_4)
Experiment-11. Synthesis of MnO_2 (Ref. 2)
Experiment-12. Synthesis of CuxS nano-particles. (Ref. 5-7)

Part-IV: Applications of Solid-State Materials (any three)
Experiment-13. Removal and kinetics of photocatalytic dyes, degradation (methylene blue) by ZnO TiO_2 photocatalysis (Ref-2)
Experiment-14. Study of adsorption of sulfide on Fe_2O_3 (Ref-2)
Experiment-15. Heterogeneous Catalysis: Study on decomposition of H_2O_2 by non - catalysed and MnO_2 catalysed method (Ref. 2, 8)
Experiment-16. Study of non-stoichiometry of synthesised CuxS (Estimation of Cu(II) by colorimetry)

Part-V: Table Work Compulsory
Experiment-17. ZnO nanoparticles powder XRD, SEM, TEM.

References:
1. Text book of Quantitative Analysis by A.I. Vogel 3edednn (1963).
2. Experimental Inorganic Chemistry, Mounir A. Malati, Horwood Series in Chemical Science (Harwood publishing, Chichester) 1999
3. Nanotechnology: Principles and Practices, Sulbha Kulkarni, Springer, (2015)

4. Synthesis of Copper(I) Oxide Particles with Variable Color: Demonstrating Size Dependent Optical Properties for High School Students; J. Chem. Educ; DOI:10.1021/acs.jchemed.5b00563
5. CuS Nanoparticles Trigger Sulfite for Fast Degradation of Organic Dyes under Dark Conditions; CS Omega 2022, 7, 5, 4140-4149; DOI: 10.1021/acsomega.1c05697.
6. A facile chemical route to copper sulfide CuS nano-crystallites – pH effect of the morphology and the shape of them; journal of optoelectronics and advanced materials; Vol. 8, No. 2, April 2006, p. 597 – 60
7. Facial Grinding Method for Synthesis of High-Purity CuS Nano sheets; Ind. Eng. Chem.Res. 2018, 57, 8, 2759–2764; https://doi.org/10.1021/acs.iecr.7b04616
8. Practical Physical Chemistry, B. Vishwanathan and P. S. Raghwan, Viva Books (2005)

Course Outcome: Student will able to

CO-1: Prepare solution of required conc. And handle laboratory equipment property.
CO-2: Perform experiment accurately and able to perform calculation.
CO-3: Explain experiment and principal of experiment in detail.
CO-4: Write / discuss results and conclusions of the experiment.
CO-5: Apply knowledge to a) design experiment for given aim or modify experiment to enhance results. b) to find out lacuna in experimental procedure.
CO-6: Solve problem/ numerical depending on given data / information.

CHRMT-511

Research Methodology in Chemistry 2 Credit (30 L)

Module-I	Introduction to Research methodology	2 L
	Scope of Research and Ethics	5 L
	Literature Survey and Search technique	5 L
	Overview of the journal article	3 L
Module-II	Extraction and Purification Processes in Research, Solvent Extraction, Extraction of Solids, Solvents and Reagents, The Purification of Common Organic Solvents	6 L
	Green Chemistry Principles	9 L

1: Introduction to Research methodology: (02L)

Objective of research, motivation in research, types of research, Fundamental research, applied research, experimental research, and interdisciplinary research.

2: Scope of Research and Ethics: (05 L)

Steps in scientific research: scientific methods of research, criteria of good research, and characteristics of a good research, Research problem: Identification, Selection, developing research title, Criteria for prioritizing topics for research, Prioritizing Topics for Research, Formulation of research objectives.

Types and importance of research ethics, Institutional ethics committee, Plagiarism, Patenting and intellectual property rights. Publication ethics: definition, introduction, and importance.

3: Literature Survey and Search technique: (05L)

Print: Sources of information: Primary, secondary, tertiary sources; Journals: Journal abbreviations, abstracts, current titles, reviews, monographs, dictionaries, Introduction to Chemical Abstracts and Beilstein, Subject Index, Substance Index, Author Index, and Formula Index. Literature Search technique**:** SCOPUS, Google Scholar, PUBMED, Web of Science, science direct, Indian Citation Index, Research Gate, and scifinder, Scirus, ChemIndustry, Wiki- Databases, ChemSpider.

4: Overview of the journal article: (03 L)

Selection of journals, Data bases and research metrics Databases: i) indexing databases ii) Citation databases: Web of Science, Scopus, UGC-Care List etc.

Research Metrics: a) Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score b) Metrics: h-index, g index, i10 index.

5a. Extraction and Purification Processes in Research (05 L)
5b. Solvent Extraction (02 L)

Extraction of Liquids- Batch-extraction processes, Continuous extractions of liquids, Extraction by chemically active solvents.

5c. Extraction of Solids

Drying of Liquids or of Solutions of Organic Compounds In Organic Solvents (01 L)

Common drying agents for organic compounds- Anhydrous Calcium Chloride, Magnesium Sulphate, Anhydrous Sodium Sulphate, Anhydrous Calcium Sulphate, Anhydrous Potassium Carbonate, Sodium And Potassium Hydroxides, Calcium Oxide, Phosphoric Oxide

Drying By Distillation, Distillation At Atmospheric Pressure, Steam Distillation, Distillation Under Diminished Pressure ('Vacuum' 50 Distillation) (02 L)

Reference- Vogel's Textbook Of Practical Organic Chemistry, Fifth Edition, B. S. Furniss, A. J. Hannaford, P. W.G. Smith, A. R. Tatchell Page No. 156-186

5d. Solvents and Reagents (02 L)

5e. The Purification of Common Organic Solvents: - (02 L)

Saturated aliphatic hydrocarbons, Aromatic hydrocarbons, Halogenated hydrocarbons, Aliphatic alcohols, Ethers, Ketones, Esters, Nitrogen-containing solvents, Sulphur-containing solvents, Phosphorus-containing solvents.

Reference- Vogel's Textbook Of Practical Organic Chemistry, Fifth Edition, B. S. Furniss, A. J. Hannaford, P. W.G. Smith, A. R. Tatchell Page No. 395-412

6. Introduction to Green Chemistry

Introduction to green chemistry (Ref-1: Chapter-1, pp 1 to 15);

Twelve Principles of green chemistry (Ref-1, Chapter-2 pp 16-72)

Referene-1: An Introduction to Green Chemistry, Indu Sidhwani and Rakesh Sharma, Wiley, 2020

CHRMP-512

Practical Research Methodology

Research Methodology Practical Course (2 Credits)

Experiment-1: Safety in Chemistry Laboratory – Handling of chemicals and hazardous chemicals, storage of chemicals, MSDS sheet, what to do in case – 1) spillover of chemicals / solvents, 2) Fire in laboratory. Care and use of electrical equipment's. Use of eye wash station, water bath station. Recycling, recovery and reuse of laboratory chemicals, distillation and deionization of water. Disposal of waste chemicals.

Expt. No.- 2 and 3: Formulation of Research Problem:

a) Objective: Learn how to define and formulate a research problem.

b) Activity: Identify a problem statement in your domain; define scope, objectives, and research questions.

c) Title of research work and review writing related to research title (at least 30 papers must be included in last 15 years in the area of research work). Literature review using databases (e.g., Scopus, JSTOR, Google Scholar, etc).

Expt. No.- 4 and 5: Writing research proposal in proper format.

Activity: write a research proposal to the research funding agency in proper format. It shall include -

Title: Concise, informative title summarizing the research area
Summary: A overview of the background, objectives, methods, and expected outcomes.
Introduction: Context, background, and the specific problem to be addressed.
Literature Review: A critical analysis of existing research to identify gaps the study will fill.

Research Aims/Questions: Specific, measurable (SMART) questions or hypotheses guiding the research.

Methodology: Research design, data collection methods (surveys, interviews, experiments), and analysis techniques.

Significance/Expected Outcomes: Impact on the field and potential for future research.

Timeline/Budget: A realistic schedule (e.g., Gantt chart) and, if applicable, projected costs.

References: A list of all cited sources.

Expt. No.-6. Research Design Selection

a) Objective: Compare and choose between qualitative, quantitative, and mixed-methods designs. b) Activity: Prepare a research design for a given problem.

Expt. No. 7-8: Data entry and calculation using EXCEL, (using different formulas of EXCEL for calculation); Analyse a dataset and interpret statistical test results. (mean, standard deviation, RSD, CV, standard error of the mean, Q-Test (reliability of results), Confidence Interval**,** Comparison of Results **(**student t-test, students F-test, etc.); Comparison of the Means of Two Samples; Paired t-test, The Number of Replicate Determinations (Ref-1).

Expt. No.-9: Graphical representation using EXCEL. Correlation and Regression for XY linear plots (calibration curves). (Ref-1)

Expt. No.-10: Preparation of power point presentation of research proposal / research work.

Expt. No.-11: Research report writing / Research paper writing

Objective: Learn structure and formatting of research reports/papers.

Activity: Prepare a mini research report following specific format (APA/MLA/Chicago) format. (Dummy experimental data should be provided to the students).

Expt. No.- 12: a) Grammar checking tools b) Plagiarism-use of google tools to check Plagiarism c) Use of AI for your research.

Expt. No.-13: Effect use of software's for in your subject for - research, in writing, in presentation and calculation.

Course Outcome

Apply laboratory safety protocols: Demonstrate safe handling, storage, and disposal of chemicals. Operate safety equipment (eye wash, water bath, electrical devices) effectively. Respond appropriately to emergencies such as chemical spills or fires.

Formulate and define research problems: Identify relevant problem statements in a chosen domain. Establish scope, objectives, and research questions. Conduct comprehensive literature reviews using academic databases.

Develop structured research proposals: Write proposals in standard formats for funding agencies. Integrate background, aims, methodology, and expected outcomes. Prepare realistic timelines and budgets.

Design appropriate research methodologies: Compare qualitative, quantitative, and mixed-methods designs. Select and justify suitable research designs for specific problems. Plan data collection and analysis strategies.

Perform data analysis and visualization using Excel: Enter, calculate, and statistically analyze datasets (mean, SD, t-test, F-test, CI, etc.). Apply correlation and regression for calibration curves. Create graphical representations to interpret and present results.

Communicate research effectively: Prepare PowerPoint presentations, research reports, and papers in accepted formats (APA/MLA/Chicago). Use grammar-checking, plagiarism tools, and AI responsibly in research. Employ subject-specific software for writing, presentation, and data analysis.

Ref-1: Vogels textbook of Inorganic Quantitative Analysis, 5th Ed.

References:

1) Kothari, C.R. and Garg, G., *Research Methodology: Methods and Techniques*, New Age International Publishers.
2) Creswell, J.W. and Creswell, J.D., *Research Design: Qualitative, Quantitative and Mixed Methods Approaches*, Sage Publications.
3) Montgomery, D.C., *Design and Analysis of Experiments*, Wiley.
4) Field, A., *Discovering Statistics Using SPSS*, Sage Publications.
5) American Psychological Association, *Publication Manual of the American Psychological Association (APA Style Guide)*.
6) Day, R.A. and Gastel, B., *How to Write and Publish a Scientific Paper*, Cambridge University Press.

Semester-II

CHMAT-521

Quantum Chemistry and Bonding Theories, [2-Credits, 30 L]

Chapter No.	Name of the Chapter	Lectures Assigned
Module-I	The origins of quantum mechanics	03 L
	The particle in a box [transitional motion]	03 L
	Operators	05 L
	The harmonic Oscillator [Vibrational Motion]	04 L
Module-II	The Hydrogen Atom	04 L
	Electronic Structure of Diatomic Molecule	03 L
	Molecular Orbital Theory: The hydrogen Molecule ion	02 L
	Molecular Orbital Theory: Homonuclear Diatomic Molecules	02 L
	Molecular Orbital Theory: Hetero-nuclear Diatomic Molecules	02 L
	Molecular Orbital Theory: Polyatomic molecules	02 L

Chapter-1: The origins of quantum mechanics [3 L]

Quantum chemistry, historical background of quantum mechanics, Heisenberg's uncertainty Principle, Energy Quantization, (Black-body radiation, Heat capacity, Atomic and molecular spectra) Wave–particle duality (The particle character of electromagnetic radiation, The wave character of particles), Wavefunctions: The time dependent Schrödinger equation, The time independent Schrödinger equation, Probability, Complex Numbers, units. ***Reference-1:*** *pp-1 to 18.*

Chapter-2: The particle in a box [transitional motion] [3 L]

Differential equations, Particle in a one-dimensional box, The free particle in a one dimension, Particle in a rectangular well, Tunnelling**, Reference-*1:*** *pp-21 to 32*

Chapter-3: Operators [5 L]

Operators, Eigenfunctions and Eigenvalues, Operators and quantum mechanics, The three-dimensional many particle Schrödinger equation, The particle in a three-dimensional box, Degeneracy, Average values, Requirement for an acceptable wave function. ***Reference-1:*** *pp-35 to 58*

Chapter-4: The harmonic Oscillator [Vibrational Motion] [4 L]

The one-dimensional Harmonic oscillator (classical mechanical treatment, quantum mechanical treatment, Even and Odd functions, the harmonic Oscillator wave functions,), Vibration of molecules, ***Reference-1:*** *pp-62 to 77*

Chapter-5: The Hydrogen Atom [4 L]

The hydrogen atom, solution of the radial equation, Degeneracy, The bound state hydrogen atom wave functions (radial factor, Ground state wave function and energy, wave function for n=2, the radial distribution function, the radial hydrogen like functions, hydrogen like orbitals, the Zeeman effect, ***Reference-1:*** *pp-134 to 156* ; The Pauli Exclusion principle, Hund's Rule: ***Reference-2:*** *relevant pages*

Chapter-6: Electronic Structure of Diatomic Molecule [3 L]

The Born-Oppenheimer Approximation, Valence bond Theory (diatomic molecules, polyatomic molecules, promotion, hybridization, ***Referenc-2****: pp- 343 to 350.*

Chapter-7: Molecular Orbital Theory: The hydrogen Molecule ion [2 L]

Introduction, Linear combination of atomic orbitals (the construction of linear combinations, bonding orbitals, Antibonding orbitals, Orbital Notations. ***Referenc-2****: pp-351 to 356*

Chapter-8: Molecular Orbital Theory: Homonuclear Diatomic Molecules [2 L]

Introduction, Electronic configuration, sigma and pi orbitals, the bond overlap integral, period-2 diatomic molecules, MO energy level diagram, *[MO energy level diagram electronic configuration bond orders and magnetic properties homo-diatomic molecules of H to F elements i.e. second period elements for Students self-study]*, Photoelectron spectroscopy. ***Referenc-2****: pp-357 to 363.*

Chapter-9: Molecular Orbital Theory: Hetero-nuclear Diatomic Molecules [2 L]

Introduction, Polar bond and electronegativity, the variation principle, the procedure, the features of the solution, *[MO energy level diagram electronic configuration bond orders and magnetic properties homo-diatomic molecules of HF, CO and NO for Students self-study]* ***Referenc-2****: pp-359-370.*

Chapter-10: Molecular Orbital Theory: Polyatomic molecules [2 L]

Introduction, The Huckel approximation (an introduction to method, the matrix formulation of the method, finding molecular orbitals by matrix diagonalization, Applications: pi-electron binding energy, aromatic stability. ***Referenc-2****: pp-371 to 377.*

Referenc-1: Quantum Chemistry, Ira Levine, 5th Ed. Prentice Hall.
Referenc-2: Atkins Physical Chemistry**,** Peter Atkins, Julio de Paula James Keeler, 11th Ed. Oxford.

Course Outcome: Student will able to

CO-1: Define and discuss the various terms in quantum chemistry as in syllabus.
CO-2: Derive equation in quantum chemistry such energy particle 1D box, 3D box, LCAO for diatomic molecule, orbital function, etc.
CO-3: Explain application of LCAO method in deriving different molecular orbitals and formation of simple molecules. Explain different types of operators and their use in quantum chemistry calculations.
CO-4: Differentiates / compare/ relate among or between various terms in quantum chemistry as in syllabus.
CO-5: Apply knowledge of quantum chemistry to the formation of simple homo and hetero diatomic molecules. Construction of the MO energy level diagram.
CO-6: Solve problem/ numerical depending on given data / information.

CHMAT-522

Ligand Field Theory, [2-Credits, 30 L]

Chapter No.	Name of the Chapter	Lectures Assigned
Module-I	Concept and Scope of Ligand Fields	05 L
	Ligand Field Theory of Coordination Complexes	10 L
Module-II	Electronic spectra of Transition Metal Complexes	10 L
	Magnetic Properties of Coordination Complexes	05 L

Chapter-1: Concept and Scope of Ligand Fields: (05 L)

Quantum numbers, Free ion Configuration, Terms and States, Energy levels of transition metal ions, free ion terms, microstates, term wave functions, spin-orbits coupling.

Chapter-2: Ligand Field Theory of Coordination Complexes (10L)

Effect of ligand field on energy levels of transition metal ions, weak cubic ligand field effect on Russell-Saunders terms, Orgel diagrams, strong field effect, correlation diagrams, Tanabe-Sugano Diagrams, Spin-Pairing energies.

Chapter-3: Electronic spectra of Transition Metal Complexes (10 L)

Introduction, band intensities, band energies, band width and shapes, transition metal spectra of 1st, 2ndand 3 rd row ions and complexes, electronic spectra of Lanthanide and Actinide, spectro-chemical and nephelauxetic series, charge transfer and luminescence spectra, calculations of Dq, B, β parameters, percentage of covalent character for metal complexes.

Chapter-4: Magnetic Properties of Coordination Complexes (05 L)

Origin magnetism, types of magnetism, Curie law, Curie-Weiss Law, Magnetic properties of complexes-Para magnetism, 1stand 2nd Ordered Zeeman effect ,quenching of orbital angular momentum by Ligand fields, Magnetic properties of A, E and T ground terms in complexes, spin free and spin paired equilibria, temperature dependence of magnetism.

References:

1. Ligand field theory and its applications by B.N. Figgis and M.A. Hitachman
2. Symmetry and spectroscopy of molecules by K. Veera Reddy
3. Elements of Magneto-Chemistry by R. L. Datta and A. Syamal

Course Outcomes: At the end of course student should able to –

CO-1: Define R. S. term, configuration, microstate, paramagnetic, diamagnetic ferromagnetic, antiferromagnetic, Curie and Neel temperature.

CO-2: Identify complex ions showing same R.S. terms, degeneracy of ground state terms of metal ions, and spin multiplicities of different configurations.

CO-3: Interpret electronic spectra for spin allowed Oh and Td complexes using Orgel diagram, Magnetic properties of A, E and T ground terms in complexes and selection rules.

CO-4: Calculate frequencies of absorption spectrum, 10Dq, Racah and nepholauxetic parameter for a complex, and magnetic moments of complexes

CO-5: Construct microstate table for various configuration and prepare correlations diagram and Tanabe-Sugano diagram for various configurations in Td an Oh ligand field.

CO-6: Assess appropriate full spectroscopic terms for various configuration/ion/term.

CHMAT-523

Physical Methods for Material Characterization, [2-Credits, 30 L]

Chapter No.	Name of the Chapter	Lectures Assigned
Module-I	X-Ray Diffraction Methods	10 L
	Transmission Electron Microscopy	5 L
Module-II	Scanning Electron Microscopy	5 L
	X-Ray Spectroscopy for Elemental Analysis	10 L

1. X-Ray Diffraction Methods (10 L)

Miller and Weiss indices, X-Ray Radiation, Generation of X-Rays, X-Ray Absorption, Theoretical Background of Diffraction, Diffraction Geometry, Bragg's Law, Reciprocal Lattice, Diffraction Intensity, Structure Extinction, X-Ray Diffractometry, Instrumentation, System Aberrations, Samples and Data Acquisition, Sample Preparation, Acquisition and Treatment of Diffraction Data, Distortions of Diffraction Spectra, Crystallite Size, Applications, Crystal-Phase Identification, Quantitative Measurement , Wide-Angle X-Ray Diffraction and Scattering, Wide-Angle Diffraction, Wide-Angle Scattering. Problem on XRD (Calculation of d values, assigning planes, calculation of crystal parameters), Rietveld refinement of powder X-ray. Numericals References: 1 – relevant pages

2. Transmission Electron Microscopy (5 L)

Instrumentation, Electron Sources, Thermionic Emission Gun, Field Emission Gun, Electromagnetic Lenses , Specimen Stage, Specimen Preparation, Prethinning, Final Thinning, Electrolytic Thinning, Ultramicrotomy, Image Modes (Mass–Density Contrast, Diffraction Contrast, Phase Contrast), Selected-Area Diffraction (SAD), Selected-Area Diffraction Characteristics**.** **References: 1** – relevant pages

3. Scanning Electron Microscopy (5 L)

Instrumentation, Optical Arrangement , Signal Detection, Detector, Probe Size and Current Contrast Formation, Electron–Specimen Interactions, Topographic Contrast, Compositional Contrast, Operational Variables, Working Distance and Aperture Size, Acceleration Voltage and Probe Current, Astigmatism, Specimen Preparation, Preparation for Topographic examination. **References: 1** – relevant pages

4. X-Ray Spectroscopy for Elemental Analysis (10 L)

Features of Characteristic X-Rays, Types of Characteristic X-Rays, Selection Rules, Comparison of K, L, and M Series, X-Ray Fluorescence Spectrometry, Wavelength Dispersive Spectroscopy, Analyzing Crystal, Wavelength Dispersive Spectra, Energy Dispersive Spectroscopy, Detector, Energy Dispersive Spectra, Advances in Energy, Dispersive Spectroscopy, XRF Working Atmosphere and Sample Preparation, Energy Dispersive Spectroscopy in Electron Microscopes, Special Features, Scanning Modes, Qualitative and Quantitative Analysis, Qualitative Analysis, Quantitative Analysis, Quantitative Analysis by X-Ray Fluorescence, Fundamental Parameter Method, Quantitative Analysis in Electron Microscopy, Numerical. **References: 1 –** relevant pages

References:

1. Yang Leng, Materials Characterization -Introduction to Microscopic and Spectroscopic Methods, Second Ed. Wiley-VCH,

2. R. D. Braun, Introduction to Instrumental Analysis, Second Ed.

3. Elaine A. Moore, Lesley E. Smart - Solid State Chemistry - an Introduction. Fourth Ed. CRC Press (2012)

Course Outcome - At the end of course students should able to-

CO-1. Define / understand various terms in Electrochemistry

CO-2. Explain instrumentations and functioning of polarography, potentiometry, cyclic voltammetry, Stripping methods, and hydrodynamic voltammetry.

CO-3. Explain basic principles of polarography, potentiometry, cyclic voltammetry, Stripping methods, and hydrodynamic voltammetry.

CO-4. Describe applications polarography, potentiometry, cyclic voltammetry, Stripping methods, and hydrodynamic voltammetry.

CO-5. Apply / select particular method / instrumental parameters for analysis for sample polarography, potentiometry, cyclic voltammetry, Stripping methods, hydrodynamic voltammetry.

CO-6. Solve numerical problems on electrochemistry.

CHMAT-524

Advanced Organic Molecular Spectroscopy, [2-Credits, 30 L]

Chapter No.	Name of the Chapter	Lectures Assigned
Module-I	UV Spectroscopy	03 L
	IR Spectroscopy	03 L
	^{1}H-NMR Spectroscopy-I	09 L
Module-II	^{1}H-NMR Spectroscopy-II	03 L
	^{13}C-NMR Spectroscopy	05 L
	Mass spectrometry (MS)	05L
	Combined problems:	02 L

Chapter-1: UV Spectroscopy **(03 L)**

UV: Recapitulation of UV spectroscopy, Calculations of λ Max of diene, enone and Aromatic compounds, Applications of UV Spectroscopy. **Ref. 1 PP 353**

Chapter-2: IR Spectroscopy **(03 L)**

Principle, IR spectra of important functional groups, Factor affecting on IR stretching frequencies. **Ref. 1 PP 13**

Chapter-3: ^{1}H-NMR Spectroscopy-I **(9 L)**

Understanding of basic principle, chemical and magnetic non-equivalence, Homotopism, Enantiotopism, diastereotopism, chemical shifts and factors influencing chemical shift: electronegativity, NMR solvent polarity, temperature, anisotropic effect, chemical shifts of acidic protons, D_2O exchange,

Chapter-4: ^{1}H-NMR Spectroscopy-II **(3 L)**

Multiplicity patterns and Coupling Constants: Pascal's triangle, understanding of tree diagram, complex splitting patterns in aromatic, vinylic, saturated monocyclic compounds, bicyclic compounds (fused and bridged rings), Integration: NMR of racemic mixture, relationship between integration and ee % in diasterotomers. **Ref. 1 PP 102**

Chapter-5: ^{13}C-NMR Spectroscopy **(05 L)**

Basic of ^{13}C-NMR: Chemical shift and factors affecting chemical shifts in 13C NMR, off resoanance and proton decoupled spectra. Simple problems on ^{13}C-NMR. **Ref. 1 PP 167**

Chapter-6: Mass spectrometry (MS) **(05 L)**

Basic principle of MS, significance of M+ (m/z) in determination of molecular formula, Rule of 13. Genesis of m/z fragments: alkanes (cyclic and acyclic), alcohols, amines. **Ref. 1 PP 390**

Chapter-7: Combined problems: **(02 L)**

Problems based on UV, IR, MS, ^{1}H-NMR, ^{13}C-NMR & study of its sprctra. **Ref. 1 PP 466**

References:

1. Introduction to Spectroscopy, Donald L. Pavia and Gary M. Lampman.
2. Elementary Organic Spectroscopy, Y. R. Sharma, S. Chand & Company PVT. LTD.
3. Organic Structures from Spectra, L. D. Field, S. Sternhell, J. R. Kalman, Fourth edition, JOHN WILEY AND SONS, LTD.
4. Guide to Spectroscopic Identification of Organic Compounds, Karen Feinstein.
5. Applications of NMR Spectroscopy, Atta-ur-Rahman, M. Iqbal Choudhar.

Course Outcome:

Student will able to

CO-1: Calculate λ max of organic compounds containing more than one and less than four conjugated systems and aromatic compounds.

CO-2: Correlate IR bands with functional groups using numerical data as well as spectral data.

CO-3: Solve ^{1}H-NMR problems.

CO-4: Draw the ^{1}H-NMR spectrum for simple organic compounds mentioning multiplicity pattern and coupling constant with the help of "Tree Diagram" and able to predict and analyze the multiplicity patterns with more than one coupling constants.

CO-5: Use ^{13}C-NMR data to interpret the structure.

CO-6: Understand the basic principle of spectroscopic methods and their applications in structure elucidation of organic compounds using given spectroscopic data or spectra.

CHMAT-525

Photochemistry and Pericyclic reactions, [2-Credits, 30 L]

Chapter No.	Name of the Chapter	Lectures Assigned
Module-I	Photochemistry	15 L
Module-II	Pericyclic Reactions	15 L

Photochemistry **(15 L)**

Principles of Photochemistry, photochemistry of carbonyl compounds, alkenes, dienes, and aromatic compounds, photo rearrangements, Barton reaction. **Ref. 1; relevant pages**

Pericyclic Reactions **(15 L)**

Electrocyclic reactions, Cycloaddition reactions, Analysis by correlation diagrams, FMO approach, sigmatropic and ene reactions, 1,3-dipolar additions. **Ref. 2 PP 663 to 740**

References:

1. Introduction To Organic Photochemistry, J. D. Coyle -Wiley (1991)
2. Advanced Organic Chemistry, Jagdamba Singh, L. D. S. Yadav, Pragati Prakashan, 20th edition (2014)
3. Excited states in Organic Chemistry by J.A. Barltrop and J.D.Coyle
4. Organic photochemistry: A visual approach by Jan Kopecky
5. Pericyclic Reactions, Ian Fleming
6. Pericyclic Reactions by A Mechanistic and Problem-Solving Approach, Sunil Kumar Vinod Kumar S.P. Singh
7. The Conservation of Orbital symmetry, R. B. Woodward and Roald Hoffmann, Angew. Chem. Internat. Edit. 1 Vol. 8 (1969) 1 No. 11, 781-932.
8. Pericyclic Reactions, S. Shankar Raman (Text Book)

Course Outcome:

Student will able to

CO-1: Understand Photochemical excitations in molecule

CO-2: Explain different photochemical reactions

CO-3: Discuss stability and reactivity, the stereochemistry as well as to understand the preferred reaction pathways.
CO-4: Predict the probable reaction mechanisms.
CO-5: Write MO diagram for various olefinic compounds and able to predict the products
CO-6: Extend the knowledge of pericyclic reactions in predicting reaction mechanism and stereochemistry of pericyclic reactions

CHMAP-526

Practical Inorganic Chemistry –II, [2-Credits]

Part-I: Synthesis of coordination complexes (any three) (Ref. 2)
Experiment-1. Synthesis of Cis and Trans[$Cu(gly)_2H_2O$]
Experiment-2. Synthesis and Purity Chloropentaamminecobalt(III) chloride.
Experiment-3. Synthesis and Purity Nitro pentaamminecobalt(III) chloride.
Experiment-4. Synthesis and Purity Tris(thiourea) Cu(I) Chloride

Part-II: Inorganic Conductometry (any two)
Experiment-5. Structural determination of metal complexes by conductometric measurement. (Ref-3)
Experiment-6. To study complex formation between Fe(III) with sulfosalicylic acid by conductometry (Ref-3).
Experiment-7. Determination of Pb(II) in solution with Na_2SO_4 solution and determination of solubility product of $PbSO_4$ (Ref-4)

Part-III: Inorganic characterization techniques (any two of the following)
Experiment-8. Determination of equilibrium constant of M – L systems Fe(III)–salicylic acid or Fe(III)–β–resorcilic acid by Job's continuous variation method. (Ref.-3, 5)
Experiment-9. Solution state preparation of $[Ni(en)_3]S_2O_3$, $[Ni(H_2O)_6]Cl_2$, $[Ni(NH_3)_6]Cl_2$. Record absorption spectra in solution of all three complexes and calculate 10 Dq. Arrange three ligands according to their increasing strength depending on your observations. (Ref. -5)
Experiment-10. Determination of magnetic susceptibility (χg and χm) of mercury tetracyanato cobalt or $Fe(acac)_3$ or Ferrous ammonium sulfate by Faraday or Gouy method. (Ref. -3, 5)
Part-IV: Inorganic Kinetics Experiment (any two)
Experiment-11. Synthesis and photochemistry of $K_3[Fe(C_2O_4)_3].3H_2O$. (Ref-4)
Experiment-12. Kinetics of substitution reaction of $[Fe(Phen)_3]^{2+}$ (Ref-3)
Experiment-13. Kinetics of formation of Cr(III)-EDTA complex (Ref-3)

Part-V: Ion – Exchange Chromatography (Ref. -1 and 3)
Experiment-14. Separation of mixture of Zn(II) and Mg(II) using Amberlite IRA 400 anion exchanger and quantitative estimation of separated ions Zn(II) and Mg(II)

Part-VI: Solvent Extraction and colorimetric (any one experiment) (Ref. -1 and 3)
Experiment-15. Determination of Cu(II) by solvent extraction as Dithiocarbamate complex (Ref-1)
Experiment-16. Determination of iron by solvent extraction techniques in a mixture of Fe(III) +Al(III) or Fe(III) + Ni(III) using 8–hydroxyl-quinoline reagent. (Ref. -1)

References:

1. Vogel's Textbook of Inorganic quantitative analysis
2. Experimental Inorganic Chemistry, Mounir A. Malati, Horwood Series in Chemical Science (Horwood publishing, Chichester) 1999.
3. Experiments in Chemistry, D. V. Jahagirdar, Himalaya Publishing House
4. General Chemistry Experiments, Anil. J Elias, University Press (2002)
5. Practical physical Chemistry, B. Vishwanathan and P. S. Raghwan, Viva Book

CHMAP-527

Practical Organic Chemistry –II, [2-Credits]

Perform any 12 experiments

Experiment-1. Base catalyzed aldol condensation using $LiOH.H_2O$ as a Catalyst.
Experiment-2. Bromination of *trans*-stilbene using sodium bromide and sodium bromate
Experiment-3. [4+2] cycloaddition reaction in aqueous medium at room temperature
Experiment-4. Benzil Benzilic acid rearrangement under solvent free condition
Experiment-5. Clay catalyzed solid state synthesis of 7-hydroxy-4-methylcoumarin
Experiment-6. Ecofriendly nitration of phenols and its derivatives using Calcium nitrate
Experiment-7. Bromination of acetanilide using ceric ammonium nitrate in aqueous medium
Experiment-8. Green approach for preparation of benzopinacolone from bezopinacol using iodine catalyst,
Experiment-9. Preparation of 1, 1-bis-2-naphthol under grinding at room temperature.
Experiment-10. Solvent free aldol condensation between 3,4-dimethoxybenzaldehyde and 1-indanone
Experiment-11. Preparation of azalactone from hippuric acid.
Experiment-12. Preparation of thioamide from benzaldehyde in water.
Experiment-13: Transesterification reaction (Synthesis of biodiesel)
Experiment-14: Three component coupling (Synthesis of dihydropyrimidinone)
Experiment-15: Acetylation of primary amine (Preparation of acetanilide).

Note: Students should perform a) Relevant chemical analysis. b) Column chromatography. c) Elemental analysis. d) Spectroscopic interpretation. e) How to draw schemes and mechanism using Chem-Draw / ISIS Draw etc.

References:

1. Comprehensive Practical Organic Chemistry by V.K. Ahluwalia and Renu Aggarwal
2. Monograph on Green Chemistry Laboratory Experiments by Green Chemistry Task Force Committee, DST

Course Outcome: Student will able to

CO-1: The course includes synthesis of some derivatives and organic compounds, which will help them while working in research laboratory in future.
CO-2: Making derivatives of organic compounds will help them in industry or while doing research in medicinal chemistry for Drug development.
CO-3: Ccarrying out different types of reactions and their workup methods.
CO-4: Understand the green chemistry and role of green chemistry in pollution reduction.
CO-5: Avoid solvents and do solvent free reaction.
CO-6: Also the work-up procedure in many experiments is made more eco-friendly to environment.

CHMET-521A

Electro Analytical Chemistry, [2 Credits, 30 L]

Chapter No.	Name of the Chapter	Lectures Assigned
Module-I	Potentiometry with Ion Selective Electrode	06 L
	Polarography (linear scan polarography)	09 L
Module-II	Voltammetry Methods of Analysis.	15 L

Chapter-1: **Potentiometry with Ion Selective Electrode** **[6 L]**

General principles, Electrochemical cell, Definitions: Reference electrode, working electrode, electrode and standard electrode potential, Reference electrode (saturated calomel and Ag-AgCl electrode), Membrane indicator electrodes, Classification of membranes, glass electrode for pH measurement, crystalline membrane electrodes, Liquid membrane electrodes, Ion selective FET, Molecular selective electrode systems (gas sensing probes, Biosensors), instrument for measuring cell potential, Direct

potentiometric measurement, methods to determine end point of potentiometric titration and applications, Potentiometric titrations (Ref-1: 601 to 631, relevant part only supplementary : Ref 2: 550 - 573).

Chapter-2: Polarography (linear scan polarography) [9 L]

Polarographic principles, Instrumentation (different types of microelectrode such as dropping mercury electrode, the static drop mercury electrode, rotating disc and ring disc electrode, cell for polarography, reference and counter electrode and circuit diagram), polarogram and polarographic currents, charging or capacitive current, role of supporting electrolyte, factors affecting on polarographic wave, Ilkovic Equation, advantages and disadvantages of DME, polarographic maxima and maxima suppresors, interference due to dissolved oxygen, Applications (qualitative analysis, quantitative analysis by calibration curve and standard addition methods), specific examples of analysis – analysis of Cu, Cd, Zn, Pb, etc. from tap water and alloys., problems.(Ref-1: 716-723, Ref-2, Supplementary Ref. 3 and 4)

Chapter-3: Voltammetry Methods of Analysis. [15 L]

a) Hydrodynamic Voltametry: Hydrodynamic voltametry and applications of hydrodynamic voltametry (volatameric detectors in chromatography and flow injection analysis, Voltametric oxygen sensors, amperometric titration. (Ref-1: 723-735)

b) Cyclic Voltametry: Principle of cyclic Voltammetry, cyclic voltamogram of $K_3[Fe(CN)_6]$ and parathion (Fundamental studies), determination of analytes using CV, criteria of reversibility of electrochemical reactions, quasi-reversible and irreversible processes(Ref1:735-742 Ref-2: Relevant pages, Supplementary Ref.-5: 27-68)

c) Pulse Polarography: different types of excitation signals in pulse polarography, Differential pulse polarography, square wave polarography, and Stripping method. Voltammetry with ultra-microelectrode, Applications of these techniques Cu and Zn from tap water by differential pulse polarography and by square wave polarography, Vitamin-C by differential pulse polarography, Determination of Pb in tap water by stripping method. (Ref-1: 742-753 2, Supplementary Ref. 3 and 4)

References 1. Principles of Instrumental Analysis, Skoog, West, Holler, 6th Ed. Cengage Publication.

Referenc-2. Vogel's Text Book of Quantitative Chemical Analysis, 6th Ed.

Reference-3. Introduction to Instrumental Analysis by R. D. Braun, Pharmamed Press.

Reference-4. Analytical Chemistry, A Modern Approach to Analytical Science, Ed. by R. Kellner, J. M. Mermet, O. Otto, M. Valcarcel, H. M. Widmer, Second Ed. Wiley –VCH CBCS: 2019 Pattern

Reference-5. Cyclic Voltammetery, Simultaneous Analysis and Reaction Mechanism, David K Gosser, VCH, 1994.

Course Outcome: Student will able to

CO-1. Define various terms in electrochemistry included in syllabus.

CO-2. Explain / discuss instrumentation in electrochemistry. Differentiate among the various methods of electrochemistry

CO-3. Describe basic principles of electrochemistry and applications of electrochemistry in industry and in analytical laboratory.

CO-4. Apply / select particular method of analysis for sample to be analysed.

CO-5. Solve numerical problems on electrochemistry.

CO-6. Interpret polarogram, cyclic voltammogram, pulse polarogram, thermogram, differential thermogram and DSC thermogram

CHMET-522A

Chemistry of Main Group Elements, [2 Credits, 30 L]

Chapter No.	Name of the Chapter	Lectures Assigned
Module-I	Hydrogen and its compounds	03 L
	Alkali and Alkaline Earth Metals	02 L
	Boron Group	05 L
	Carbon Group	05 L
Module-II	Nitrogen Group	05 L
	Oxygen Group	04 L
	Halogen Group	03 L
	Noble gases	03 L

Chapter-1: Hydrogen and its compounds: (03 L)

Classification of Hydrides: Molecular hydrides, saline hydrides, metallic hydrides and electron deficient, electron precise and electron rich hydrides. ***Reference-1***, page no. 283 to 290

Chapter-2. Alkali and Alkaline Earth Metals (02 L)

Solutions in liquid ammonia, application of crown ether in extraction of alkali and alkaline earth metal. ***Reference-1***, page no. 305 to 307

Chapter-3. Boron Group (05L)

Simple hydrides of boron, Boron trihalides, Boron–oxygen compounds, Compounds of boron with nitrogen, Metal borides, Higher boranes and borohydrides, Metallaboranes and carborane, ***Reference-1***, page no. 330 to 343

Chapter-4. Carbon Group (05L)

Allotropes of carbon: Diamond, Graphite, Graphene, fullerenes and carbon nanotube, Carbides, Extended silicon oxygen compounds, Organo-silicon compounds. ***Reference-1***, page no. 354 to 358, 368 to 371

Chapter- 5. Nitrogen Group (05L)

Nitrogen activation, nitrides and azides, phosphides, Oxidation states of nitrogen and their interconversion, Halides, Oxohalides, Oxides and oxoanions and oxyacid of nitrogen, Condensed phosphates and Phosphazenes. ***Reference-1,*** page no. 381 to 383, 385 to 395

Chapter-6. Oxygen Group (04 L)

Metal sulfides, selenides, tellurides, and polonides, Oxides, Oxoacids of sulphur, Polyanions of sulfur, Polycations of sulfur, selenium, and tellurium, Sulfur-nitrogen compounds. ***Reference-1,*** page no. 409 to 417

Chapter-7. Halogen Group: (03 L)

Pseudohalogens, Special properties of fluorine compounds, Structural features, The interhalogens, Halogen oxides, Oxoacids and oxoanions**.** ***Reference-1,*** page no. 427 to 434

Chapter-8. Noble gases: (03 L)

Occurrence, Synthesis and structure of xenon fluorides, Reactions of xenon fluorides, and Xenon-oxygen compounds. ***Reference-1,*** page no. 441 to 445

Note: Student should learn the name of element, symbol, atomic number and electronic configuration present in respective group.

References:

1) Inorganic Chemistry by Shriver and Atkins
2) Concise Inorganic Chemistry by J. D. Lee
3) Inorganic chemistry by Principle of Structures and Reactivity by Huheey, Keiter, Medhi
4) Inorganic Chemistry by Catherine Housecraft

Course Outcomes: At the end of course student should able to -

CO-1: Define electron deficient, electron precise and electron rich species, Pseudohalogens, Oxoacids and Oxidation state.

CO-2: Describe special properties of fluorine, Nitrogen activation, Oxo acids of nitrogen, sulphur and phosphorous, synthesis and structure of xenon fluorides.
CO-3: Explain term metal sulfides, selenides, tellurides, polonide, inter-halogens, Halogen oxides, Graphene, fullerenes and carbon nanotube.
CO-4: Determine Oxidation states of nitrogen and their interconversion and application of crown ether in extraction of alkali and alkaline earth metal.
CO-5: Differentiate between diamond and graphite, Pseudohalogens and interhalogens.
CO-6: Classify the hydrides, borides and oxyacids and draw their structure.

CHMEP-521B
Practical Electrochemistry, [2 Credits, 30 L]

Part-I: Conductometry: (Any three)
Experiment-1. Hydrolysis of NH_4Cl or CH_3COONa or aniline hydrochloride.
Experiment-2. Determination of $\lambda 0$ or $\lambda\alpha$ and dissociation constant of acetic acid.
Experiment-3. Hydrolysis of ethyl acetate by NaOH.
Experiment-4. Determination of ΔG, ΔH, and ΔS of silver benzoate by conductometry.
Experiment-5. Determination of critical micellar concentration (CMC) and ΔG of micellization of sodium Lauryl Sulphate / Detergent
Part-II: Polarography (any one)
Experiment-6. Determination of half wave potential E 1/2 and unknown concentration of Cu or Pb or Zn ion.
Experiment-7. Amperometric titration of $Pb(NO_3)_2$ with $K_2Cr_2O_7$.
Part-III: Potentiomerty: (Any three)
Experiment-8. Stability Constant of a complex ion.
Experiment-9. Solubility of a sparingly soluble salt.
Experiment-10. To determine the ionic product of H_2O
Experiment-11. Estimation of halide in mixture.
Part-IV: pH metry (any two)
Experiment-12. Determination of the acid and base dissociation constant of an amino acid and hence the isoelectric point of the acid.
Experiment-13. Determination of dissociation constants of tribasic acid (phospheric acid)
Experiment-14. Construct pH curve for titration of strong base – strong acid, strong base - weak acid and predict the best indicator in these titrations (methyl orange, methyl orange, brocresol green, phenolphthalein, etc.)
Part-V: Table Work (any two)
Experiment-15. Analysis of powder XRD of $SrTiO_3$ and Ag metal or any two compounds (Calculation d, lattice constant, crystal volume and density, and assigning planes to peaks using JCPDS data)
Experiment-16. Cyclic voltamogram of $K_3Fe(CN)_6$ in KCl/H_2O / Ferrocene in TEAP//MeCN
Experiment-17. Detailed interpretation of Raman spectra of diatomic molecules
References:
1. Practical physical chemistry, A. Findlay, T.A. Kitchner (Longmans, Green and Co.)
2. Experiments in Physical Chemistry, J.M. Wilson, K.J. Newcombe, A.r. Denko. R.M.W. Richett(Pergamon Press)
3. Senior Practical Physical Chemistry, B.D. Khosla and V.S. Garg (R. Chand and Co., Delhi.).
4. Experimental Physical Chemistry by D. P. Shoemaker, Mc. Growhill, 7th Edition, 2003.
5. Physical chemistry by Wien (2001)
6. Advance Physical Chemistry Experiment, Gurtu and Gurtu, Pragati Publication (Meerut)

Course Outcome: Student will able to

CO-1: Prepare solution of required conc. and handle laboratory equipment property.

CO-2: Perform experiment accurately and able to perform calculation.

CO-3: Explain experiment and principal of experiment in detail.

CO-4: Write / discuss results and conclusions of the experiment.

CO-5: Apply knowledge to a) design experiment for given aim or modify experiment to enhance results. b) to find out lacuna in experimental procedure.

CO-6: Solve problem/ numerical depending on given data / information.

CHMEP-522B

Practical on main group element, [2 Credits]

1. Synthesis of graphene oxide by modified Hummer's method (Ref-1)
2. Synthesis of silica nanoparticles from sodium silicate under alkaline conditions (Ref-2, 3)
3. Synthesis of cadmium sulfide thin films (Ref-4, 5, 6, 7)
4. Synthesis of carbon nitride or graphitic carbon nitride and its band gap / photocatalytic application. (ref- 8, 9, 10, 11)
5. Laboratory Preparation of Borazine (Ref: 12)
6. Synthesis and analysis of - $K_3[Al(C_2O_4)_3]3H_2O$ or Synthesis of $[Al(acac)_3]$ and study of its IR spectra.
7. Adsorption of methylene blue on nano silica (ref-13)
8. Synthesis of Alumina and adsorption (Ref: 14-17)
9. Determination of point of zero charge (PZC) of oxide powder (alumina or silica).P-block Analytical Chemistry (any four experiments) (Ref-18, 19)
10. Estimation of Ca and Mg in dolomite ore.
11. Estimation of Ca from soil or milk powder as Ca-oxalate.
12. Estimation of Al and Silica in bauxite ore.
13. Analysis of Solder Alloy for Sn and Pb content.
14. Estimation of KI/KIO_3 content in iodized salt.
15. Estimation of Phosphate from soil or fertilizer.
16. Estimation of organic nitrogen by Kjedahl's method.
17. Estimation of K potash fertilizer by gravimetric method.
18. NaOCl content of commercial NaOCl solution. Any three experiments (Ref-18, 19)
19. Solubility product of $Ca(OH)_2$ or $Mg(OH)_2$ and effect of OH^- conc. on solubility product.
20. Study on basicity of boric acid.
21. Determination of Pka of Orthophosphoric Acid
22. Water of crystallization of $MgSO_47H_2O$
23. Kinetics of oxidation of iodide (I^-) with Fe(III)

ati, Horwood
3. Nanotechnology by S. K. Kulkarni

Course Outcome: Student will able to

CO-1: Prepare solution of required conc. And handle laboratory equipment property.

CO-2: Perform experiment accurately and able to perform calculation.

CO-3: Explain experiment and principal of experiment in detail.

CO-4: Write / discuss results and conclusions of the experiment.

CO-5: Apply knowledge to a) design experiment for given aim or modify experiment to enhance results. b) to find out lacuna in experimental procedure.

CO-6: Solve problem/ numerical depending on given data / information.

References

1. Ref: Synthesis of Graphene Oxide using Modified Hummers Method: Solvent Influence, https://doi.org/10.1016/j.proeng.2017.04.118
2. Zulfiqar, U., Subhani, T. & Wilayat Husain, S. Synthesis of silica nanoparticles from sodium silicate under alkaline conditions. *J Sol-Gel Sci Technol* 77, 753–758 (2016). https://doi.org/10.1007/s10971-015-3950-7
3. Evaluation of scale-up strategies for the batch synthesis of dense and hollow mesoporous silica microspheres; https://doi.org/10.1016/j.cej.2017.11.026
4. A facile route for synthesis of cadmium sulfide thin films; doi:10.1016/j.tsf.2018.08.034
5. CdS Thin Film Photo-Electrochemical Electrodes: Combined Electrochemical and Chemical Bath Depositions By Sahar Mustafa Asad Khudruj.
6. Photoelectrochemical investigations of cadmium sulphide (CdS) thin film electrodes prepared by spray pyrolysis; https://doi.org/10.1016/j.jallcom.2011.02.061
7. Novel-approach for fabrication of CdS thin films for photoelectrochemical solar cell application. *J Mater Sci: Mater Electron* 25, 5606–5617 (2014). https://doi.org/10.1007/s10854-014-2350-z
8. Simple pyrolysis of urea into graphitic carbon nitride with recyclable adsorption and photocatalytic activity; DOI **https://doi.org/10.1039/C1JM12620B**
9. Facile Large-Scale Synthesis of Urea-Derived Porous Graphitic Carbon Nitride with Extraordinary Visible-Light Spectrum Photodegradation; https://doi.org/10.1021/acs.iecr.6b00041
10. Molecular Mechanism for the Self-Supported Synthesis of Graphitic Carbon Nitride from Urea Pyrolysis; https://doi.org/10.1021/acs.jpclett.0c03559
11. Melamine-derived graphitic carbon nitride as a new effective metal-free catalyst for Knoevenagel condensation of benzaldehyde with ethylcyanoacetate; **DOI: https://doi.org/10.1039/C8CY00253C**
12. Convenient Procedures for the Laboratory Preparation of Borazine; https://doi.org/10.1021/ic00108a039
13. Adsorption of methylene blue on silica nanoparticles: Modelling analysis of the adsorption mechanism via a double layer model; https://doi.org/10.1016/j.molliq.2020.114348
14. Synthesis of mesoporous silica nanoparticles derived from rice husk and surface-controlled amine functionalization for efficient adsorption of methylene blue from aqueous solution; https://doi.org/10.1016/j.crgsc.2021.100116
15. Synthesis of alumina nanoparticles by sol-gel method and their applications in the removal of copper ions (Cu^{2+}) from the solution; 10.1088/1757-899X/701/1/012034
16. **Synthesis and structural characterization of alumina nanoparticles;** https://doi.org/10.1080/01411594.2020.1765245
17. Low-Cost Synthesis of Alumina Nanoparticles and Their Usage for Bisphenol-A Removal from Aqueous Solutions, https://doi.org/10.3390/pr9101709
18. Vogel's textbook of inorganic quantitative analysis.
19. Experimental inorganic / Physical Chemistry; Mounir A. Malati, Harwood Series in Chemical sciences.

CHOJP-521

On Job training (OJT) [4 Credits]

Course/ Paper Title	**On Job training (OJT)**
Course Code	**CHOJT-521**
Semester	**II**
No. of Credits	**4 (60 L)**

- ✓ The students, as a part of their course, will be given opportunities to enroll for Field Project(s) or on job training.
- ✓ The student must undergo field work project which related to chemistry.
- ✓ The students must undergo industrial on job training/internship in the 2nd semester in any of the reputed industry, Government-sponsored Research & Development Organization, and reputed academic institution/foreign universities.

Question Paper Pattern-NEP MSc-I

	Marks: 30		**Time:** 2 Hour
Instructions to the Candidate: 1. All questions are compulsory. 2. Figures to right indicate full marks. 3. Use of Log table and scientific calculator is allowed.			
Question-1	**Solve Any five of the following (Short Answers)** **i.** **ii.** **iii.** **iv.** **v.** **vi.** **vii.**	Three def. type, two tricky questions and two questions problem type (if applicable)	5 Marks
Question-2	**A. Solve any two of the following** **i.** **ii.** **iii.**	Note or Describe type questions	6 Marks
	B. Solve the following Single question of four marks or two questions of 2 marks.	Problem type or tricky reasoning type question	4 marks
Question-3	**A. Solve any two of the following** **i.** **ii.** **iii.**	Write Note / Differentiate type questions	6 Marks
	B. Solve the following Single question of four marks or two questions of 2 marks.	Problem type or Justification type question	4 marks
Question-4	**A. Solve any one of the following** i. **ii.**	Application type or Derive equation or Justification type question	5 Marks