Estd. 1962
"A++" Accredited by
NAAC (2021)
With CGPA 3.52

**SHIVAJI UNIVERSITY, KOLHAPUR - 416004, MAHARASHTRA**

PHONE:EPABX-2609000, www.unishivaji.ac.in, bos@unishivaji.ac.in

**शिवाजी विद्यापीठ, कोल्हापूर -४१६००४,महाराष्ट्र**

दूरध्वनी-ईपीएबीएक्स -२६०९०००, अभ्यासमंडळे विभाग दुरध्वनी ०२३१—२६०९०९४
०२३१—२६०९४८७

**Ref.No.SU/BOS/Science/147** **Date: 26/05/2026**

The Principal,
All Concerned Affiliated Colleges/Institutions
Shivaji University, Kolhapur

The Head/Co-ordinator/Director
All Concerned Department (Science)
Shivaji University, Kolhapur.

**Subject:** Regarding revised syllabi of M.Sc. Part-II (Sem III & IV ) degree programme under the Faculty of Science and Technology as per NEP-2020 (2.0)

**Sir/Madam,**

With reference to the subject mentioned above, I am directed to inform you that the university authorities have accepted and granted approval to the syllabi, nature of question paper of M.Sc. Part-II (Sem III & IV ) degree programme under the Faculty of Science and Technology as per NEP-2020 (2.0).

| **M.Sc. Part-II (Sem. III & IV ) as per NEP-2020 (2.0)** | | | |
|---|---|---|---|
| 1. | Chemistry | 7. | Data Science |
| 2. | Mathematics (Online Mode) | 8. | Computer Science |

This syllabus, nature of question and equivalence shall be implemented from the academic year 2026-2027 onwards. A soft copy containing the syllabus is attached herewith and it is also available on university website **www.unishivaji.ac.in>Syllabus>Syllabus as per NEP2020.**

The question papers on the pre-revised syllabi of above-mentioned course will be set for the examinations to be held in October /November 2026 & March/April 2027. These chances are available for repeater students, if any.

You are, therefore, requested to bring this to the notice of all students and teachers concerned.

Thanking you,

**Yours faithfully,**

**Dy Registrar**

**Encl: as above**

**for information and necessary action**

**Copy to:**

| | | | |
|---|---|---|---|
| 1 | I/C Dean, Faculty of Science & Technology | 6 | Appointment Section A & B |
| 2 | Director, Board of Examinations and Evaluation | 7 | I.T.Cell /Computer Centre |
| 3 | Chairman, Respective Board of Studies | 8 | Eligibility Section |
| 4 | B.Sc.-M.Sc. Exam Section | 9 | Affiliation Section (T.1) (T.2) |
| 5 | Internal Quality Assurance Cell (IQAC Cell) | 10 | P.G. Seminar Section |
| | | 11 | Distance and Online Education |

# Shivaji University, Kolhapur

## DEPARTMENT OF CHEMISTRY

**The Program Structure and Syllabus as per NEP-2020**

## For M.Sc. Part-II Chemistry

**(Inorganic, Organic, Physical, Analytical, Industrial and Applied Chemistry)**

## Under the Faculty of Science and Technology

**Applicable for University Department and Affiliated College PG Centres**

**To be implemented with effect from Academic Year 2026-2027**

## 1. Preamble:

The National Education Policy 2020 for higher education aims to transform India's existing higher education system. This policy emphasises promoting interdisciplinary studies, introducing new subjects, and providing flexibility in courses and fresh opportunities for students. It aims to increase the Gross Enrolment Ratio (GER) in higher education, provide multiple entry and exit options, and allow students to choose courses according to their interests and aptitude.

The policy envisions setting up of a National Research Foundation, a National Education Technology Forum, and setting up of more Higher Education Institutions in the country. The policy is aimed at creating a holistic and flexible education system that is adaptive to the needs of the $21^{st}$ century.

The M.Sc. Chemistry syllabi is designed in such a way that it addresses chemical safety, green chemistry principles and industrial skills to provide a comprehensive and in-depth understanding of the fascinating world of chemistry. we aim to nurture the intellectual curiosity, sharpen their scientific temper, preparing them for successful careers in various sectors of the chemical sciences so in all, students to keep them up to date on recent developments in the field.

The Programme exposes students to significant advances in chemical sciences as well as related fields through learning; innovative pedagogies and assessment strategies; multidisciplinary and Interdisciplinary education; creative and critical thinking; student-centric participatory learning; imaginative abilities and flexible curricular structures to enable creative combination of disciplines for the study.

## 2. General Objectives of the Course:

Chemistry is a pervasive subject. All the branches of science need chemistry. It is an experimental science and students need to trend in practicals to get expertise in doing fine experiments and handle sophisticated instruments. Along with the data obtained its statistical analysis is also required to establish authenticity in the fields like environmental science, space chemistry and biotechnology. There is an immense potentiality for chemistry and post graduates to undertake advanced research or in Industries as skilled chemists.

## 3. Terms and Definitions:

The terms used in the NEP- Regulations shall have the meaning allotted to them as follows:

**Credit:** It is a unit by which the coursework is measured. It determines the number of hours of instruction required per week during a semester (Minimum 15 weeks). One credit is equivalent to 15 hours of teaching (lecture and /or tutorial) or 30 hours of practical and/or field work or community engagement and service per semester.

**Academic Year:** It means that if academic year begin in the month of June and ending is the month of May.

**Semester:** It means 15-16 weeks of teaching-learning sessions of which two weeks shall be set apart for examination and evaluation; A semester comprises 90 working days and an academic year is divided into two semesters.

**OJT/ Field Project:** It can be carried out after end of first semester examination.

**Grade:** It means a letter grade assigned to a student in a Course for her/his performance at academic sessions as denoted in symbols of: O (outstanding), $A^{+}$(Excellent), A(Very good), B+(Good), B(Above average), C(Average), P(Pass) F(Fail) and Ab( Absent) with a numeric value of O=10, A+=9, A=8, B+=7, B=6, C=5 P=4, and F=0, Ab=0;

**Semester Grade Point Average (SGPA):** is computed from the grades as a measure of the students' performance in a given semester.

**Cumulative GPA (CGPA):** is the weighted average of all courses the student has taken in a given Programme.

**Programme**: It means a set of Courses that allows a student to structure and study to attain the status of being admitted to a Degree/Diploma of the University.

**Credit Requirement:** for a Degree/Diploma/Certificate Programme means the minimum number of credits that a student shall accumulate to achieve the status of being qualified to receive the said Degree, Diploma/Certificate as the case may be.

**Multiple Entry and Multiple Exit:**

**a) Exit option**: it means the option exercised by the students, to leave the Programme at the end of any given Academic year.

**b) Lateral entry:** It means a student being admitted into an ongoing Programme of the University other than in the 1st year of the programme.

**Academic Bank of Credit:** (ABC) shall be established which would digitally store the academic credits earned from various recognized HEIs so that the degrees from an HEI can be awarded taking into account credits earned.

## 4. Program Educational Objectives (PEOs):

**PEO-1:** To impart proficiency in the fundamentals and applications of all disciplines of chemistry.

**PEO-2:** To inculcate critical thinking and analytical reasoning in the development of chemicals, materials and processes for sustainable domestic and industrial applications.

**PEO-3:** To provide solutions to chemistry related societal and industrial challenges with suitable research methodologies.

**PEO-4:** To formulate procedures and regulations with environmental and ecological dimensions for safe handling and endurable benefits of chemicals.

## 5. Program Outcomes (POs):

1. Learn theory, computation and hands-on experiments. in Organic, Inorganic, Physical, Analytical, Industrial and Applied Chemistries.
2. Gain the knowledge of chemistry to meet specific needs with appropriate considerations towards public health, safety and environment.
3. Apply appropriate analytical techniques to complex chemistry activities with an understanding of the limitations.
4. Utilize research-based knowledge in designing and executing new experiments through independent and life-long learning with up-to-date scientific skills.

## 6. Programme Specific Outcomes (PSOs):

1. Understand the basic concepts of all disciplines of Chemistry.
2. Apply the chemistry knowledge to provide solutions to the contemporary societal problems in fields of materials science, environmental science, and pharmaceutical chemistry.
3. Able to Interpret the properties of various chemicals using the analytical techniques learned and relate the chemical characteristics to functioning and performance of various functional materials.

4. To assess and evaluate facts, claims and arguments using their scientific knowledge.
5. To define a problem, analyse, interpret and draw conclusion by planning, implementing and reporting the results of an experiment.

## 7. Credit Framework:

| Year (2 yr. PG) | Level | Semester | Major-Mandatory, Cr. | Major-Electives, Cr. | RM, Cr. | OJT/FP, Cr. | RP, Cr. | Total |
|---|---|---|---|---|---|---|---|---|
| 1 | 6.0 | I | 14 | 4 | 4 | - | - | 22 |
| | | II | 14 | 4 | - | 4 | - | 22 |
| Exit Option: Award of PG Diploma in Chemistry on Completion of 44 credits at 6.0 level (PG First Year) or Continue with PG Second Year | | | | | | | | |
| 2 | 6.5 | III | 14 | 4 | - | - | 4 | 22 |
| | | IV | 12 | 4 | - | - | 6 | 22 |
| Total 4 semester | | | 54 | 16 | 4 | 4 | 10 | 88 |

**Abbreviation:** yr.: Year, Cr.: Credit, RM: Research Methodology, OJT: On Job Training, FP: Field project, RP: Research project, T: Theory, P: Practical

## 8. Conduction of classes:

a) A student has to attend 1-hour classroom teaching for one credit of theory per week and 2 hours' lab work/problem-solving session/related activities for one credit of practical per week. Practical sessions (lab work/problem-solving session/related activity) will be conducted in batches. A batch for such sessions will be of maximum 10 students.

b) The Department may conduct necessary lectures/workshops as a part of OJT/FP.

c) Each course of 4 credits will carry 100 marks and 2 credit courses will carry 50 marks.

d) There will be Continuous Internal Evaluation (CIE) and University Examination (UE) for each course as per University Guidelines.

## 9. Evaluation Process:

a) The CIE should be implemented as per the University Circular.

b) Students have to score a minimum of 40 % separately in CIE and UE, otherwise the result of such a course will be FAIL.

e) Second Year Students shall visit Industry/Research Institutes as a Study/Industrial Tour.

f) Seminar Activity is compulsory for Second Year Students.

## 10. Pattern of Examination:

a) The Examination will be conducted semester wise for Theory and Practicals.

b) Practical Examination and Research Project assessment will be conducted Odd-Odd and Even-Even semesters only.

c) For 4 Cr of theory/Practical: 60 (University Exam) + 40 (Internal Exam).

d) 2 Cr of Theory/ Practical: 30 (University Exam) + 20 (Internal Exam).

**11. Attendance**: Every student must have at least 75% attendance in each paper (Theory & Practical) in each semester as per the ordinance 31. Shortage of attendance will be dealt with as per the university rules from time to time.

**12. Medium of instruction**: The medium of instruction shall be English.

## 13. Scheme of Teaching and Examination:

(Applicable to University Department and University affiliated college centers)

a. Entire course of M.Sc. Chemistry will be of **2200** marks.

b. Examination of each **theory course** shall be of **100 marks** (60 + 40).

c. University examination of 60 marks (2 hours' duration) will be conducted at the end of each Semester. CIE of 40 marks will be carried out as a continuous formative evaluation during each semester.

d. Research Project is compulsory for the second year (10 Credits).

e. On- Job training (OJT/FP) is mandatory for the second semester (4 Credits)

f. Seminar activity is compulsory for M. Sc. II year students.

g. Question papers will be set in view of the entire syllabus and preferably covering each unit of the syllabus. Equal weightage should be provided to each unit.

## 14. Standard of Passing:

There will be separate passing for theory courses and practical courses. Minimum 40% marks will be required for passing separately for theory and practical courses.

**15. Nature of IE/CIE:** Follow University Circular.

## 16. Nature of Question Paper

**Total Marks 60**

**i. Theory Examination of 4 Credit course (Total Marks: 60; Time: 2 hours)**

***Instruction*:** All the 5 questions are compulsory.

Q. 1: Any *one* of the following- 12 marks

a) Based on Unit I

b) Based on Unit I

Q. 2: Any *one* of the following- 12 marks

a) Based on Unit II

b) Based on Unit II

Q. 3: Any *one* of the following- 12 marks

a) Based on Unit III

b) Based on Unit III

Q. 4: Any *one* of the following- 12 marks

a) Based on Unit IV

b) Based on Unit IV

Q. 5: Any *four* of the following- 12 marks

a) Based on Unit I

b) Based on Unit II

c) Based on Unit III

d) Based on Unit IV

e) Based on Unit I/II

f) Based on Unit III/IV

## 17. Course Structure:

**M.Sc. II Inorganic Chemistry**

**Revised Credit Frameworks for M.Sc. Programs as per NEP 2.0 with effect from 2026-27**

| **Year** | **Level** | **Sem** | **Major** | | **RM** | **OJT/FP** | **RP** | **Cumm. Cr.** | **Degree** |
|---|---|---|---|---|---|---|---|---|---|
| | | | **Mandatory** | **Elective (Choose any one)** | | | | | |
| II | 6.5 | III | ICHT301 (4 Cr)<br>ICHT302 (4 Cr)<br>ICHP304 (4 Cr)<br>ICHP305 (2 Cr) | E-ICHT303 (A) (4 Cr)<br>E-ICHT303 (B) (4 Cr)<br>E-ICHT303 (C) (4 Cr)<br>E-ICHT303 (D) (4 Cr) | --- | --- | RP-306 (4 Cr) | 22 | **PG Degree After 3-Yr UG**<br>**Or**<br>**PG Degree after 4-Yr UG** |
| | | IV | ICHT401 (4 Cr)<br>ICHT402 (4 Cr)<br>ICHP404 (4 Cr) | E-ICHT403 (A) (4 Cr)<br>E-ICHT403 (B) (4 Cr)<br>E-ICHT403 (C) (4 Cr)<br>E-ICHT403 (D) (4 Cr) | --- | --- | RP-405 (6 Cr) | 22 | **Note: All the practicals/Project will be discipline specific i.e. Inorganic Chemistry oriented** |
| **Cum. Cr. For 2 Year PG Degree in Inorganic Chemistry** | | | **26** | **8** | | | **10** | **44** | |
| 2 Years-4 Sem. PG Degree in Inorganic Chemistry (88 credits) after Three Year UG Degree or 1 Year-2 Sem PG Degree in Inorganic Chemistry (44 credits) after Four Year UG Degree | | | | | | | | | |

**Abbreviations:** Yr.: Year; Sem.: Semester; RP: Research Project; Cum. Cr: Cumulative Credits. ICHT: Inorganic Chem Theory, ICHP: Inorganic Chem Practical.

## M.Sc. II Organic Chemistry
## Revised Credit Frameworks for M.Sc. Programs as per NEP 2.0 with effect from 2026-27

<table>
<tr><th rowspan="2">Year</th><th rowspan="2">Level</th><th rowspan="2">Sem</th><th colspan="2">Major</th><th rowspan="2">RM</th><th rowspan="2">OJT/FP</th><th rowspan="2">RP</th><th rowspan="2">Cumm. Cr.</th><th rowspan="2">Degree</th></tr>
<tr><th>Mandatory</th><th>Elective<br>(Choose any one)</th></tr>
<tr><td rowspan="2">II</td><td rowspan="2">6.5</td><td>III</td><td>OCHT301 (4 Cr)<br>OCHT302 (4 Cr)<br><br>OCHP304 (4 Cr)<br>OCHP305 (2 Cr)</td><td>E-OCHT303 (A) (4 Cr)<br>E-OCHT303 (B) (4 Cr)<br>E-OCHT303 (C) (4 Cr)<br>E-OCHT303 (D) (4 Cr)</td><td>---</td><td>---</td><td>RP-306<br>(4 Cr)</td><td>22</td><td rowspan="2">PG Degree After 3-Yr UG<br>Or<br>PG Degree after 4-Yr UG<br><br>Note: All the practicals/Project will be discipline specific i.e. Organic Chemistry oriented</td></tr>
<tr><td>IV</td><td>OCHT401 (4 Cr)<br>OCHT402 (4 Cr)<br><br>OCHP404 (4 Cr)</td><td>E-OCHT403 (A) (4 Cr)<br>E-OCHT403 (B) (4 Cr)<br>E-OCHT403 (C) (4 Cr)<br>E-OCHT403 (D) (4 Cr)</td><td>---</td><td>---</td><td>RP-405<br>(6 Cr)</td><td>22</td></tr>
<tr><td colspan="3">Cum. Cr. For 2 Year PG Degree in Organic Chemistry</td><td>26</td><td>8</td><td>4</td><td>4</td><td>10</td><td>44</td><td></td></tr>
<tr><td colspan="10">2 Years-4 Sem. PG Degree in Organic Chemistry (88 credits) after Three Year UG Degree or 1 Year-2 Sem PG Degree in Organic Chemistry (44 credits) after Four Year UG Degree</td></tr>
</table>

**Abbreviations:** Yr.: Year; Sem.: Semester; OJT: On Job Training: Internship/ Apprenticeship; FP: Field projects; RM: Research Methodology; Research Project: RP; Cumulative Credits: Cum. Cr., OCHT: Organic Chem Theory, OCHP: Organic Chem Practical.

**M.Sc. II Physical Chemistry**
**Revised Credit Frameworks for M.Sc. Programs as per NEP 2.0 with effect from 2026-27**

<table>
<tr><th rowspan="2">Year</th><th rowspan="2">Level</th><th rowspan="2">Sem</th><th colspan="2">Major</th><th rowspan="2">RM</th><th rowspan="2">OJT/FP</th><th rowspan="2">RP</th><th rowspan="2">Cumm. Cr.</th><th rowspan="2">Degree</th></tr>
<tr><th>Mandatory</th><th>Elective<br>(Choose any one)</th></tr>
<tr><td rowspan="2">II</td><td rowspan="2">6.5</td><td>III</td><td>PCHT301 (4 Cr)<br>PCHT302 (4 Cr)<br><br>PCHP304 (4 Cr)<br>PCHP305 (2 Cr)</td><td>E-PCHT303 (A) (4 Cr)<br>E-PCHT303 (B) (4 Cr)<br>E-PCHT303 (C) (4 Cr)<br>E-PCHT303 (D) (4 Cr)</td><td>---</td><td>---</td><td>RP-306<br>(4 Cr)</td><td>22</td><td rowspan="2">PG Degree After 3-Yr UG<br>Or<br>PG Degree after 4-Yr UG<br><br>Note: All the practicals/Project will be discipline specific i.e. Physical Chemistry oriented</td></tr>
<tr><td>IV</td><td>PCHT401 (4 Cr)<br>PCHT402 (4 Cr)<br><br>PCHP404 (4 Cr)</td><td>E-PCHT403 (A) (4 Cr)<br>E-PCHT403 (B) (4 Cr)<br>E-PCHT403 (C) (4 Cr)<br>E-PCHT403 (D) (4 Cr)</td><td>---</td><td>---</td><td>RP-405<br>(6 Cr)</td><td>22</td></tr>
<tr><td colspan="3">Cum. Cr. For 2 Year PG Degree in Physical Chemistry</td><td>26</td><td>8</td><td></td><td></td><td>10</td><td>44</td><td></td></tr>
<tr><td colspan="10">2 Years-4 Sem. PG Degree in Physical Chemistry (88 credits) after Three Year UG Degree or 1 Year-2 Sem PG Degree in Physical Chemistry (44 credits) after Four Year UG Degree</td></tr>
</table>

**Abbreviations:** Yr.: Year; Sem.: Semester; OJT: On Job Training: Internship/ Apprenticeship; FP: Field projects; RM: Research Methodology; Research Project: RP; Cumulative Credits: Cum. Cr. PCHT: Physical Chem Theory paper, PCHP: Physical Chem Practical paper

**M.Sc. II Analytical Chemistry**
**Revised Credit Frameworks for M.Sc. Programs as per NEP 2.0 with effect from 2026-27**

| Year | Level | Sem | Major | | RM | OJT/FP | RP | Cumm. Cr. | Degree |
|---|---|---|---|---|---|---|---|---|---|
| | | | Mandatory | Elective (Choose any one) | | | | | |
| II | 6.5 | III | ACHT301 (4 Cr)<br>ACHT302 (4 Cr)<br><br>ACHP304 (4 Cr)<br>ACHP305 (2 Cr) | E-ACHT303 (A) (4 Cr)<br>E-ACHT303 (B) (4 Cr)<br>E-ACHT303 (C) (4 Cr)<br>E-ACHT303 (D) (4 Cr) | --- | --- | RP-306 (4 Cr) | 22 | **PG Degree After 3-Yr UG Or PG Degree after 4-Yr UG**<br><br>**Note: All the practicals/Project will be discipline specific i.e. Analytical Chemistry oriented** |
| | | IV | ACHT401 (4 Cr)<br>ACHT402 (4 Cr)<br><br>ACHP404 (4 Cr) | E-ACHT403 (A) (4 Cr)<br>E-ACHT403 (B) (4 Cr)<br>E-ACHT403 (C) (4 Cr)<br>E-ACHT403 (D) (4 Cr) | --- | --- | RP-405 (6 Cr) | 22 | |
| **Cum. Cr. For 2 Year PG Degree in Analytical Chemistry** | | | **26** | **8** | | | **10** | **44** | |
| 2 Years-4 Sem. PG Degree in Analytical Chemistry (88 credits) after Three Year UG Degree or 1 Year-2 Sem PG Degree in Analytical Chemistry (44 credits) after Four Year UG Degree | | | | | | | | | |

**Abbreviations:** Yr.: Year; Sem.: Semester; OJT: On Job Training: Internship/ Apprenticeship; FP: Field projects; RM: Research Methodology; Research Project: RP; Cumulative Credits: Cum. Cr. ACHT: Analytical Chem Theory paper, ACHP: Analytical Chem Practical paper

**M.Sc. II Industrial Chemistry**
**Revised Credit Frameworks for M.Sc. Programs as per NEP 2.0 with effect from 2026-27**

| Year | Level | Sem | Major | | RM | OJT/FP | RP | Cumm. Cr. | Degree |
|---|---|---|---|---|---|---|---|---|---|
| | | | Mandatory | Elective (Choose any one) | | | | | |
| II | 6.5 | III | INDCHT301 (4 Cr)<br>INDCHT302 (4 Cr)<br><br>INDCHP304 (4 Cr)<br>INDCHP305 (2 Cr) | E-INDCHT303 (A) (4 Cr)<br>E-INDCHT303 (B) (4 Cr)<br>E-INDCHT303 (C) (4 Cr)<br>E-INDCHT303 (D) (4 Cr) | --- | --- | RP-306 (4 Cr) | 22 | **PG Degree After 3-Yr UG**<br>**Or**<br>**PG Degree after 4-Yr UG**<br><br>**Note: All the practicals/Project will be discipline specific i.e. Industrial Chemistry oriented** |
| | | IV | INDCHT401 (4 Cr)<br>INDCHT402 (4 Cr)<br><br>INDCHP404 (4 Cr) | E-INDCHT403 (A) (4 Cr)<br>E-INDCHT403 (B) (4 Cr)<br>E-INDCHT403 (C) (4 Cr)<br>E-INDCHT403 (D) (4 Cr) | --- | --- | RP-405 (6 Cr) | 22 | |
| **Cum. Cr. For 2 Year PG Degree in Industrial Chemistry** | | | **26** | **8** | | | **10** | **44** | |
| 2 Years-4 Sem. PG Degree in Industrial Chemistry (88 credits) after Three Year UG Degree or 1 Year-2 Sem PG Degree in Industrial Chemistry (44 credits) after Four Year UG Degree | | | | | | | | | |

**Abbreviations:** Yr.: Year; Sem.: Semester; OJT: On Job Training: Internship/ Apprenticeship; FP: Field projects; RM: Research Methodology; Research Project: RP; Cumulative Credits: Cum. Cr. INDCHT: Industrial Chem Theory paper, INDCHP: Industrial Chem Practical paper

## M.Sc. II Applied Chemistry

## Revised Credit Frameworks for M.Sc. Programs as per NEP 2.0 with effect from 2026-27

<table>
<tr><th rowspan="2">Year</th><th rowspan="2">Level</th><th rowspan="2">Sem</th><th colspan="2">Major</th><th rowspan="2">RM</th><th rowspan="2">OJT/FP</th><th rowspan="2">RP</th><th rowspan="2">Cumm. Cr.</th><th rowspan="2">Degree</th></tr>
<tr><th>Mandatory</th><th>Elective<br>(Choose any one)</th></tr>
<tr><td rowspan="2">II</td><td rowspan="2">6.5</td><td>III</td><td>APCHT301 (4 Cr)<br>APCHT302 (4 Cr)<br><br>APCHP304 (4 Cr)<br>APCHP305 (2 Cr)</td><td>E-APCHT303 (A) (4 Cr)<br>E-APCHT303 (B) (4 Cr)<br>E-APCHT303 (C) (4 Cr)<br>E-APCHT303 (D) (4 Cr)</td><td>---</td><td>---</td><td>RP-306<br>(4 Cr)</td><td>22</td><td rowspan="2">PG Degree After 3-Yr UG<br>Or<br>PG Degree after 4-Yr UG<br><br>Note: All the practicals/Project will be discipline specific i.e. Applied Chemistry oriented</td></tr>
<tr><td>IV</td><td>APCHT401 (4 Cr)<br>APCHT402 (4 Cr)<br><br>APCHP404 (4 Cr)</td><td>E-APCHT403 (A) (4 Cr)<br>E-APCHT403 (B) (4 Cr)<br>E-APCHT403 (C) (4 Cr)<br>E-APCHT403 (D) (4 Cr)</td><td>---</td><td>---</td><td>RP-405<br>(6 Cr)</td><td>22</td></tr>
<tr><td colspan="3">Cum. Cr. For 2 Year PG Degree in Applied Chemistry</td><td>26</td><td>8</td><td></td><td></td><td>10</td><td>44</td><td></td></tr>
<tr><td colspan="10">2 Years-4 Sem. PG Degree in Applied Chemistry (88 credits) after Three Year UG Degree or 1 Year-2 Sem PG Degree in Applied Chemistry (44 credits) after Four Year UG Degree</td></tr>
</table>

**Abbreviations:** Yr.: Year; Sem.: Semester; OJT: On Job Training: Internship/ Apprenticeship; FP: Field projects; RM: Research Methodology; Research Project: RP; Cumulative Credits: Cum. Cr. APCHT: Applied Chem Theory paper, APCHP: Applied Chem Practical paper

# Shivaji University Kolhapur

## Syllabus as per NEP-2020

**For**

**M. Sc. Part- II Inorganic Chemistry**

**Semester III & IV**

## Under the Faculty of Science and Technology

**To be implemented with effect from Academic Year 2026-2027**

This is applicable for University Department and Affiliated College PG Centres

## Name of Program: M.Sc. Part-II Inorganic Chemistry

M.Sc. in Inorganic Chemistry offers diverse career paths in the pharmaceutical, chemical manufacturing, and petrochemical industries, as well as in research and development, environmental agencies, and academia. Students can work as research scientists, quality control chemists, and lecturers, with potential for roles in emerging fields like battery technology, sustainable materials, and microchip manufacturing. The program prepares students not only in education but to work in sectors such as government, petrochemicals, pharmaceuticals, polymers, textiles, food, and paints**.**

## Programme Educational Objectives (PEOs)

The students will be able to

PEO-1: demonstrate strong theoretical and practical knowledge in inorganic chemistry, with the ability to use advanced analytical techniques to solve complex problems

PEO-2: To mould the overall personality of the students by providing training and

opportunities to enhance their communication skills, team management, co-ordination

skills and leadership qualities.

PEO-3: To guide and create awareness among the students to learn and adopt new skills and techniques to overcome the problem related with new technologies.

PEO-4: Students should be prepared for diverse career paths in academia, government, and industry, or be able to pursue entrepreneurial opportunities.

## Program Outcomes (POs)

PO1: Students will have a thorough knowledge in the fundamentals and application of modern chemical and scientific theories including those in all branches of chemical sciences.

PO2: Students will be able to design and carry out scientific experiments as well as accurately record and analyse the results of such experiments.

PO3: Students will be able to use the evidence based comparative chemistry approach for synthesis and analysis of the chemical compounds.

PO4: Students will be skilled in problem solving, critical thinking and analytical reasoning as applied to scientific problems.

PO5: Students will be able to clearly communicate the results of scientific task in oral and written formats. Students will be able to function as a member of an interdisciplinary problem solving team.

PO6: Students will be able to explain the role of Inorganic Chemistry for addressing social, economic, and environmental problems.

## Program Specific Outcomes (PSOs)

PSO1: The students will be able to get global level research opportunities to pursue Ph.D. programme, targeted approach of competitive Exams such as CSIR-NET/GATE/SET, discipline specific competitive exams conducted by service commission, etc.

PSO2: The students will be able to get employment opportunities in various industries like petrochemicals, metallurgical, materials and pharmaceutical, etc.

PSO3: Understands the background of Inorganic reaction mechanisms, complex chemical structures, and instrumental methods of chemical analysis, separation techniques and analytical methods of general purpose.

PSO4: Gains complete knowledge about all fundamental aspects of all the elements of chemistry.

**MANDATORY PAPERS**

Paper VII: ICHT301 (4 Cr): Inorganic Chemical Spectroscopy

Paper VIII: ICHT302 (4 Cr): Coordination Chemistry – I

ICHP304 (4 Cr): Practical-V

ICHP305 (2 Cr): Practical-VI

RP306 (4Cr): Research Project

**ELECTIVE PAPERS: (Choose any one)**

Paper IX: E-ICHT303 (A) (4 Cr): Nuclear Chemistry

Paper IX: E-ICHT303 (B) (4 Cr): Organometallic and Bioinorganic Chemistry

Paper IX: E-ICHT303 (C) (4 Cr): Selected Topics in Inorganic Chemistry

Paper IX: E-ICHT303 (D) (4 Cr): Environmental Chemistry

## Inorganic Chemistry: SEMESTER- IV

**MANDATORY PAPERS**

Paper X**:** ICHT401 (4 Cr): Instrumental Techniques

Paper XI: ICHT402 (4 Cr): Coordination Chemistry-II

ICHP404 (4 Cr) : Practical-VII

RP405 (6 Cr) : Research Project

**ELECTIVE PAPERS: (Choose any one)**

Paper XII: E-ICHT403 (A) (4 Cr): Chemistry of Inorganic Materials

Paper XII: E-ICHT403 (B) (4 Cr): Energy and Environmental Chemistry

Paper XII: E-ICHT403 (C) (4 Cr): Radiation Chemistry

Paper XII: E-ICHT403 (D) (4 Cr): Applied Bioinorganic Chemistry

## Detailed Syllabus:

## M.Sc. Part-II (Sem- III) Inorganic Chemistry

## Paper VII, ICHT301: Inorganic Chemical Spectroscopy (4 Credits, 60hrs)

**Course Outcomes (COs**):

**CO1:** At the end the student should be able to: Recognize symmetry elements in a molecule; State the point group a molecule belongs to; Combine matrices and set up matrix for transformations and acquisition of a theoretical support which underlies much of spectroscopy.

**CO2:** Able to describe molecular vibration with the interaction of matter with light, Explain the basic concepts in IR and Raman Spectroscopy, Examines IR and Raman spectroscopy and molecular structure determination by the simple molecules.

**CO3:** Students will be able to identify, describe and explain the function of the several components of a mass spectrometer and predict the fragmentation patterns expected.

**CO4:** The ability to investigate and determine the local structure of typical elements in inorganic compounds and able to explain the surface composition and chemical nature of the surface elements.

**Unit I: Molecular Symmetry and Group Theory** **15 hrs.**

Introduction to Symmetry, Symmetry operations, Symmetry elements, Point group and its classification (Cn-type, Dn-type, Special-type), Schoenflies symbol for point groups, Determination of point group for $AB_2$ (Bent), $AB_3$ (Trigonal pyramid), $AB_3$ (Trigonal

Planar), $AB_4$ (Square planar), $AB_5$ (Trigonalbipyramidal), $AB_6$ (Octahedral), $CO_2$, HCl, CO, Ortho–, meta– & para–disubstituted benzene molecules. Symmetry and dipole moment of molecule, Symmetry and optical activity, Group and its Properties, Group multiplication table, Matrix representation of symmetry elements, Reducible and Irreducible representations, Character of a representation (character of matrix), Properties of Irreducible representation, Great orthogonally theorem (without proof) and its importance, Construction of character table for $C_{2v}$& $C_{3v}$ point groups, Mulliken symbolism rules for irreducible representations & its illustrations, Direct product, Standard reduction formula.

**Unit II: IR and Raman Spectroscopy** **15 hrs.**

**A) Infrared spectroscopy:** The vibrating diatomic molecule, The simple harmonic oscillator, The anharmonic oscillator, The diatomic vibrating rotator, Vibration– rotation spectrum of carbon monoxide, Breakdown of Born–Oppenheimur approximation, The vibration of polyatomic molecules, Overtones and combination frequencies, The influence of rotation of the spectra of polyatomic molecules, Techniques and Instrumentation, Applications.

**B) Raman spectroscopy:** Classical and Quantum theory, Pure rotational Raman Spectra, vibrational Raman spectra, Rule of mutual exclusion, Overtone and combination vibrations, Rotational fine structure, Outline of technique and instrumentation, Applications. Modes of vibrations, Selection Rules for Infrared and Raman Spectra, Normal modes of vibrations in $AB_2$ (Linear/Bent), $AB_3$, $AB_4$, $AB_5$, Octahedral $AB_6$ molecules with factors affecting band frequencies.

**Unit III: Mass Spectroscopy:** **15 hrs.**

Basic principle, Instrumentation, Electron-impact Induced and Fast Atom Bombardment (FAB) spectrometry, qualitative and semiquantitative theories including QET, concept of metastable ions transitions, Stevensons's rules. Applications to metal compounds containing carbonyl, alkyl, cyclopentadienyl and acetylacetonate.

**Unit IV: NMR and X-ray Photo electron Spectroscopy**

**A) NMR Spectroscopy:** **8 hrs.**

Principle Instrumentation of NMR, the chemical shift, mechanism of electron shielding and factors contributing to the magnitude of chemical shift. Local & remote effect, spin-spin splitting, applications of spin coupling to structural determination, double Resonance techniques. The contact and Pseudo contact shifts Factors affecting nuclear relaxation, an overview of NMR of metal nucleus with emphasis on $^{195}Ag$ &$^{119}Sn$ NMR, applications of solid-state NMR technique.

**B) X-ray Photo electron Spectroscopy (XPS) 7 hrs.**

Introduction and basic theory, Instrumentation, sample selection and preparation, spectral analysis, Ar ion sputtering technique and applications of XPS.

**Reference Books:**


1. K. Burger, Coordination Chemistry-experimental methods, Butterworth's
2. R. Drago: Physical method in Inorganic Chemistry, DUSAP.
3. Hill & Day advanced methods in Inorganic Chemistry, J.Weily
4. F.A. Cotton, chemical application of group theory, Weily eastern
5. Figgis, Introduction to ligand field theory field
6. Schaefer & Gilman: Basic principles of ligand field Theory, J. Wiely
7. P.R. Backer: Molecular symmetry and Spectroscopy A.P.
8. Ferraro Ziomeek, Introduction to Group theory, plenum
9. Scotland Molecular symmetry DVN
10. Dorian: symmetry in Chemistry EWAP
11. Hall: Group theory and symmetry in Chemistry MGLt
12. Nakamoto Infrared R Raman Spectra of Inorganic & Coordination compounds J.Weily
13. Nakanisha: Spectroscopy and structure J. Weily
14. Ferroro: Metal ligand and related vibrations
15. CNR Rao Spectroscopy in Inorganic Chemistry Vol I, II, III


## Paper VIII: ICHT302: Coordination Chemistry-I (4 Cr, 60 hrs.)

**Course Outcomes (COs):**

**CO1:** To be able to describe and explain the bonding in d-metal complexes using crystal field and ligand field theories and calculate the crystal field stabilization energy and its role in stabilizing the complexes.

**CO2:** At the end of the course students should be able to interpret simple electronic spectra and predict both position and intensity based on Orgel/Tanabe-Sugano diagrams and explain the spectroscopic properties of transition metal complexes.

**CO3:** Students should be able to estimate the spin-only magnetic moment for given complex and predict the nature of magnetic properties.

**CO4:** Students will be able to explain the reactivity and stabilities of ternary complexes and their reactions.

**Unit I: Metal-ligand bonding: 15 hrs.**

Crystal Field Theory: Splitting of d-orbital in tetragonal, square planar and trigonal bipyramid complexes. CFSE-factors affecting the magnitude of 10 Dq-evidence for crystal field stabilization, tetragonal distortion from octahedral symmetry, John teller effect, nephelauxetic effect. CFSE and their uses, factors affecting CFSE, Limitations of crystal field theory. M.O. theory for octahedral, tetrahedral and square planar complexes with and without π-bonding.

**Unit II: Electronic spectra of Transition Metal complexes: 15 hrs.**

Determining the Energy terms, Spin-orbit (L-S) coupling scheme, Hund's rule, Derivation of the term symbol for a $d^1$ to $d^9$ configuration, electronic spectra of transition metal complexes-Laporte 'orbital' selection rule, spin selection rule. Orgel diagrams for octahedral metal complexes. Racah parameters, calculations of 10 Dq, B and β parameters for octahedral complexes of cobalt and nickel, Tanabe-Sugano diagrams for octahedral complexes, Charge transfer spectra, Selection rule and charge transfer spectra.

**Unit III: Magnetic properties of Transition metal complexes: 15 hrs.**

Types of magnetic behaviour, origin of paramagnetism, Spin-orbit interaction, Lande interval rule, Diamagnetism, Pascal constants, Ferromagnetism and antiferromagnetism of metal complexes; temperature dependent paramagnetism, Van Vleck's equation, Its derivation and applications, magnetic anisotropy, anamoulous magnetic moment, Quenching of orbital moment, Spin orbit coupling and magnetic moment, Determination of magnetic susceptibility. Spins crossover phenomenon.

**Unit IV: Mixed Ligand complexes 15 hrs.**

Stabilities of ternary complexes, Dynamics of formation of ternary complexes reaction of Coordination ligand in ternary complexes, Mimicking reactions in biological systems, enzyme models, Amino acids ester hydrolysis, peptide synthesis & hydrolysis, Decarboxylation of βketo acids, Applications of mixed ligand complexes in catalysis.

**Reference Books:**

1. Jones: Elementary Coordination Chemistry. J. Weily
2. Graddon: Introduction to Coordination Chemistry. J. Weily
3. Drago: Physical methods of Inorganic Chemistry. J. Weily.
4. Graddon: Introduction to coordination Chemistry, Parasmom
5. Lewis and Wilkins: Coordination Chemistry. J. Weily
6. Msrtel: Coordination Chemistry Vol I, II VNR
7. Earnshaw: Introduction to Magneto Chemistry
8. Mabbs & Machin Magnetism & transition metal complexes Chamman hall
9. Calvin, Magnetic properties of transition metal complexes.
10. L.N. Maley: Magneto Chemistry
11. Datta & Shymlal: Elements of Magneto Chemistry
12. Martel & Taqui Khan: homogeneous catalysis with metal complexes Vol.I & II AP.
13. James E. Huheey: Inorganic Chemistry Principles of Structure and reactivity, Harber and Row, Publishers Inc. New York 1972.
14. K.P. Purcell & J.C. Kote: An Introduction to Inorganic Chemistry Holt Sounders, Japan 1980.
15. William L. Jolly: Modern Inorganic Chemistry, Mecgrow Hill USA, 1984
16. F.A. Cotton & R.G. Wilkinson: Advanced Inorganic Chemistry

## ELECTIVE PAPERS: Choose Any one

## Paper IX: E-ICHT303 (A): Nuclear Chemistry (4 Cr, 60 Hrs)

**Course Outcomes (COs):**

**CO1:** Students will be able to different modes of radioactive decay and also theories of radioactive decay.

**CO2:** Students will be able to explain the nuclear structure and stability using various models.

**CO3:** Students will get basic knowledge of nuclear reactions, mechanism and energy calculations.

**CO4:** At the end students should be able to describe the fundamentals of nuclear reactors, isotopic chemistry, and the applications of radioactivity.

**UNIT-I: Systematic of alpha, beta and gamma decays 15 hrs.**

Alpha decay, energy curve, spectra of alpha particles, Giger-Nuttal law, theory of alpha decay, penetration of potential barrier, beta decay, range of energy relationship, beta spectrum, sergeants curve, Fermi theory of beta decay, matrix elements, allowed and forbidden transitions, curie plots, gamma decay, Nuclear energy levels, selection rule, isomeric transitions, Internal conversion, Auger effect

**UNIT-II: Nuclear Structure and Stability 15 hrs.**

Binding energy, empirical mass equation, The nuclear models, the liquid drop model, Single particle shell model, Fermi gas model & collective/lunified nuclear model, nuclear spin, parity & magnetic moments of odd mass number nuclei and numerical.

**Unit III: Nuclear reactions and nuclear fission 15 hrs.**

Introduction, Production of projectiles, nuclear cross section, nuclear dynamics, threshold energy of nuclear reaction, Coulomb scattering, potential barrier, potential well, formation of a compound nucleus, Nuclear reactions, direct Nuclear reactions, heavy-ion induced nuclear reactions, photonuclear reactions. Liquid drop model of fission, fission barrier and threshold, fission cross section, mass energy and charge distribution of fission products, symmetric and a symmetric fission, decay chains and delayed neutrons

**UNIT-IV: Reactor Theory and Applications of Radioactivity 15 hrs.**

Nuclear fission as a source of energy, Nuclear chain reacting systems, critical size of a reaction, research reactors, graphite moderated, heterogeneous, enriched uranium reactors, light water moderated, heterogeneous, enriched uranium reactors, water boilers enriched aq. Homogeneous reactors, Thermonuclear reactors, gamma interactions, shielding and health protection. Reactors in India, Tracer technique in the field of analytical chemistry structure determination elucidation of reaction mechanism, isotopic dilution analysis, neutron activation analysis applications in biological, medical, industrial fields, Age determination.

**Reference Books:**


1. Friedlander, Kennedy and Miller, Nuclear and Radio Chemistry: John Wiley
2. B. G. Harvey, Nuclear Chemistry
3. Hassinsky: Translated by D. G. Tuck, Nuclear Chemistry and its application: Addison Wiley.
4. B.G. Harvey, Introduction to Nuclear Physics and Chemistry
5. Maeclefort: Nuclear Chemistry: D. Van Nostrand
6. An N. Nesmeyannoy: Radiochemistry: Mir

7. Jacobs et al: Basic Principles of nuclear Science and Reactors, V. Nost & EWAP
8. N. Jay: Nuclear Power Today Tomorrow: ELBS
9. Kenneth: Nuclear Power Today, Tomorrow: ELBS
10. Essentials of Nuclear Chemistry, W. J. Arnikar, John Wiley
11. Nuclear and Radiation Chemistry: B. K. Sharma, Krishna Publication
12. A Introduction to Nuclear Physics: R. Babber and Puri.
13. Essential of Nuclear Chemistry by H. J. Arnikar

## Paper IX: E-ICHT303(B): Organometallic and Bioinorganic Chemistry (4 Cr) (60 hrs)

**Course Outcomes (COs):**

**CO1:** After successful completion of the course the students should be able to explain the synthesis, structure, bonding, properties and reactivity of Alkyls and Aryls of Transition Metals.

**CO2:** After successful completion of the course the students should be able to explain the synthesis, structure, bonding, properties and reactivity of Compounds of Transition Metal-carbon with Multiple bonds.

**CO3:** Students should be able to describe the role of metals in medicines, deficiency disorders of metals and use of platinum, gold and lithium compounds in the treatment of cancer, arthritis and psycho drugs, respectively.

**CO4:** At the end of the course student should be able to explain the natural proteins that carry dioxygen in various animals, the role of myoglobin and hemoglobin in carrying dioxygen in mammals and other non-heme proteins for oxygen uptake.

**Unit I: Organotransition Metal Chemistry 15 hrs.**

Alkyls and Aryls of Transition Metals: Types, routes of synthesis, stability and decomposition pathways of alkyls and aryls of transition metals. Organocopper in Organic synthesis, Compounds of Transition Metal –Carbon Multiple bonds: Alkylidenes, alkylidynes, low valent carbenes and carbynes–synthesis, nature of bond, structural characteristics, nucleophilic and electrophilic reactions on ligands, role in organic synthesis.

**Unit-II: Transition Metal Pi-complexes 15 hrs.**

Carbon multiple bonds. Nature of bonding, structural characteristics & synthesis, properties of transition metal Pi-Complexes with unsaturated organic molecules, alkenes alkynes, allyl, diene, dienyl, arene and trienyl complexes. Application of transition metal, organometallic intermediates in oraganic synthesis relating to nucleophilic and electrophilic attack onligands, role in organic synthesis.

**Unit III: Metal Compounds in Medicine** **15 hrs.**

Medicinal use of metal complexes as antibacterial, anticncer, use of cis-platin as antitumor drug, antibiotics & related compounds. Metal deficiency and disease, iron deficiency, zinc deficiency and copper deficiency, Metal used for dignosis and chemotherapy with particular reference to anti-cancer drugs. Chelate therapy, chemotherapy with compounds of some non-essential elements; platinum complexes in cancer therapy. Antiviral activity of metal complexes. Gold containing drugs used in the therapy of Rheumatic-Arthritis, Gold complexes as anticancer drug. Lithium in psycho pharmacological drugs. Antimicrobial agents.

**Unit-IV: Oxygen Transport and Storage** **15 hrs.**

Heme proteins and oxygen uptake, structure and functions of haemoglobin, myoglobin, hemocyanins & hemerythrin. Perutz mechanism for structural changes in porphyrin ring system, Oxygenation and deoxygenation. Oxygen adsorption isotherm and cooperativity, physiological significance of haemoglobin, role of globin chain in gaemoglobin, Cyanide poisoning and treatment.

**Reference Books:**

1. Yamamoto, Organo Transition Metal Chemistry, Wiley (1986).
2. R. H. Crabtree, The Organometallic Chemistry of the Transition Metals (4th edn.), John Wiley (2005).
3. A. J. Pearson. Metallo-Organic Chemistry, John Wiley & Sons (1985).
4. M. Bochmann. Organometallics-I Complexes with Transition Metal-Carbon σ-Bonds, Oxford Chemistry Primers (1994).
5. Principles of Biochemistry, A. L. Lehinger, Worth Publications.
6. Biochemistry, L. Stryer, W. H. Freeman
7. Biochemistry, J. David Rawn, Neil Patterson.
8. Biochemistry, Voet and Voet, John Wiley.
9. Outlines of Biochemistry, E. E. Conn and P. K. Stumpt, John Wiley.
10. D. F. Shriver, P. W. Atkins and C. H. Langford, Inorganic Chemistry, Oxford Univ. Press,

1990.

## Paper IX: E-ICHT303(C): Selected Topics in Inorganic Chemistry (4 Cr) (60 hrs)

**Course Outcomes (COs)**

CO1: Students will learn about the basic principles of catalysis.

CO2: Students will get knowledge about the coordination polymers.

CO3: After completion of the course students will be able to learn about the non-conventional sources of energy.

CO4: Students will be able to understand the supra-molecular chemistry and the principles of it.

**UNIT-I: Catalysis** **15 Hrs**

Basic principals, thermodynamic and kinetic aspects, industrial requirements, classification, theories of catalysis, homogeneous and heterogeneous catalysis. Introduction, types & characteristics of substrate-catalyst interactions, kinetics and energetic aspects of catalysis, selectivity, stereochemistry, orbital symmetry and reactivity. Catalytic reactions of coordination and Organometallic compounds including polymerization activation of small molecules, addition to multiple bonds, hydrogenation, Zeigler-Natta polymerization of olefins, monsanto acetic acid process.

**UNIT-II: Coordination Polymers** **15 Hrs**

Natural polymers and reactions yielding coordination polymers. Synthesis of coordination polymers. Use of polymeric ligands in synthesis of coordination polymers. Metal coordination polymers. Silicon polymers. Organosilicon polymers: synthesis and their uses

**UNIT-III: Non-conventional sources of energy** **15 Hrs**

**a) Alternate source of energy**

Solar sources: Photochemical methods, thermodynamic efficiency of energy conversion, energy from solar radiations, transition metal complexes for energy production, solar hydrogen system, photochemical processes at semiconductors electrodes, photo galvanic and Photovoltaic cells based on Inorganic photochemical systems.

b) Geothermal energy c) Energy from biogas sources, biodiesel, d) Tidal wind sources e) Energy from fission and fusion reaction.

**Unit-IV Supramolecular Chemistry:** **15 Hrs**

Concepts and principles, Host-Guest Chemistry, Non-covalent bonds, crown ethers, cryptands and their metal complexes, Molecular recognition for different types of molecules, spherical recognition, Tetrahedral recognition, cooperativity and multivalency, Design and synthesis of co-receptor molecules and multiple recognition, supramolecular reactivity and catalysis, supramolecular devices, supramolecular photochemistry.

## Reference Books


1. Heterogeneous catalysis 2nd edn. Bond C. Chapman all (1987).
2. The application & Chemistry of catalysis by suitable transition metal complexes Parashall. W. Weily N. 1980.
3. Homogeneous transition metal catalysis, A general art, Masters C. Chapman and Hall, London 1981.
4. Introduction to the principles of heterogeneous catalysis, Thomas J.M., Thomas W.J. Academic press N.Y. 1967
5. Inorganic polymers: Mark J.F., Allock H.R. West, Prentice hall
6. Inorganic polymers: Ring N.H., Academic Press N.Y. 1978
7. The Inorganic heterocyclic chemistry of sulphur, nitrogen, phosphorous, Heal A.G. Acta, Press N.Y. 1980.
8. Solar energy Principles of thermal collections and storage, Sukhatme S.P., Tata Macgrow Hill New Delhi 1984.
9. Fuel Cells, Bockeris JOM, Sriniwasan S. and Mac grow Hills 1969
10. Solar Energy Rai C.D.
11. Energy Resources, Simon A.L. 1975
12. Direct Energy Conversion, Addison Wesley, 1970, All M and Kottani S.
13. Outlines in Chemical Technology Vol I, S.D. Sukla & Pandey G.N.M.


## Paper IX: E-ICHT303(D): Environmental Chemistry (4 Cr) (60 hrs)

**Course Outcomes (COs)**

CO1: Students will learn about the basic principles of air pollution and water pollution.

CO2: Students will get knowledge about the Control of Air and water pollutants.

CO3: After completion of the course students will be able to learn about Electrochemical and spectral methods for pollutant analysis

CO4: Students will be able to understand the Monitoring, sampling and Analysis of Air and water pollutants

**UNIT-I: Air pollution and water pollution (15 hrs)**

Air pollution – types and sources; Atmospheric chemistry, depletion of stratospheric ozone, industrial and transport-related air pollution; Global warming and its effects. Acid rain Water pollution – types and sources, physical and chemical water pollutants, waste water treatment, criteria of water quality, mercury pollution and estimation of organomercurials. Effect of Air pollutant and Water pollutant on living and nonliving things.

**UNIT-II: Control of Air and water pollutants (15 hrs)**

Method of control of air pollution, electrostatic precipitation wet & dries scrubber, filters, gravity and cyclonic separation, Adsorption, absorption and condensation of gaseous effluent. Water and waste water treatment, aerobic and anaerobic, aeration of water, principle of coagulation, flocculation, softening, disinfection, demineralization and fluoridation.

**UNIT–III: Electrochemical and spectral methods for pollutant analysis (15 hrs)**

Polarography: Principle, instrumentation and applications, Cyclic Voltammetry, Anodic stripping voltammetry, Amperometry, Coulometry, and conductance methods; Potentiometry: Ion selective electrodes; Atomic absorption spectroscopy; Atomic fluorescence spectrometry; Turbidimetry and Nephelometry. GC & HPLC.

**UNIT–IV: Monitoring, sampling and Analysis of Air and water pollutants (15 hrs)**

Methods of monitoring and sampling of gaseous, liquid and solid pollutants, analysis of CO, $CO_2$, $NO_2$, $SO_2$, $H_2S$, analysis of toxic heavy metals, Cd, Cr, Hg, As, Pb, Speciation Separation and analysis of Co, Cu, Mg, Mn, Fe, Al, analysis of anions $SO_4^{2-}$, $PO_4^{3-}$, $NO_3^-$, $NO_2^-$. Pesticide, residue analysis soil pollution, Sources of pesticide residue in the Environment, pesticide degradation by natural forces, effect of pesticide residue on life, Analytical techniques for pesticide residue analysis.

## Reference Books:


1. Environmental Pollution, A. K. De
2. Air Pollution, Wark & Werner
3. Environmental Pollution Control in Process Industries, S. P. Mahajan
4. Environmental Pollution, B. K. Sharma & H. Kaur
5. Introduction to Air Pollution, P. K. Trivedi
6. Environmental Pollution Analysis, S. M. Khopkar
7. A Text Book of Environmental Pollution: A. D. Tyagi, M. Mehre
8. Environmental Pollution Engineering and Control, C. S. Rao
9. Chemical in the Environment, Satake & M. Midu
10. Environmental Sciences, E. G. Engel
11. Fundamentals of Electroanalytical chemistry: John Willey & Sons (2001) P. M. S. Monk
12. Environmental Chemistry at a Glance: Blackwell publishing (2006), I. Pulford 4 H. Flowers
13. Instrumental Methods of Chemical Analysis, H. Kaur.


# Inorganic Chemistry Practicals

## ICHP304: Practical-V (4 Cr, 120Hrs)

**Course Outcomes (COs):**

**CO1:** Accurately operate advanced instrumentation, including conductometer, fluorimeter, polarograph, potentiometer, pH meter, and spectrophotometer.

**CO2:** Conduct conductometric titrations to determine critical micelle concentration (CMC) and quantify acetic acid in vinegar using conductivity trends.

**CO3:** Experimental spectral measurements and analysis for understanding binding equilibria.

**CO4:** Construct and interpret calibration curves, titration plots, and spectral data

**A) List of Experiments:**

1. Spectrophotometry
2. pH Metry
3. Nephelometry
4. Potentiometry
5. Conductometry
6. Spectro Fluorimetry

7. Thermal analysis

(Any other experiments may be added whenever required)

**B) Interpretation exercises**

1. X-ray powder diffraction analysis of cubic compound
   a. Determination of lattice constants and geometry
   b. Partical Size
   c. Density
2. Interpretation of Mossbaur spectrum with reference to determination of a) isomer shift b) quadruple splitting c) Internal magnetic field d) general comment
3. Interpretation of IR spectrum with reference to stretching vibration 0-2 C=N, C=O, N-, M-O.
4. Interpretation of NMR spectrum with reference to calculation of chemical shifts and general comments.
5. Interpretation of absorption spectra for
   a. Verification of position of ligands in spectrochemical series
   b. Determination of geometry (Octahedral, Square planar, tetrahedral) of a given compound.
   c. Calculation of spectral splitting parameters.

**NOTE: Any other experiments may be added when required**

## ICHP305: Practical-VI (2 Cr, 60 Hrs)

### Course Outcomes (COs):

**CO1:** The students will acquire hands on training for conducting the representative experiments for the analysis of wide variety of samples of inorganic, organic and physical approaches by qualitative and quantitative analysis.

**CO2:** Student would learn the sample preparation and characterization for purity and qualitative and quantitative analysis of samples.

**CO3:** Students will have good experimental skills for separation and estimation of amount of metal, metal ions in given samples.

**CO4:** Students will be acquainted with the separation and estimation of organic compounds in given samples

**List of Experiments:**

1. Ore Analysis

2. Alloy Analysis
3. Preparation of coordination complexes
4. Separation and estimation of ions using ion exchange chromatography
5. Gravimetric Estimation of Si and Ca from Plaster of Paris sample
6. Estimation of Magnesium from tablet of Milk of magnesia
7. Estimation of calcium from calcium supplementary tablet
8. Estimation of Iron and Zinc from iron-zinc supplementary Multivitamin Tablet
9. Estimation of Aluminum from alum sample
10. Estimation of Phosphate from Fertilizer sample
11. Estimation of Total Hardness of Borewell water
12. Estimation of Phosphoric acid from coca-cola sample
13. Estimation of Chemical Oxygen Demand (COD) from sewage/effluent sample
14. Interpretation of absorption spectra for
    a. Verification of position of ligands in spectrochemical series
    b. Determination of geometry (Octahedral, Square planar, tetrahedral) of a given compound.
    c. Calculation of spectral splitting parameters.

**Note: Any other experiments may be added when required**

## RP306 (4Cr, 120 Hrs): Research Project

**See Annexure-I for details (In the end of this document).**

# Inorganic Chemistry: SEMESTER- IV

## MANDATORY PAPERS

## Paper X: ICHT401: Instrumental Techniques (4 Cr, 60 hrs)

**Course Outcome (COs):**

**CO1:** Students will obtain knowledge of the working principles involved for selective analytical methods and the fundamental basics of the instrumentation including electronic spectroscopy and diffraction techniques.

**CO2:** Students will understand the advanced methods involved in determination of the quality and quantity of chemical substances in given compounds.

**CO3:** At the end of the course students will learn the interpretation of the experimental data obtained using various techniques and instruments for laboratory analysis carried out for quality assurance.

**CO4:** Students will be able to demonstrate the use of complementary analytical techniques to define the system/materials more precisely. To know the recent advancements in the instrumental methods of temperature programmed analysis.

**Unit I: X-ray Diffraction Techniques** **15 hrs.**

X-ray Sources (X-ray tube and synchrotron sources with their principle of working characteristics of emission spectrum), Bragg's law of diffraction, methods of diffraction (powder and single crystal), Powder diffraction: instrumentation, use of standards, characteristics of powder XRD pattern, significance of peak intensities, systematic absences of reflections, indexing of powder XRD pattern, determination of lattice parameters and solving cubic crystal structure using powder XRD data, qualitative (identification of the phases) and quantitative analysis (phase quantification), crystallite size determination, determination of relative % crystallinity. Single crystal diffraction: Advantages of single crystal diffraction over powder diffraction, introduction to Laue, rotation photograph and oscillation methods. Introduction to crystallographic database and file formats (raw data files, cif and pdf), Open source computer based crystal structure building and visualization tools.

**Unit II: Mossbauer Spectroscopy** **15 hrs.**

Principle of Mossbauer spectroscopy, Recoiless absorption and emission of gamma-rays, Doppler shift, Instrumentation, Isomer shift and its factors affecting, Quadruple splitting, Temperature Dependence of MB parameters, Zeeman Splitting (Six fingered MB lines), MB spectra of iron and tin compounds, Applications, Numericals.

**Unit III: Electron Spin Resonance Spectroscopy** **15 hrs.**

Principle of ESR Spectroscopy, Presentation of spectrum, Hyperfine splitting in some proton systems, Rules for evaluating ESR lines (Naphthalene anion radical, Pyrazine anion radical, Isomers of Xylene anion radicals, VO2+, Quinoline radical, Isoquinoline radical, Quinoxaline radical, Anthracene radical, Phenanthracne radical, Pyrene radical, Alkyl halide radicals, Quinone & Isoquinone anion radicals, nitrogen/deuterium containing radicals), Superhyperfine splitting, Instrumentation,'g' value and factors affecting it, Zero field splitting, Karmers's degeneracy, Applications, Numericals.

**Unit-IV: Advanced Instrumental Tools for Analysis of Inorganic materials** **15 hrs.**

Time resolved studies of chemical reactions such as material synthesis (solid state, hydrothermal, sol/gel, thin film growth etc., cathode/anode materials in lithium ion batteries during charge/discharge cycles, in situ X-ray diffraction methods for thermal expansion/contraction studies, structural studies as a function of temperature and pressure (XRD methods), Temperature programmed techniques (temperature programmed desorption/oxidation/reduction: TPD/TPR), methods of determination of surface acidity and basicity of solid catalysts, Computer softwares for plotting and analysis of the XRD data, Structure drawing softwares (VESTA)

**Reference Books:**

1. Powder Diffraction Theory and Practice, Edited by R E Dinnebier and S J L Billinge, RSC publishing, 2008.
2. Catalysis, Principles and Applications, Editors: B. Viswanathan, S. Sivasanker, A.V. Ramswamy, Narosa Publishing House
3. VESTA 3 for three-dimensional visualization of crystal, volumetric and morphology data, K. Momma and F. Izumi (2011), J. Appl. Crystallogr., 44, 1272-1276.
4. Elements of X-ray Diffraction, B.D. Cullity, Second Edition, Addison Wesley, 1978. Neutron Scattering in Chemistry, Baun, G.E. Butleworth, London, 1971.
5. Mossbaur Spectroscopy, Greenwood N.N., Gibbs T.C., Chapmann Hall, 1971.
6. Chemical Application of Mossbaur Spectroscopy, Goldanski V.I & Harber R.H., Academic Press 1968.
7. Spectroscopy in Inorganic Compounds CNR Rao & Ferraro G.R., Academic Press, 1970.
8. Basic Principles of Spectroscopy Cheney R.Mac Grows Hill, 1971.
9. Thermal Method, Wendlandt, W.W. John, Wiley, 1986.
10. Principles of Instrumental analysis, Skoog, III rd edn., Sounders, 1985.

## Paper XI: ICHT402: Coordination Chemistry-II (4 Cr) (60 hrs)

**Course Outcome (COs):**

**CO1:** After successful completion of the course students will be able to familiar with various reactions of transition metal complexes and will be able to predict the mechanism involved using direct and indirect evidences.

**CO2:** At the end students will be able to explain the cis-effect, trans-effect, and mechanism of electron transfer reactions.

**CO3:** Students will be able to explain the photochemistry of transition metal complexes.

**CO4:** Students will be able to describe the industrial applications of transition metals as catalysts

**Unit-I Reaction Mechanism of Transition Metal complexes-I 15 hrs.**

Energy profile of reaction. Inert and labile complexes, interpretation of liability and inertness of transition metal complexes on the basis of VBT and CFT. Factors affecting the liability of a complex, transition state or activated complex, substrate, attacking reagents electrophilic and nucleophilic, Nature of central atom. Reactions of metal complexes, ligand substitution reaction, Kinetics of octahedral substitution, acid hydrolysis, factors affecting acid hydrolysis, base hydrolysis, conjugate base mechanism, direct & indirect evidences in favour of conjugate mechanism, anation reaction.

**Unit-II Reaction Mechanism of Transition Metal complexes-II 15 hrs.**

Substitution reaction in square planer complexes: the trans-effect, Theories of Trans effect, uses of trans-effect, cis effect, Electron transfer reactions. Types of electron transfer reactions, conditions of electron transfer, and mechanism of one-electron transfer reactions, outer sphere and inner sphere mechanisms, two electron transfer reactions, complimentary and non-complimentary electron transfer reactions. Marcus Theory, Cross reactions, Inner sphere Reactions, Recimization and isomerisation in transition metal complexes.

**Unit-III Photochemistry 15 hrs.**

Absorption, excitation, photochemical laws and quantum yield, Electronically excited states and their life-time measurement, Electronically excited states of Metal complexes, type of photochemical reactions, substitutions reactions, rearrangement reactions, redox reaction, Photochemistry of Coordination compounds, LMCT states and MLCT states, Charge transfer spectra, charge transfer excitations, methods for obtaining charge transfer spectra.

**Unit-IV Applications of Coordination Compounds 15 hrs.**

Metal Complexes in Analytical Chemistry Inorganic Qualitative Analysis, The 'brown ring' test, Complexometric Titrations, Complexes in Colourimetry, Coordination Compounds in Gravimetry, Stabilization of Oxidation States, Complexes in Separation of Metals. Metal Complexes in Medicinal Chemistry: Complexation in Food Poisoning, Metal Complexes in Therapy. Metal Complexes in Industrial Processes: Heavy Metals-protein Complexes in the Rasching Process, The Ziegler-Natta Catalyst, Metal complexes in alkene conversions, Complexes and Electroplating, Complexes in Metallurgy. Copper Metal dissolves in Aqueous Potassium Cyanide, Complexes in water softening, Metal complexes in Agriculture.

**Reference Books:**


1. R. Gopalan and V. Ramlingam: Concise Coordination Chemistry.
2. J. E. Huheey, Ellen A. Keiter and Okhil K. Medhi: Inorganic Chemistry: Principle of Structure and Reactivity.
3. K. F. Purcell, J. C. Kotz: An Introduction to Inorganic Chemistry.
4. F. Basolo and R. Pearsons: Mechanism of Inorganic Reactions: A Study of Metal Complexes in Solution.
5. Obe, M. L. Inorganic reaction mechanism, Nelson, London, 1972.
6. Taube, electron transfer reactions of metal complex ions in solution. Academic Press, 1970
7. E. S. Gould, Inorganic Chemistry.
8. V. Balzani and V. Cavassiti, Photochemistry of coordination compounds, AP, London, 1970.
9. K. Burger, Coordination Chemistry Experimental methods, Butterworths.
10. K. K. Rastogi and Mukharjee, Fundamentals of photochemistry, Wiley eastern.
11. J. G. Calverts and J. N. Pits, Photochemicals of Photochemistry, John Wiley.
12. Wells, Introduction to Photochemistry.
13. K. M. Macky, R. A. Macky, Modern Inorganic Chemistry, 4th edn., Blackie, London 1989.

## ELECTIVE PAPERS: (Choose any one)

## Paper XII: E-ICHT403(A): Chemistry of Inorganic Materials (4 Cr, 60 hrs)

**Course Outcome (COs):**

**CO1:** At the end of the course students should be able to explain the bonding and structures of the solid-state materials.

**CO2:** After completion of this course students will be able to explain the various defects present in the solid-state materials and their impact on electronic and structural properties of the same. **CO3:** Students will be able to explain the various synthesis methods and advanced instrumentation tools used for characterization of nano-materials.

**CO4:** At the end students will be able to explain the optical, magnetic and structural properties of the nanomaterials and will be able to explain their applications in various industrial fields such as electronic devices, Energy generation and storage, Automobiles, Sports and toys, Textile Industries, Cosmetics Production, etc.

**Unit-I: Solid State Materials** **15 hrs.**

**A)** Bonding in crystals, Crystal systems and Bravais Lattice, Lattice planes and their designation. Metallic Crystal structures: Face-centered cubic (fcc), body-centered cubic (bcc), hexagonal close-packed (hcp) structure. Radius ratio rule (2, 3,4,6,8 co–ordinate structures), octahedral and tetrahedral voids. Isomorphism and polymorphism, Numericals.

**B)** **Simple type structures:**

AB type: NaCl, CsCl, Zinc sulphide (sphalerite or cubic and hexagonal), $AB_2$ type: Fluorite ($CaF_2$), $TiO_2$(Rutile), $CdCl_2$, $CdI_2$ structures, $AB_3$ type: $ReO_3$, $BiI_3$, $A_2B_3$ type: Corundum $Al_2O_3$, α-$Fe_2O_3$, $Mn_2O_3$, $ABO_3$type: Perovskite Structures (Barium titanate, lead titanate, $CaTiO_3$, $FeTiO_3$), $AB_2O_4$ type- Spinel structure, Normal & Inverse, Factors causing distortion in spinel, $A_2B_2O_7$ type: Pyrochlores ($La_2Sn_2O_7$).

**Unit-II: Imperfections in Materials** **15 hrs.**

Perfect &Imperfect crystals, point defects, Interstitial, Schottky defect, Frenkel defect, line defect & other entities, thermodynamics of Schottky& Frankel defects, Dissociation, theory of dislocation, plane defects-Lineage boundary, grain boundary, stacking fault, 3D defects, Defects & their concentrations, ionic conductivity in solids, Non stoichiometric compounds.

Electronic properties of Non-stoichiometric oxides, solid electrolytes, pyknometric & electrical conductivity methods of study of defects, photo-radiation effects on solid nature and properties, photography, colour centers, order-disorder changes, defects, imperfection equilibrium, atom movements, and defect interactions.

**Unit III: Synthesis and Characterization of Nanomaterials 15 hrs.**

General introduction to Nanomaterials, Nanoscience and nanotechnology, History, Chemical Methods: Metal nanoparticles: Reduction method, Semiconducting or composite nanomaterials: Hydrothermal and Solvothermal method, Sol-gel, Arrested Precipitation, and other methods include) Langmuir-Blodgett, Micelles-Microemulsions. Characterization Tools: Electron Microscopy (TEM & SEM), Probe Microscopy (STM & AFM), Diffraction Technique (XRD), UV-Visible-NIR spectroscopy, BET.

**Unit IV: Properties and Applications of Nanomaterials 15 hrs.**

Properties of Nanomaterials: Optical, Magnetic, Electrical, Mechanical, Structural properties Illustrative Nanomaterials: Carbon nanostructures (CNTs, Graphene and its derivatives, fullerenes, Metal oxides (TiO2 and ZnO) & its composites, Quantum dots, Core-Shell nanoparticles, Different morphological nanomaterials. Applications in the various fields: Electronic devices, Energy generation and storage, Automobiles, Sports and toys, Textile Industries, Cosmetics Products, Domestic appliances, Sensors, Biotechnology and medical field, Space and Defense, Catalysis, Environment.

**Reference Books:**


1. New Directions in Solid State Chemistry (Second Eds.),
   C.N.R.Rao and G. Gopalkrishnan, Cambridge Oxford Press.
2. A basic course in crystallography, JAK Tareen, TRN Kutty, Universities press.
3. Essentials of crystallography, M.A. Wahab, Narosa Publications.
4. Synthesis of Inorgnic Materials: Ulrich Schubert, Nicola Hüsing.
5. Solid State Chemistry: Lasley E. Smart, Elaine A. Moore.
6. Introduction to Solid State Physics: Charles Kittel.
7. Solid State Chemistry: A. H. Hanny
8. Wilcox: Preparation and Properties of Solid State Materials: Vol I & II, Dekker
9. Hagenmuller, Preparative Methods in Solis State Chemistry

10. Lohn Wulff, The Structure and Properties of Materials Vol. IV, Electronic Properties (Wily Eastern)
11. Chemistry of Imprefect Crystals (Holland) E.A. Kroger
12. Solid State Chemistry A. R. West,
13. Principles of the Solid-State Chemistry, Wiley Eastern. H. V. Keer:

## Paper XII: E-ICHT403(B): Energy and Environmental Chemistry(4 Cr, 60 hrs)

**Course Outcome (COs):**

**CO1:** At the end, students will be able to: Learn basic concepts of solid waste management, beginning from source generation to waste disposal.

**CO2:** Students should be able to-Characterize the solid waste in terms of hazardous waste components; impact of waste management on health and environment; understand steps towards solid waste management-waste reduction at source, materials and resource recovery/recycling, treatment and disposal techniques.

**CO3:** After completion of the course student will be able to explain the advanced energy conversion devices such as Fuel cells, and the various techniques involves in the production of Hydrogen (future fuel).

**CO4:** Students will be able to demonstrate the reactions involved in the advanced energy storage devices, can predict the theoretical energy storage capacities of such devices, and understand the chemistry of various batteries.

**Unit I: Energy Conversion Devices 15 hrs.**

Fuel Cells: Working of Fuel Cells, Types of fuel cells, Current capabilities/uses, Fuel cell stacks and systems, Hydrogen as a fuel, Production of hydrogen: Electrolysis, Thermochemical Processes, Steam Reformer Processes, Water Gas Processes, Bosch Process, Biosynthesis and Photochemical Processes, Coal Gasification, Steam Iron Process, Partial Oxidation Processes. Storage, Transport, and Handling of Hydrogen.

**UNIT II: Energy Storage Devices: Batteries 15 hrs.**

Li-ion batteries: Principle of operation, Battery components and design, Electrode materials (LiCoO2, LiNiO2, LiNi1/3Mn1/3Co1/3O2, LiMn2O4, LiFePO4, graphitic carbon) their synthesis and characterization, Theoretical capacity, Energy density, power density, cycle life, Electrode and battery fabrication, Battery modules and packs, Li-polymer batteries and applications, Electrolytes for Li-ion batteries, All solid-state batteries. Future developments and beyond lithium batteries: Li-S battery, Li-Air battery, Advanced lead-acid batteries, Sodium-battery, Magnesium battery, Aluminium battery, Silicon battery, Battery Recycling Technologies.

**UNIT III:**

**A) Waste Treatment** **8 hrs.**

Electronic waste recycling programs, E-waste – non-recycling impacts, Materials Used in Manufacturing Electrical and Electronic Products, Solid Waste Management: Gas to Energy projects, Incandescent vs. compact florescent light bulbs, Value-added Material Recovery, Cost effective treatment of refractory organics,

**B) Air and Water Pollution control** **7 hrs.**

Control of NOx, SOx and particulate pollution, Sewage and industrial waste water treatment, water softening, municipal water purification.

**UNIT-IV:**

**A) Monitoring, sampling and Analysis of Air and water pollutants** **8 hrs.**

**B)** Methods of monitoring and sampling of gaseous, liquid and solid pollutants, analysis of CO, $CO_2$, $NO_2$, $SO_2$, $H_2S$, analysis of toxic heavy metals, Cd, Cr, Hg, As, Pb, analysis of anions $SO_4^{2-}$, $PO_4^{3-}$, $NO_3^{-}$, estimation of COD and BOD

**C) Techniques in Environmental Analysis** **7 hrs.**

ND-IR Spectroscopy, FTIR, AAS, ICP-AES, GC, GC-MS, HPLC, Anodic stripping voltammetry with case studies

## Reference Books:


1. Lithium ion Batteries: Basics and Applications, R. Korthauer, Springer
2. Lithium ion Batteries: Fundamentals and applications, Yuping Wu, CRC Press, Taylor & Francis group
3. Lithium ion batteries: Materials, Technology and new applications, K. Ozawa, Wiley 30 Years of Lithium-Ion Batteries, Advanced Materials, M. Li et al., Vol 30, issue 33, 2018,1800561
4. Fuel Cell Fundamentals, R. O'Hayre, et al., John Wiley & Sons, 2016

5. George Techobanoglous et al,”Integrated Solid Waste Management” McGraw - Hill, 1993.
6. Environmental Chemistry, H. Kaur, PragatiPrakashan, 10th edition 2016.
7. Environmental Pollution, A. K. De
8. Environmental Pollution Analysis, S. M. Khopkar
9. Compendium of R&D Projects, Waste Management Technologies (WMT) Programme, Technology Development and Transfer Division, Department of Science and Technology, New-Delhi 2018-2019.
10. Environmental Waste Management, Ed. Ram Chandra, CRC Press 2015, 1st Edition
11. Electronic Waste Management, RSC Publishers, Editors: R E Hester, R M Harrison, 2009.

## Paper XII:E-ICHT403(C): RADIATION CHEMISTRY (4 Cr, 60 hrs)

**UNIT-I: A] Isotopes (08 hrs)**

Difference between Isotopes and Isobars, isotope separation, thermodynamic and kinetic isotope effects, isotope exchange reaction kinetics, determination of exchange rate constant, production and applications of radio isotopes.

**B] Biological effects of Radiation (07 hrs)**

Introduction, genetic and somatic effect on human being, effect of radiation on plants and aquatic Environment.

**UNIT-II: Radiochemical Separation (15 hrs)**

The need of radiochemical separation techniques, carrier techniques, isotope and nonisotopic carriers, coprecipitation and adsorption, ion exchange, solvent extraction, electrolytes behavior of carrier free tracer radionuclide.

**UNIT-III: Principle of tracer chemistry (15 hrs)**

Introduction to tracers, application of tracers in physiochemical studies, diffusion studies, isotopic and exchange reactions, tracer in the study of the mechanism of the inorganic chemical reaction, atom transfer and electron transfer mechanisms. Heterogeneous catalysis and surface area measurements, radio carbon dating, tracer studies with tritium, application in metallurgy and preservation of food, geochemical application and hot atom chemistry.

**UNIT-IV: Radiation detection and measurements (15 hrs)**

Ionization current measurements, multiplicative ion collector, methods not based on ion collection, auxiliary Instrumentation and health physical instruments and counting statistics. Working of Scintillation and Geiger Muller Counter.

## Recommended Books:


1. Friedlander, Kennedy and Miller, Nuclear and radio Chemistry, ohm Wiley.
2. B.G. Harvey, Nuclear Chemistry.
3. Haissinsky, Translated by D.G, Tuck, Nuclear physics and Chemistry.
4. Mark lefort, Nuclear Chemistry, D.V. Nostrand.
5. An N.Nesmeyanov, Radiochemistry, Mir.
6. Jacobs, et al, Basic Principles of nuclear science and reactors, V.Nost, EW AP.
7. N. Jay, Nuclear power, today tomorrow, ELBS.
8. Kenneth, Nuclear power, today and tomorrow, ELBS.
9. Essentials of Nuclear Chemistry, J. Arnikar, John Wiley.


## Paper XII:E-ICHT403(D): APPLIED BIOINORGANIC CHEMISTRY (4 Cr, 60 hrs)

**UNIT-I: An Overview of Characterization Methods in Bioinorganic Chemistry (15 hrs)**

Review the basic principles of these analytical techniques and their application to inorganic biomolecules: Methods used for structural elucidation, as well as mechanistic studies - X-Ray crystallography; nuclear magnetic resonance (NMR) spectroscopy; vibrational spectroscopies, such as infrared (IR) and Raman spectroscopies; and electronic spectroscopies, such as ultraviolet-visible (UV-Vis) spectroscopy and electron paramagnetic resonance (EPR) spectroscopy.

**UNIT-II: Metalloproteins and Metalloenzyme (15 hrs)**

Transition elements in biology - their occurrence and function, active-site structure and function of metalloproteins and metalloenzymes with various transition metal ions and ligand systems; O2 binding properties of heme (haemoglobin and myoglobin) and non-heme proteins hemocyanin & hemerythrin), their coordination geometry and electronic structure, co-operativity effect, Hill coefficient and Bohr Effect; characterization of O2 bound species by Raman and infrared spectroscopic methods; representative synthetic models of heme and non-heme systems.

Electron transfer proteins - active site structure and functions of ferredoxin, rubredoxin and cytochromes, and their comparisons. Vitamin B12 and cytochrome P450 and their mechanisms of action.

**UNIT-III: A] Applications of bioinorganic chemistry** **(8 hrs)**

Metals in medicine - therapeutic applications of anti-cancer agents e.g. cis-platin, radiopharmaceuticals – e.g. radio-isotopes Tc and I2, and MRI agents e.g. Gd in MRI. Toxicity of Hg, Cd, Pb and As and chelation therapy.

**B] Nitrogen Fixation, Nitrification, Denitrification** **(7 hrs)**

Transport of O2 **-** the hemoglobin family, the hemocyanin family.

**UNIT-IV: A] Trace Metals in Plant Life** **(8hrs)**

Micronutrients in soil, role of micronutrients in plant life

**B] Biogeochemistry** **(7 hrs)**

Biodegradation of minerals bacteria leaching and its applications.

## Recommended Books:

1. D. F. Shriver, P. W. Atkins and C. H. Langford, Inorganic Chemistry, Oxford Univ. Press, 1990.

2. J. E. Huheey, E. A. Keiter and R.L. Keiter Inorganic Chemistry, Principles of Structure and Reactivity, Pearson Education, 2004.

3. F. A. Carey G. Wilkinson, C. A. Murillo and M. Bochmann, Advanced Inorganic Chemistry, Wiley Interscience, 2003.

4. C. E. Housecroft and A. G. Sharpe, Inorganic Chemistry, Prentice Hall, 2005.

5. S. J. Lippard and J. M. Berg, Principles of Bioinorganic Chemistry, Univ. Science Books, 1994.

6. W. Kaim and B. Schwederski, Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life (An introduction and Guide), John Wiley & Sons, 1994.

**7.** Eichhorn: Inorganic Biochemistry : Vol I , 2 Elsevier

8. Ochiai: Bioinorganic Chemistry: Allyn & Bacon Burton

9. Williams: an Introduction to Bioinorganic Chemistry, C.C. Thomos Spring III

10. Wallace: Decade on synthetic chelating agent in Inorganic plant nutrition, Wallace

## Inorganic Chemistry Practical Course

## ICHP404: Practical-VII (4 Cr, 120Hrs)

## List of Experiments

1. Ore Analysis -3
2. Preparation of coordination compounds (Three) and preparations of mixed metal Oxides (two)
3. Ion Exchange chromatography; separation of multicomponent mixtures
4. Spectrophotometry
5. pH Metry
6. Conductometry
7. Polarography
8. Electrogravimetry
9. Nuclear and radiochemistry
10. Analysis of Portland cement
11. Pigment [e.g. chromium from Zinc chrome]
12. Pharmaceutical products [e.g. magnesium from tablet of "Milk of magnesia", calcium from calcium-supplementary tablet, iron and zinc from iron- (and zinc)-supplementary capsule]
13. Consumer products [e.g. aluminium from alum]
14. Ion exchange chromatography [separation and estimation of mixture of zinc (II) and magnesium (II)]

**15.** Synthesis of coordination compounds:

i) $M(acac)_2 \cdot xH_2O$ [where $M^{+2} = Mn^{+2}, Co^{+2}, Cu^{+2}$, x = 2,2,0 respectively]

$M(acac)_3$ [where $M^{+3} = Mn^{+3}, Fe^{+3}$]

ii) trans-$[Co(en)_2Cl_2]Cl$ / cis-$[Co(en)_2Cl_2]Cl$

iii) $[Ni(en)_3]S_2O_3$ / $Hg[Co(SCN)_4]$

iv) $[Fe(1, 2, 4\text{-triazole})_3](ClO_4)_2$

v) $Fe(DTC)_3$

**Note: Any other experiments may be added when required**

## RP-405 Research Project (06 Cr, 180 Hrs)

**See Annexures II for details (In the end of this document).**

**Note: Study tour is compulsory for M. Sc. Part- II Students to visit Chemical Industries in India.**

# Shivaji University Kolhapur

## Syllabus as per NEP-2020

**For**

**M. Sc. Part- II Organic Chemistry**

**Semester III & IV**

## Under the Faculty of Science and Technology

**To be implemented with effect from Academic Year 2026-2027**

This is applicable for University Department and Affiliated College PG Centres

# M. Sc. Part II: Organic Chemistry
# (SEM-III and SEM-IV)

M. Sc. Organic Chemistry, a post-graduate degree program of the Shivaji University, is one of the best in the country because it’s curriculum involves most advanced topics like Organic reaction mechanism, Advance spectroscopic methods, Advance synthetic methods, Drug and Heterocycles, Theoretical Organic Chemistry, Stereochemistry, Chemistry of Natural Products, Applied organic chemistry, etc. and the practical training based on these advanced topics required to understand problems of the present time. Successful students of this course are capable of doing independent research work not only in relevant world class laboratories but also in R&D sectors and in quality teaching institutes.

**Programme Educational Objectives (PEOs):**

**PEO-1:** To provide students with advanced theoretical and practical knowledge in organic chemistry, enabling them to understand and solve complex chemical problems in both academic and industrial settings.

**PEO-2:** To cultivate a strong foundation in organic synthesis, reaction mechanisms, spectroscopy, and modern analytical techniques, thereby preparing students for research, innovation, and higher studies (Ph.D., Postdoctoral Research, etc.).

**PEO-3**: To in still professional ethics, scientific temper, teamwork, and effective communication skills necessary for careers in academia, pharmaceutical industries, chemical manufacturing, or entrepreneurship.

**PEO-4:** To encourage lifelong learning, critical thinking, and application of organic chemistry knowledge to address societal and environmental challenges through green chemistry and sustainable practices.

**Program Outcomes (POs):**

**PO1**: Students will be able to acquire in depth knowledge about fundamental as well as applied organic chemistry concepts.

**PO2:** Students will be able to solve various problems by identifying the essential parts of a problem, formulate strategy for solving the problem, applying appropriate techniques to arrive at a solution, test the precision an accuracy of the solution and interpret the results.

**PO3**: Students will be able to acquire domain specific knowledge and technical skills needed for employment in industries, teaching fields and pursue research.

**PO4**: Students will be able to apply the fundamental knowledge to address the cross-cutting issues such as sustainable development

**PO5**: Students will get perfect insight into organic chemistry research ethics for production of quality research.

**PO6**: Students will be able to communicate effectively i. e. being able to comprehend and write effective reports, make effective presentations and documentation and capable of expressing the subject through technical writing as well as through oral presentation.

**Program Specific Outcomes (PSOs):**

Upon completion of the M.Sc. Chemistry program, post graduates will possess the ability to:

**PSO1**: Students will be able to qualify competitive examinations like NET, SET, GATE, etc.

**PSO2**: Students will have opportunities to serve in different Chemical, Pharmaceutical as well as food and agrochemical industries.

**PSO3**: Students will have global level research opportunities in Ph.D. programme.

**PSO4**: Collaborate effectively on team-oriented projects in the field of Chemistry or other related fields.

**PSO5**: Students can start their own chemical industry / business (entrepreneurship).

**PSO6**: Students will be able to interpret NMR, MS, IR for structural elucidation

## Organic Chemistry: SEMESTER- III

**MANDATORY PAPERS**

Paper VII: OCHT301 (4 Cr): Organic Reaction Mechanism

Paper VIII: OCHT302 (4 Cr): Advanced Spectroscopic methods

OCHP304 (4 Cr): Practical-V

OCHP305 (2 Cr): Practical-VI

RP-306 (4Cr): Research Project

**ELECTIVE PAPERS: (Choose any one)**

Paper IX: E-OCHT303 (A) (4 Cr): Advanced Synthetic methods-I

Paper IX: E-OCHT303 (B) (4 Cr): Medicinal Chemistry

Paper IX: E-OCHT303 (C) (4 Cr): Chemistry of Heterocycles

Paper IX: E-OCHT303 (D) (4 Cr): Polymer Chemistry

## Organic Chemistry: SEMESTER- IV

**MANDATORY PAPERS**

Paper X**:** OCHT401 (4 Cr): Stereochemistry

Paper XI: OCHT402 (4 Cr): Chemistry of Natural Products

OCHP404 (4 Cr) : Practical-VII

RP-405 (6 Cr) : Research Project

**ELECTIVE PAPERS: (Choose any one)**

Paper XII: E-OCHT403 (A) (4 Cr): Theoretical Organic Chemistry

Paper XII: E-OCHT403 (B) (4 Cr): Applied Organic Chemistry

Paper XII: E-OCHT403 (C) (4 Cr): Bioorganic Chemistry

Paper XII: E-OCHT403 (D) (4 Cr): Advanced Synthetic Methods-II

## DETAILED SYLLABUS:

## Paper VII: OCH301: Organic Reaction Mechanism (4 Cr, 60 hrs.)

## Course Outcomes (COs):

On completing the module students will be able to:

CO1: Adopt the knowledge about the pathway and determine reaction rates using kinetic and non-kinetic methods. This involves steps such as reaction rate determination, order and molecularity, testing and trapping of intermediates, stereochemistry, and the Hammet-Taft equation.

CO2: Familiarize with the concept of Pericyclic reactions, Woodward-Hoffmann correlation diagrams, and the Frontier Molecular Orbital (FMO) and Molecular Orbital (PMO) approaches. Understand conrotatory and disrotatory motion, and be able to identify reactions as 4n, 4n+2, and 2+2 addition of ketenes. Additionally, learn about sigmatropic shifts (3,3) and (5,5), Claisen and Cope rearrangements, and Aza-Cope rearrangement.

CO3: Learn the new concept of supramolecular chemistry, advanced synthetic methods by using microwave ovens, ultrasound waves, using enzymes, electroorganic synthesis, use of multicomponent reactions as well as the use of Ionic liquids in chemical reactions.

CO4: Adapt the knowledge about photochemistry – photochemical reactions, their types, and laws of photochemistry. Also, know quenching and chemiluminescence.

**Unit I: Methods of determining reaction mechanism 15 hrs.**

**(A) Kinetic Methods:** Order and Molecularity, Methods of following reaction rates, Types of reactions: 1st, 2nd, and 3rd order reactions, Reversible, Consecutive, and Parallel reactions Energy of Activation, Entropy of Activation, Effect of Ionic strength, Solvent effect, and Kinetic isotopic effect

**(B) Non-Kinetic Methods:** Identification of reaction products, Testing of the possible intermediates, Trapping of the intermediates, Isotopic labelling, Reaction catalysis, Crossover experiments, Stereochemical studies, and Use of physical properties. Hammett and Taft equations.

**Unit II: Pericyclic reactions 15 hrs.**

Molecular orbital symmetry, Frontier orbital of ethylene, 1,3- butadiene, 1,3,5-hexatriene and allyl system, Classification of peri cyclic reaction, Wood-ward Hoffman correlation diagrams, FMO and PMO approach, Electrocyclic reactions, Conrotatory and disrotatary motions, 4n, 4n+2 and allyl systems, Cycloaddition, and supra and antara facial additions, 4n and 4n+2 systems, 2+2 additions of ketenes, 1,3-dipolar cycloaddition and Chelotropic reactions, Sigmatropic rearrangement, supra and antarafacial shifts of H, Sigmatropic shifts involving carbon moieties, (3,3) and (5,5) sigmatropic rearrangement and Claisen and Cope and Aza Cope rearrangement, Ene reaction.

**Unit–III: Applications of the following methods in organic synthesis 15 hrs.**

(a) Synthesis and applications of Merrifield resin

(b) Electro-organic synthesis

(c) Enzyme catalyzed reaction

(d) Solvent free synthesis

(e) Multicomponent reactions

(f) Microwave techniques and their applications

(g) Ultrasound techniques and their applications

(h) Mechano chemical synthesis

**Unit IV: Free radical reactions** **15 hrs.**

Types of free radical reactions, Detection by ESR, Mechanism of free radical substitution, Neighbouring group assistance. Reactivity for aliphatic and aromatic substrates at a bridgehead. Reactivity in attacking radicals. The effect of solvent on reactivity. Allylic halogenation (NBS), Oxidation of aldehydes to carboxylic acids, Auto-oxidation, Coupling of alkynes, Arylation of aromatic compounds by diazonium salt, Sandmeyers reaction, Hunsdiecker reaction.

## Reference Books:


1. A guide book to mechanism in organic chemistry (orient- Longmans)- Peter Sykes
2. Organic Reaction Mechanism (Benjumin)- R. Breslow
3. Mechanism and structure in Organic Chemistry (Holt Reinhartwinston)- B. S. Gould
4. Organic chemistry (McGraw Hill)- Hendrikson, cram and Hammond
5. Basic principles of organic chemistry (Benjamin) J. D. Roberts and M. C. Caeserio.
6. Enzyme catalysed reactions.C. J. Gray:
7. Electroorganic Chemistry. T. Shona:
8. Phase transfer catalyst in organic synthesis. Weber & Gokel
9. Fundamentals of photochemistry K. K. Rohtagi- Mukherji Wiley- Eastern
10. Essentials of molecular photochemistry, A. Gilbert and J. Baggott. Blackwell Scientific Publication.
11. Molecular photochemistry, N.J. Urro, W. A. Benjamin
12. Introductory photochemistry. Cox and T. Camp McGraw -Hill
13. Photochemistry R.P. Kundall and A. Gilbert. Thomson Nelson.
14. Organic photochemistry J. Coxon and B. Hallon Cambridge University press.

## Paper VIII: OCHT302: Advanced Spectroscopic methods (4 Cr,60 hrs.)

## Course Outcomes (COs):

Upon course completion the student is able to:

CO1: Learn about the principles and theory behind UV and IR spectroscopy, including molecular vibrations due to IR radiation absorption and electronic excitations from UV radiation absorption. This will help students identify unknown organic compound structures and recognize functional groups such as alcohol, aldehyde, ketone, ester, and aromatic compounds. They will also study overtones, combination bands, and Fermi resonance in FT-IR spectroscopy.

CO2: Recap proton NMR spectroscopy, factors affecting coupling constants, analyse first-order spectra, simplify complex spectra, understand second-order spectra, effect of deuteration, and spectra of Homotopic, Enantiotopic, and Diastereotopic systems. Also, learn about the Advanced NMR technique, Fourier transform technique, Nuclear Overhauser Effect (NOE), COSEY, NOSEY, and resonance of F19 and P31 nuclei.

CO3: Learn about ion production methods (EI, CI, FD, and FAB) and factors affecting fragmentation analysis. Also understand mass spectral fragmentation of functional groups (e.g., aldehydes, ketones, esters, alcohols) to solve mass spectroscopy problems.

CO4: Understand the concept of C13 NMR spectroscopy – chemical shift values of alkanes, alkenes, alkynes, aromatic compounds, carbonyl and heterocyclic compounds. Also learn this advanced C13 technique – NOE, DEPT, HETCOR and heteronuclear coupling. They will become confident to solve the problems on C13 NMR.

**UNIT–I: Study of Ultraviolet and IR Spectroscopy 15 hrs.**

**(A) Ultraviolet Spectroscopy: (5)**

Woodward-Fisher rules for conjugated dienes and carbonyl compounds, Calculation of $\lambda$ max of conjugated dienes and carbonyl compounds. Ultraviolet spectra of aromatic and heterocyclic compounds, Steric effect in biphenyls.

**(B) IR Spectroscopy: (10)**

Characteristic vibrational frequencies of ( i ) alkanes, ( i i ) alkenes, ( i i i ) alkynes, (iv) aromatic compounds, (v) alcohols, (vi) ethers, (vii) phenols, (viii) amines. Detailed study of vibrational frequencies of carbonyl compounds; (i) ketones, (ii) aldehydes (iii) esters (iv)amides (v) acids (vi) anhydrides (vii) lactones (viii) lactams, and (ix) conjugated carbonylcompounds. Effect of hydrogen bonding and solvent effect on vibrational frequencies, Overtones, combination bands, and Fermi resonance, FT-IR of gaseous; solids and polymeric materials.

**UNIT- II: NMR Spectroscopy 15 hrs**

General introduction and definition; chemical shift, spin-spin interaction, shielding mechanism of measurement, Chemical shift values, and correlation for protons bonded to (a) carbons: aliphatic, olefinic, aldehydic, and aromatic and (b) other nuclei: alcohols, phenols, enols, acids, amines, amides and mercaptons, Chemical exchange; effect of deuteration, Complex spin-spin interaction (first order spectra) between (i) two (ii) three (iv) four and (v) five nuclei, Virtual coupling, Stereochemistry; hindered rotation, Karplus curve variation of coupling constant with dihedral angle, Simplification: Simplification of complex spectra, nuclear magnetic double resonance, shift reagent, solvent effect. Fourier transform technique, Nuclear overhauser effect [NOE], NMR of F, and P nuclei.

**UNIT-III: Mass Spectrometry 15 hrs.**

Introduction of MS, Ionization methods; (i) EI, (ii) CI, (iii) FD (iv) FAB, and (v) MALDI-TOF, Factors affecting on fragmentation, Ion analysis, Ion abundance. Molecular ion peak, Metastable peak, McLafferty rearrangement, Nitrogen rule. Mass spectral fragmentation of organic compounds; (i) hydrocarbons (aliphatic and aromatic), (ii), carbonyls (aldehydes, ketones, acids, acid chlorides, esters, amides), (iii) halogen compounds (iv) amines, (iv) nitro compounds, Highresolution mass spectrometry (HRMS).

**UNIT-IV: Study of 13C NMR and Combined problems 15 hrs**

**(A) Carbon-13 NMR Spectroscopy: (7)**

General considerations; chemical shift; aliphatic, olefinic, alkyne, aromatic, heteroaromatic, and carbonyl compounds, problems associated with 13C, FT- NMR, proton decoupled off-resonance.

**(B) Structural Problems: (8)**

Structural problems based on combined spectroscopic techniques (including reaction sequences)

## Reference Books:

1. V.M. Parikh, Application spectroscopy of organic molecules. (Mehta)
2. D.W. Williams and Flemming, Spectroscopic methods of organic compound.
3. Silverstein and Basslar, Spectroscopic identification of organic compounds V.M. Parikh ORPTION SPECTROSCOPY OF ORGANIC MOLECULES ( J. Wiley )
4. P.S. Kalsi Spectroscope of organic compounds ( New age publisher )
5. J.R. Dyer. Application of absorption spectroscopy of organic compounds.
6. Jackman and Sterneil , Application of NMR spectroscopy
7. Nuclear magnetic resonance. J.D. Roberts (J. Wiley)
8. Theory and application of U.V. Jafee and Orchin.
9. Mass spectroscopy K. Benjamin.
10. The mass spectra of organic molecules. Beynon J H.
11. Interpretation of carbon 13 NMR Wehli F.W, Marchand A. P. ( J. Wiley )
12. Organic Spectroscopy W. Kemp, ELBS
13. Instrumental methods of analysis CBS. Willard Merritt and Dean.
14. Mass Spectroscopy. Das and Jame
15. Organic structural spectroscopy: J. B. Lambert, S. Gronert, H. F. Shurvell, D. Lightneli, R. G. Cooks (Prentice Hall 2 nd editi

## ELECTIVE PAPERS: Choose Any one

## Paper IX: E-OCHT303 (A): Advanced Synthetic methods (4 Cr, 60 hrs)

## Course Outcomes (COs):

On completing the module students will be able to:

CO1: Understand the concept of the disconnection approach through the introduction of synthons, synthetic equivalents, and functional group interconversions. Also, understand retrosynthesis of difunctional compounds. Importance of the order of reaction in organic synthesis. They will learn Diel's Alder reaction, Michael addition, Robinson annulation, and what is meant by Umpolung reaction.

CO2: Study the applications of different reagents in chemical reactions and also study of Woodward – Prevost hydroxylation, Barton and Shapiro reaction as well as Grub's catalysis.

CO3: Learn how the different metals and ligands in organic chemistry.

CO4: Learn about the mechanisms, stereochemistry, migratory aptitude, and applications of different name reactions,Ylide chemistry and its applications.

**UNIT- I: Disconnection Approach** **15 hrs.**

(a) Terms involved in retrosynthesis; synthons, synthetic equivalents, disconnection approach, functional group interconversions.

(b) Importance of the order of events in organic synthesis

(c) Chemoselectivity, Regioselectivity, and Stereoselectivity, Protecting groups,

(d) One group C-X and two group disconnections in (i) 1, 2, (ii) 1, 3 (iii) 1, 4, and (iv) 1, 5-difunctional compounds,

(e) Retrosynthesis of (i) alkanes (ii) alkene, (iii) acetylenes, (iv) nitro (v) alcohols (vi) carbonyl compounds, (vii) amines, (viii) aromatic heterocycles (ix) 3, 4, 5 and 6 membered rings.

(f) Reversal of polarity (Umpolung).

(g) Use of Diels-Alder reaction, Michael addition, and Robinson annulation in Retrosynthesis

**UNIT– II: Applications of the following in organic synthesis** **15 hrs.**

(A) Reagents: Lithium diisopropylamide(LDA) Dicyclohexyl carbodiimide(DCC), lead tetra acetate, PPA, Diazomethane, ozone, phase transfer catalyst, Selenium dioxide, Dess Martin periodinane, and iodoisobenzyldiacetate, periodic acid

(B) Reactions: Woodward-Prevost hydroxylation, Barton and Shapiro reaction, Hoffmann–Loffler-Fretag, Peterson synthesis, Olefin metathesis using Grub's catalysts.

**UNIT- III: Applications of metals and ligands in organic synthesis** **15 hrs.**

**(A) Applications of metals in organic synthesis** **(7)**

(i) Ti, (ii) Ce, (iii) Tl and (iv) Si

**(B) Applications of ligands in organic synthesis: Synthesis and Applications** **(8)**

(i) Phosphines, (ii) N-heterocyclic carbenes (NHC), and (iii) Oxazoline

**Unit IV: Study of the intermediate and name reactions** **15 hrs.**

**(A) Ylids:** Nitrogen, Sulfur and Phosphorous ylides: Synthesis and applications in organic synthesis.

**(B) Name Reactions:** Alkyne metathesis reaction, Weinreb ketone synthesis, Petasis reaction, Henry reaction, Corey Kim oxidation. Reactions of carboxylic acids and esters.

## Reference Books:

1. Designing of organic synthesis. S. Warren
2. Organic synthesis J. Fuhrhop & G. Penzlin. (2nd ed.)
3. Some modern methods of organic synthesis.Carruthres:
4. Modern synthetic reaction. H. O. House
5. Reagent in organic synthesis. Fieser & Fieser
6. Principle of organic synthesis. R. O. C. Norman
7. Advanced organic Chemistry. Carey & Sundharg
8. Organic synthesis. P. E. Realand:
9. Comprehensive organic Chemistry. Bartan and Ollis :
10. Organic reactions. R. Admas:
11. Advances in organometallic Chemistry. Stone & West:
12. Transition metal intermediate in organic synthesis. C. W. Bird:
13. Organometallic in organic synthesis. Swan & black :
14. Polymer supported reaction in organic synthesis. P. Hodge & D. C. Sherrington:
15. Reactive intermediates in organic chemistry, (J. Wiley) N. S. Issacs.
16. Organic reaction mechanism (McGraw Hill ) R. K. Bansal
17. Strategic applications of named reactions in organic synthesis by Laszlo Kurti and Barbara Czako.

## Paper IX: E-OCHT303 (B): Medicinal Chemistry (4 Cr, 60 hrs.)

**Course Outcomes (COs):**

CO1: Understand the principles of drug design and discovery, including concepts like prodrugs, isosterism, bioisosterism, pharmacophores, and QSAR, and apply these concepts in evaluating drug-receptor interactions and structure–activity relationships.

CO2: Explain and interpret pharmacokinetic and pharmacodynamic processes, including drug absorption, distribution, metabolism, excretion, enzyme inhibition/stimulation, and toxicity mechanisms, essential for determining drug efficacy and safety.

CO3: Demonstrate knowledge of synthesis, classification, and mechanism of action of various clinically important drug classes, such as antibiotics, anaesthetics, antimalarials, anti-inflammatory agents, and psychoactive drugs.

CO4: Analyze and describe the mechanism of action, synthesis, and therapeutic applications of drugs used in treating major diseases, including tuberculosis, cancer, cardiovascular conditions, and AIDS, with a focus on recent developments and natural products.

**Unit-I: Drug and Drug Design** **15 hrs**

Concepts of prodrugs, hard and soft drugs, Isosterism, bioisosterism, agonists, antagonist, pharmacophores, lead molecule, lethal dose (LD50) and effective dose (ED50), drug receptors. Procedures followed in drug design, factors affecting development of new drugs,factors affecting bioactivity, Theories of drug activity, Structure activity relationship (SAR), QSAR theory.

**Unit-II:** **15 hrs.**

**a) Pharmacokinetics:** Introductions, Drug Absorption, Distribution and Disposition of Drugs, Excretion and Elimination, Pharmacokinetics of Elimination.

**b) Pharmacodynamics:** Introduction, Enzyme Stimulation, Enzyme Inhibition, Membrane Active Drugs, Drugs Metabolism, Biotransformation, Toxicology, Types of Interactions.

**Unit-III:** **15 hrs.**

a) **Study of Antibiotics:** Introduction and Classification of antibiotics, Synthesis of Penicillin G, Penicillin V, semi synthetic penicillin: Ampicillin and Amoxycillin, Conversion of penicillin into cephalosporin, Tetracyclin and Strectomycin.

b) **General anaesthetics and local anaesthetics:** Introduction, Classification, Mode of Action and mechanism of action of general and local anaesthetics.

**Unit-IV:** **15 hrs.**

**Study of the Following Drugs**

**a) Antimalerials:** Trimethoprim, Amodiaquine

**b) Analgesic & Antipyretics:** Meperidine, Aminopyrine, Diflunisal

**c) Anti- inflammatory:** Oxyphenylbutazone, Indomethacin

**d) Antitubercular & antileprotic:** Dapsone, Pyrazinamide, Ethionamide

**e) Anaesthetics:** Lidocaine, Thiopental

**f) Antihistamines:** Cyproheptadine, Cetirizine

**g) Psychoactive:** Ethiosuximide, Glutethimide

**h) Antiinfective:** Grisefulvin, norfloxacin

**i) Cardiovascular:** Warfarim, Clofibrate, Quinidine, Methyldopa, Atenolol

**j) Anti-neoplastic:** Recent development in cancer chemotherapy. Hormones and natural products. Synthesis of (i) Mechloraethamine, (ii) Cyclophosphamide, (iii) Mephalan, (iv) Uracils, (v) Mustards.

**k) Anti-AIDS:** General study

**Reference Books**

1. Medicinal Chemistry. Burger
2. Medicinal Chemistry A. Kar. (Wiley East)
3. Principals of medicinal chemistry.W. O. Foye:
4. Text book of organic medical and pharmaceutical chemistry. Wilson, Gisvold &Dorque:
5. Pharmaceutical manufacturing encyclopedia.
6. D. Sriram, P. Yogeeswari: Medicinal Chemistry
7. Medicinal Chemistry by Alka L. Gupta.
8. Medicinal Chemistry by AshutoshKar, New Age International Publishers

## Paper IX: E-OCHT303 (C): Chemistry of Heterocycles (4 Cr, 60 hrs.)

**Course Outcomes (COs):**

CO1: Understand and apply IUPAC nomenclature rules to systematically name a wide range of heterocyclic compounds, including small, fused, and multi-heteroatom ring systems.

CO2: Explain the synthesis, structural features, and chemical reactivity of 3-, 4-, 5-, 6-, and 7-membered heterocycles containing nitrogen, oxygen, and sulfur atoms.

CO3: Analyze and compare the synthetic routes and reactions of benzofused heterocycles and diazines/triazines, emphasizing their aromaticity, electronic effects, and functional group transformations.
CO4: Recognize the structure, biosynthetic origin, and biological significance of naturally occurring heterocycles, highlighting their roles in medicinal and biological chemistry.

**Unit – I** **15 hrs.**

**A) Nomenclature of Heterocyclic Compounds**

**B)Small ring heterocycles:**

3 and 4 membered heterocycles: Synthesis and reactions of (i) aziridines, (ii) oxiranes,
(iii) thiranes, (iv) azetidines v) oxitanes and vi) thietanes

**Unit - II:** **15 hrs.**

**A) Five membered heterocycles with one heteroatom:** Pyrroles, Furans, Thiophenes

**B) Benzofused five membered Heterocycles with one and two heteroatom**: Synthesis and reactions of benzopyrroles, benzofurans, benzothiophenes, benzimidazole, benzoxazoleand benzthiazole

**Unit - III:** **15 hrs.**

**A) Six membered Heterocycles with one heteroatom:** Synthesis and reactions of pyrilium salts, pyrones, coumarins, chromones.

**B) Six membered Heterocycles with two and more Heteroatoms:** Synthesis and reactions of diazines & triazines

**Unit - IV:** **15 hrs.**

**A) Seven membered heterocyclic compounds:** Azepine, Oxepine, Thiepins

**B) Study of some naturally occurring heterocycles:** Caffeine, Guanine, Thiamine, Biotin, Xanthones

## Reference Books:

1) An introduction to chemistry of heterocyclic compounds. R. M. Acheson :( Interscience).

2) Heterocyclic chemistry. Joule &Smith: (Van Nostrand).

3) Heterocyclic chemistry. R. K. Bansal: (Wiley E).

4) Principals of modern heterocyclic chemistry.L. A. Paquitte:
5) The structure and reactions of heterocyclic compounds.M. H. Palamer:
6) Advances in Heterocyclic chemistry. A. R. Katritzky: (A.P.).
7) Organic chemistry (Vol. 1& 2) Finar.
8) Heterocyclic Chemistry. Vol-1-3, R. R. Gupta, M. Kumar and V. Gupta, Springer Veriag.
9) The Chemistry of Heterocycles. T. Eicher and S. Hauptmann, Thieme
10) Heterocyclic Chemistry. J. A. Joule, K. Mills and G. F. Smith, Chapman and Hall
11) Heterocyclic Chemistry. T. L. Gilchrist, Longman Scientific Technical
12) Contemporary Heterocyclic Chemistry. G. R. Nikome and W. W. Poudler, Willey
13) An Introduction to Heterocyclic Compounds, R. M. Acheson, J. Willey
14) Comprehensive Heterocyclic Chemistry. A. R. Katritzky and C. W. Rees

## Paper IX: E-OCHT 303 (D): Polymer Chemistry (4 Cr, 60 hrs.)

## Course Outcomes (COs):

CO1: Understand and explain fundamental concepts of polymer chemistry including monomers, polymerization techniques, molecular weight, and glass transition phenomena.
CO2: Analyze the crystalline nature, structural variations, and synthesis techniques of different classes of polymers, including homopolymers, copolymers, and stereoregular polymers.
CO3: Evaluate the types and mechanisms of polymer degradation and characterize polymers using molecular weight determination, rheological properties, and thermal analysis techniques.
CO4: Apply knowledge of polymer properties and reactions to synthesize, process, and identify the appropriate application areas for commercial and advanced polymers such as conducting and biomedical polymers.

**UNIT-I: 15 hrs.**

**Terminology and basic concepts of Polymers:** Monomers, Functionality, repeat units, degree of polymerization. General structure and naming of polymers. Average molecular weight and average chain dimension concept. Expressions for average molecular weighs. Molecular weight distribution and Polydispersity. Classification based on various considerations-source, preparation methods, thermal behavior, chain structure etc.

**Types** –Homopolymers and copolymers; linear, branched and network polymers.

**Techniques of polymerization:** Techniques of preparation of addition and condensation polymers.

**Kinetics of Polymerization**: Kinetics and mechanism of addition and condensation polymerization. Kinetics of copolymerization-reactivity ratio and copolymer equation. Free radical chain polymerization- Cationic polymerization – Anionic polymerization – Poly condensation. Glass transition temperature: Glassy solids and Glass transition – associated properties – Factors influencing glass transition temperature – molecular weight – Plasticisers – melting point – importance of glass transition temperature.

**UNIT –II: 15 hrs.**

**Crystalline Nature:** Crystalline soils and their behaviour towards X-rays – Polymers and X-ray diffraction – Degree of crystallinity – crystallites –factors affecting crystallinity, Helix structures.

**Copolymerization:** Free radical copolymerization – Ionic copolymerization – Copolycondensation – Individual monomers: Polyethylene, polypropylene, polystyrene, poly acrylonitrile, polymethyl methacrylate, polyesters, polycarbonates, polyamides, polyurethanes, polyvinyl acetate, polyvinyl chloride, poly isoprene's, silicone polymers.

**UNIT –III: 15 hrs.**

**Polymer degradation**: Types of degradation, thermal and mechanical – photo degradation – oxidative and hydrolytic degradation. Polymer reactions – Hydrolysis, acidolysis, aminolysis, hydrogenation, addition and substitution reactions – cyclisation, cross-linking reactions – Graft and Block copolymers.

**Experimental methods**: Polymer synthesis, isolation and purification of polymers – Fractional - Molecular weight determination – Molecular weight distribution curve – determination of glass transition temperature. Elastomeric materials – Fibre forming materials – Plastic material Rheology of polymeric materials – compounding and processing techniques.

**UNIT-IV: 15 hrs.**

**Stereochemistry of polymers:** Geometric and optical isomerism in polymers. Structure, properties and preparation of stereoregular polymers.

**Determination of molecular weight:** Osmometry and viscometry.

**Thermal Characterization:** Glass Transition and melting-correlation with structure-Factors affecting Tg and Tm. Techniques of thermal characterization: DSC, DTA, DTG and TGA techniques.

**Structural features, properties and uses of commercial polymers:** Polyethylene, polystyrene, PVC, polyesters, polyamides, polyurethanes and polycarbonates. Conducting polymers, liquid crystal polymers and biomedical polymers.

## Reference Books:


1. Contemporary Polymer Chemistry-H.R. Allcock and F.W. Lampe (Prentice Hall).
2. Polymer Science and Technology-J.R. Frird (Prentice Hall).
3. Polymer Science: V.R. Gowariker, N.V.Viswanathan & T.Sreedhar
4. Principles of Polymer Science- P.Bahadur and N.V.Sastry (Narosa Publishers)
5. 'Organic Polymer Chemistry', K.J.Saunders, Chapman and Hall, 1976.
6. 'Polymer Chemistry – An Introduction', Raymond B.Seymour, Marcel Dekker Inc., New York and Based, 1981.
7. 'Text Book of Polymer Science', Fred W.Billmeyer, Jr.John-Wiley and Sons, 3rd Edn. 1984.
8. 'Fundamentals of Polymer Science and Engineering', Kumar Gupta, Tata Mc Graw Hill, 1981.
9. "Polymer Characterization of Processing Technolgy', Stepak, Academic Press, London.
10. 'Inorganic Polymers', Stone, Academic Press, New York.
11. Polymer Chemistry, B.K.Sharma, Krishna Prakashan Mandir, Meerut.


## Organic Chemistry Practical Course

## Practical-V: OCHP304 (4 Cr, 120 Hrs)

## Course Outcomes (COs):

CO1: Apply semi-micro qualitative analysis techniques to systematically separate and purify organic compounds in ternary mixtures.

CO2: Demonstrate proficiency in using thin-layer chromatography (TLC) for the monitoring of separation and purification processes.

CO3: Perform and interpret relevant chemical tests to identify functional groups and classify organic compounds.

CO4: Demonstrate critical thinking and analytical reasoning in drawing conclusions about compound identities from experimental data.

**Qualitative Analysis**

Separation, purification and identification of compounds of ternary mixtures using **semi-microanalysis**, TLC, column chromatography and chemical tests. IR spectra to be used for functional group identification. (Minimum 10 ternary mixtures to be analyzed during the course)

**Note: Any other experiments may be added when required.**

## Practical paper-VI: OCHP305 (2 Cr, 60 Hrs)

## Course Outcomes (COs):

CO1: Apply fundamental principles of organic synthesis to perform two-step preparations of pharmaceutically and industrially relevant organic compounds.

CO2: Demonstrate proficiency in isolation, purification, and recrystallization techniques to obtain pure products from multistep organic reactions.

CO3: Analyze the structural and functional features of synthesized compounds using classical characterization methods (melting point, solubility, chemical tests).

CO4: Evaluate the efficiency of synthetic routes by calculating percentage yields and assessing reaction conditions, reagents, and green chemistry principles.

**Quantitative Analysis**

**1. Two step Preparations (Any Five)**

a) Preparation of m-Nitroaniline

b) Preparation of Benzanilide from benzophenone

c) Preparation of Phthalimide

d) Preparation of N-Bromosuccinimide

e) Preparation of 4-methyl -7-acetoxy coumarin

f) Preparation of 1, 2, 3, 4- Tetrahydro carbazole

g) Preparation of p-ethoxy acetanilide

**Note: Any other experiments may be added when required.**

**Reference books:**

1. Textbook of Practical Organic Chemistry – A. I. Vogel.

2. Practical Organic Chemistry – Mann & Saunders.

3. A Handbook of Quantitative & Qualitative Analysis- H. T. Clarke.

4. Organic Synthesis Collective Volumes by Blat

## RP-306: Research Project (4 Cr, 120 Hrs)

**See Annexture-I for details (In the end of this document).**

## M. Sc. II (SEM - IV) Organic Chemistry

**MANDATORY PAPERS**

Paper X: OCHT401 (4 Cr): Stereochemistry

Paper XI: OCHT402 (4 Cr): Chemistry of Natural Products

PCHP404 (4 Cr): Practical-VII

RP-405 (6 Cr): Research Project

**ELECTIVE PAPERS**

Paper XII: E-OCHT403 (A) (4 Cr): Theoretical Organic Chemistry

Paper XII: E-OCHT403 (B) (4 Cr): Applied Organic Chemistry

Paper XII: E-OCHT403 (C) (4 Cr): Bioorganic Chemistry

Paper XII: E-OCHT403 (D) (4 Cr): Reagents and Reactions/ Modern Organic Synthesis/ Advanced Organic Transformations

## Paper X: OCHT401: Stereochemistry (4 Cr, 60 hrs.)

## Course Outcomes (COs):

After completion of course student will able to

CO1: Approve the knowledge of about stereoselective, stereospecific synthesis, chemoselective and regioselective reactions. Undestand the enantioselective synthesis, reactions with hydride donar, catalytic hydrogenation via chiral hydrazones and oxazolines etc.

CO2: Understand in depth stability and reactivity of diastereoisomers, Curtin-Hammett principle, some aspects of stereochemistry of ring compounds. The shapes of the 5, 6 and 7 membered rings. Also, they will learn the conformational effects in medium sized rings and the concept of I-strain.

CO3: Knowledge about conformation and configuration of fused bicyclic rings and bridged rings, stereochemical restrictions, and Bredt's rule. Understand O. R. D. and C. D. curves, circular dichroism, the Octane rule and axial haloketone rule.

CO4: Explain the stereochemistry of Allenes, Spiranes, and Biphenyls and how to assign the configuration and by using physical and chemical methods.

**Unit I: Conformational analysis and reactivity of acyclic and alicyclic compounds 15 hrs.**

**A) Conformational analysis of acyclic compounds (4h)**

The difference between configuration and conformation, torsion strain, Pitzer strain, the effect of (i) van der Waals interactions, (ii) hydrogen bonding, and (iii) dipole moment on the stability of conformation withexamples, gauche effect

**B) Conformational analysis of cyclohexane compounds (4h)**

Concept of Baeyer ring strain, ring inversion, locking of conformations and groups. Conformations of (1, 4-di-t- butylcyclohexane, 1, 4-cyclohexanediol, menthol, cyclohexanone.

**C) Effect of conformation on reactivity (mechanism) of acyclic and cyclic systems (7h)**

Curtin-Hammett principle. Effect of conformation on the course and rate of reactions in cyclohexane; debromination of 2,3-dibromobutane, semipinacolic deamination of 1,2-diphenyl- 1-(pchlorophenyl)-2-amino ethanol, dehydrohalogination of stilbene dihalide and bromo-1,2- diphenyl propane, stereochemistry of molecular rearrangements; pyrolytic cis-elimination.

**Unit II: Conformational analysis and reactivity of the fused and bridged ring system 15 hrs.**

**A)Fused rings:** Types of fused ring systems; (i) Fused bicycles: cis and trans-decalins, octalins, decalols, (ii) Fused poly-bicycles: perhydroanthracene and perhydrophenanthrene (iii) effect of angular methyl group on conformation of fused ring system.

**B) Bridged rings:** Types of bridged ring systems, nomenclature, bridged bicycles: heptanes and octane, stereochemical restrictions, Bredt′s rule.

**Unit III: Stereoselective Synthesis 15 hrs.**

**A) Stereoselective addition of nucleophiles to carbonyl group (6h)**

Cram’s rule, Felkin Ahn rule, Houk's model, Cram′s chelate model. Asymmetric synthesis by use of chiral auxiliaries, use of chiral substrates, reagents, and catalysts

**B) Asymmetric Synthesis (9h)**

Asymmetric epoxidation of allylic alcohols (Sharpless Epoxidation), Dihydroxylation of olefins: Sharpless asymmetric dihydroxylation, Upjohn process, Milas hydroxylation. Asymmetric Diels-Alder Reactions using chiral Lewis acids: Chiral bissulfonamides (Corey's catalyst).

**Unit IV: Stereochemistry of compounds containing no chiral carbon atoms 15 hrs.**

A) **Stereochemistry of allens, sprains and biphenyls, assignment of configuration (4h)**
B) **Configuration of diastereomers (4h)**
   Geometrical isomerism based on physical and chemical methods.
C) **O.R.D. and C.D. (7h)**
   ORD and CD curves with Cotton effect. Empirical and semi-empirical rules; The octant rule, helicity rule, Lowe’s rule, and axial haloketone rule.

## Reference Books:

1. E.L. Eliel: Stereochemistry of carbon compounds.
2. D. Nasipuri : Stereochemistry of organic compounds

3. P.S. Kalsi: Stereochemistry, Conformation and Mechanism.
4. Eliel, Allinger, Angyal and Morrison: Conformational analysis.
5. Hallas: Organic stereochemistry
6. Mislow and Benjamin: Introduction to Stereochemistry.
7. H. Kagan: Organic stereochemistry.
8. Carl Djerassi; Optical Rotatory Dispersion.
9. P. Crabbe: Optical Rotatory Dispersion and C.D.

## Paper XI: OCHT402: Chemistry of Natural Products (4Cr, 60 hrs.)

## Course Outcomes (COs):

After completion of course student will able to learn

CO1: Learn the classification, isolation of terpenoids, structure, and synthesis of Camphor, Carvone, Abietic acid, zingiberene, alpha-santonin, and beta-caryophyllene.

CO2: Know all about Alkaloids the occurrence, isolation, structures, functions, stereochemistry, and synthesis of Morphine, Reserpine, Atropine, and Conin alkaloids.

CO3: Learn the occurrence, nomenclature, and basic skeleton of steroids as well as the synthesis of hormones like cholesterol, Androsterone, Testosterone, and Estrone. Also study the nomenclature, classification, biogenesis, physiological effects, and synthesis of prostaglandin PGE2 and PGF2.

CO4: Study about the Vitamins as well as synthesis and biological functions of vitamins B1, B2, B5, B6, and Biotin i.e. vitamin H.

**UNIT-I: Terpenoids** **15 hrs.**

Introduction of natural products and Terpenoids: Introduction of natural products: Classification and isolation methods. Terpenoids: Structure and synthesis of camphor, carvone, abietic acid, zingiberene, α-santonin, β-cuparenone. Biogenesis of abietic acid.

**UNIT – II: Alkaloids** **15 hrs.**

Structure, stereochemistry, synthesis, and biosynthesis of the following: Morphine, Reserpine, Papaverine, and Lysergic acid. Biogenesis of Coniine.

**UNIT–III: Steroids** **15 hrs.**

Occurrence, nomenclature, basic skeleton, Diels hydrocarbon. Study of the following: ormones (Structure and synthesis): Cholesterol, Androsterone, Testosterone, Estrone, Progesterone, Aldosterone and cortisone Bile acid (only synthesis) and biosynthesis of lanosterol.

**UNIT- IV: Study of Prostaglandins, Lipids and Vitamins** **15 hrs.**

**A) Prostaglandins:** **(5h)**

Occurrence, nomenclature, classification, biogenesis and physiological effects, Synthesis of PGE2 and PGF2α.

**B) Lipids:** **(4h)**

Classification, Role of Lipids, Fatty acids and glycerol derived from oils and fats.

**C) Vitamins:** **(6h)**

Synthesis and structure of biotin, vitamin B1 and B2, Biological functions of Vitamin B6, D and E.

## Reference Books:

1. Apsimon: The total synthesis of natural products.
2. Manskey and Holmes: Alkaloids
3. A.A. Newmen: Chemistry of Terpenes.
4. P. D B. Mayo: The chemistry of natural products.
5. Simonson: Terpenes.
6. T.W. Goddwin: Aspects of terpenoid chemistry and biochemistry.
7. R.T. Slicken staff A.C. Ghosh and G.C. Wole: Total synthesis of steroids.
8. The chemistry of natural products, vol. Nakanishi
9. Biochemistry of Lipids, Lipoproteins and membranes by Neele Ridgway and Roger McLeod
10. Membranes (New comprehensive biochemistry) by J E Vance and E Vance
11. Schaum's easy outline of biochemistry by Philip W Kuchel.

## ELECTIVE PAPERS (Choose any one)

## Paper XII: E-OCHT403 (A): Theoretical Organic Chemistry (4 Cr, 60 hrs.)

## Course Outcomes (COs):

After completion of course student will able to learn

CO1: Understand the concept of aromaticity, Huckel's rule, the energy level of pimolecular orbital, calculation of energies of cyclic and acyclic systems, calculation of charge densities, PMO theory, and reactivity index.

CO2: Learn synthesis and reactions of Linear and Non-linear polynuclear hydrocarbons. Understand the concept of aromaticity and anti-aromaticity as well as the concept of 3- and 5-5-membered carbocyclic compounds.

CO3: Understand the types of free radicals, detection by ESR, reaction mechanism, and reactivity. They also learn the effect of solvent on reactivity, Sandmeyer's reaction, Hunsdiecker reaction.

CO4: Learn about the Kinetic and thermodynamic control of nitration and sulphonation, about Wittig reaction, Enolization, F. C. reaction, and Diel's Alder reaction. Understand Non-classical carbonation - Formation, stability, reactivity, and synthetic applications.

**UNIT – I: Molecular Orbital Theory** **15 hrs.**

Aromaticity in benzenoids, alternant and non- alternant hydrocarbon, Huckels rule, energy level of π- molecular orbital and concept of aromaticity, calculation of energies of orbitals cyclic and acyclic systems. Determination energies and stabilities of different systems calculation of charge densities PMO theory and reactivity index.

**UNIT – II: Non benzenoid aromatic Compounds** **15 hrs.**

Aromaticity in non-benezenoid compounds Annulenes and heteroannulenes, fullerenes, azulene, fulvene, tropylium salts, ferrocene, five-membered systems. Crown ether complexes, bonding in fullerenes.

**UNIT – III: Green Chemistry** **15 hrs.**

Introduction to the principles of green chemistry – prevention of waste, atom economy, less hazardous chemical syntheses, designing safer chemicals, safer solvents and auxiliaries, design for energy efficiency, reducing derivatives, renewable feedstock, catalysis, design for degradation, realtime analysis for pollution prevention, and inherently safer chemistry for accident prevention. Green synthesis, clean routes using supercritical solvents, ionic liquids, and water.

**UNIT – IV:** **15 hrs.**

**A) Kinetic and thermodynamic control of reactions** **(9h)**

Nitration and Sulphonation of naphthalene, Wittig, Enolization, Friedel-Crafts and Diels Alder reactions

**B) Non-classical carbocations:** Formation, stability, and reactivity. **(6h)**

## Reference Books:

1. Lehar and Merchand: Orbital Symmetry.

2. R. B. Woodward and Hoffman: Conservation of orbital symmetry.

3. P. T. Anastas, J. C. Werner: Green Chemistry: Theory and Practice

4. V. K. Ahluwalia: Green chemistry, A textbook

5. V. K. Ahluwalia, R. S. Verma: Green Solvents: For Organic Synthesis

6. Ginsburg: Nonbenzenoid aromatic compound.

7. A. Streitwieser: Molecular orbital theory for organic chemistry.

8. E. Cler: The aromatic sextet.

9. Lloyd: Carbocyclic non- benzenoid aromatic compounds.

10. W. B. Smith: Molecular orbital methods in organic chemistry.

11. Grratt; Aromaticity

## Paper XII: E-OCHT403 (B): Applied Organic Chemistry (4 Cr, 60 hrs.)

## Course Outcomes (COs):

After completion of course student will able to understand

CO1: Learn about the synthesis and uses of different types of Agrochemicals such as Carbamates, organophosphorous insecticides, and Natural and Synthetic Pyrethroids. They will learn the synthesis of some plant growth regulators as well as applications of Juvenile hormones and Pheromones.

CO2: Learn about the perfumery compounds, commercial process, preparation and importance of essential oils. Also learn the synthesis of 2 - phenyl ethanol, yarayara, vanillin, synthetic musk, jasmine, ionone etc. from citral, phenyl acetate ester, benzyl acetate ester.

CO3: Understand the classification, and synthesis of azo dyes, reactive dyes, optical brighteners, dispersed dyes.

CO4: Understand the mechanism of polymerization. Also, study about the manufacturing processes of synthetic rubber plasticizers, and anti-oxidents required for natural polymers like starch and cellulose. They will get the knowledge about the Oxo and Wacker process necessary for Soap and Synthetic detergents.

**UNIT-I: Study of Agrochemicals and Perfumes** **15 hrs.**

**A) Agrochemicals** **(7h)**

(i) Organochlorine pesticides: Introduction, synthesis, and mode of action of endrin, aldrin, dieldrin. (ii) Herbicides: Synthesis and mode of action of Triazines, triazoles, pyridazinones, and bipyridylium compounds: diquat, paraquat. (iii) Juvenile hormone: introduction & structures JHA importance synthesis, IPM

**B) Synthesis and applications of perfumery** **(8h)**

2-Phenylethanol, vanillin, and other food flavors, synthetic musk, and ionones.

**UNIT –II: Unit processes** **15 hrs.**

Introduction to unit operation and unit processes. **Nitration:** Introduction, Nitrating agents, kinetics and mechanism, oxynitration, typical industrial nitration process. **Amination:** Introduction, Bechamp reduction. **Halogenation:** Introduction, Kinetics and mechanism, catalytic chlorination, manufacturing process for chlorobenzene and monochloroacetic acid. **Sulfonation**- Introduction, sulphonating agents, kinetics and mechanism, manufacturing process for benzene sulphonic acid.

**Unit-III: Dyes and Intermediates** **15 hrs.**

Classification and synthesis of important dye intermediates by using nitration, sulphonation, diazotization reactions. Synthesis of Nitro dyes, xanthenes, reactive dyes, fluorescent brightening agents, thermal sensitive dyes, dispersed dyes and reactive dyes.

**UNIT- IV: Polymers** **15 hrs.**

Mechanism of polymerization. Industrial process for synthesis of polyethylene, acrylonitrile, acrylate and methacrylate polymer, biomedical polymer, polymer processing, Plasticizers and anti -oxidants for polymers

## Reference Books:

1. Allan: Colour Chemistry

2. K. Venkataraman: Chemistry of Synthetic Dyes Vol- 1 to 7

3. G. R. Chatwal: Synthetic dyes
4. Abrahart: Dyes & their intermediates
5. N. N. Melikov: The Chemistry of Pesticides and formulations
6. K. H. Buchel: Chemistry of Pesticides.
7. R. Clemlyn: Pesticides
8. K. H. Buchel: Chemistry of Pesticides
9. H. R. Alcock and F. W. Lambe: Contemporary Polymer Chemistry
10. J. M. G. Cowie, Blackie: Physics & Chemistry of Polymers
11. I. M. Campbell: Introduction to Synthetic Polymers
12. A. L. Gupta: Polymer Chemistry
13. M. S. Bhatnagar: A textbook of Polymers

## Paper XII: E-OCHT403 (C): Bioorganic Chemistry (4Cr, 60 hrs.)

## Course Outcomes:

CO1: Understand the structural and functional organization of prokaryotic and eukaryotic cells, biomolecules, enzymes, and the origin of life, enabling students to explain cellular and biochemical processes at the molecular level.

CO2: Describe the structure, function, and metabolism of carbohydrates and lipids, including their roles in energy storage, membrane formation, and biological recognition.

CO3: Analyze the structure, synthesis, and metabolic pathways of amino acids, peptides, proteins, and nucleic acids, and understand their roles in biochemical reactions and heredity.

CO4: Apply knowledge of biomolecular structures and functions to interpret and predict biochemical processes, enzyme mechanisms, and macromolecular interactions in living systems.

**Unit I:** **15 hrs.**

**a) Cell Structure and Functions**

Structure of prokaryotic and eukaryotic cells, Intracellular organelles and their functions, comparison of plant and animal cells. Overview of metabolic process- catabolism and anabolism. ATP – the biological energy currency. Origin of life- uniqueproperties of carbon, chemical evolution and rise of living system. Introduction to biomolecules, building blocks of biomacromolecules

**b) Enzymes**

Structure activity and reactions, catalyzed determination of active site, inhibition mechanism chemical transformations using enzymes.

**Unit II: Carbohydrates** **15 hrs.**

Conformation of monosaccharides, structure and functions of important derivatives of monosaccharides like glycosides, deoxy sugars, myoinositol, amino sugars. Naceylmuramic acid, sialic acid disaccharides and polysaccharides. Structural polysccharides- cellulose and chitin. Storage polysaccharides- starch and glycogen.

Structure and biological functions of glucosaminoglycans or mucopolysaccharides. Carbohydrates of glycoprotines and glycolipids. Role of sugars in biological recognition. Blood group substances. Ascorbic acid.

Carbohydrate metabolism- Kreb's cycle, glycolysis, glycogenesis and glycogenolysis, pentose phosphate pathway.

**Unit III: Lipids** **15 hrs.**

Fatty acids, essential fatty acids, structures and function of triglycerides, glycerophspholipids, sphingolipids, cholesterol, bile acids, prostaglandins. Lipoproteinscomposition and function, role in arthrosclerosis. Properties of lipid aggregates – micelles, bilayers, liposomes and their possible biological functions. Biological members .Fluid mosaic model of membrane structure. Lipid metabolism - β-oxidation of fatty acids

**Unit IV:** **15 hrs.**

**a) Amino acids, Peptides and Proteins** **(10 h)**

Chemical and enzymatic hydrolysis of proteins to peptides, amino acid sequencing. Secondary structure of protein, forces responsible for holding of secondary structures. α-helix, β-sheets, super secondary structure, triple helix structure of collagen. Tertiary structure of protein- folding and domain structure. Quaternary structure. Amino acid metabolism degradation and biosynthesis of amino acids, sequence determination: chemical/ enzymatic/

mass spectral, racemization / detection. Chemistry of oxytocin and tryptophan releasing hormone (TRH).

**b) Nucleic Acids** **(5 h)**

Purine and pyrimidine of nucleic acids, base pairing via H – bonding. Structure of ribonucleic acids (RNA) and deoxyribonucleic acid (DNA), double helix model of DNA and forces responsible for holding it. Chemical and enzymatic hydrolysis of nucleic acids. The chemical basis for heredity, an overview of replication of DNA, transcription, translation and genetic code. Chemical synthesis of mono and poly nucleosides.

## Reference Books:


1. Principles of Biochemistry, A. L. Lehinger, Worth Publications.
2. Biochemistry, L. Stryer, W. H. Freeman
3. Biochemistry, J. David Rawn, Neil Patterson.
4. Biochemistry, Voet and Voet, John Wiley.
5. Outlines of Biochemistry, E. E. Conn and P. K. Stumpt, John Wiley.


## Paper XII: E-OCHT403 (D): Advanced Synthetic Methods-II (4 Cr, 60 hrs.)

## Course Outcomes:

CO1: Understand and explain the mechanisms and synthetic applications of key organic rearrangements, including Curtius, Hofmann-Martius, and Favorskii rearrangements.

CO2: Apply knowledge of various metal-catalyzed coupling reactions (e.g., Suzuki, Heck, Sonogashira, Buchwald-Hartwig) in the design and synthesis of complex organic molecules.

CO3: Analyze and compare the reactivity and selectivity of diverse oxidizing agents (e.g., Swern, PCC, CAN, Baeyer-Villiger, Dakin, Wacker) in organic transformations.

CO4: Demonstrate an in-depth understanding of reduction methods using catalytic and reagent-based systems, and utilize this knowledge for stereoselective and chemoselective synthesis.

**Unit - I : Study of the following rearrangements** **15 hrs.**

Curtius, Lossen, Witting, Neber, Orton, Hofmann-Martius, Demjanov, Dakin, Rupe, Gabriel–Colman, Carroll, Payne, Favorskii, Sommelet-Hauser, Stevens.

**Unit – II :Study of Coupling Reactions** **15 hrs.**

Heck, Suzuki, Stille, Nigeshi, Sonogashira, Buchwald-Hartwig, Cadiot-Chodkiewicz, $A^3$, Kumada, Ulman, Chanlam, Hiyama coupling, Tsuji-Trost reaction.

**Unit - III : Oxidation** **15 hrs.**

Applications of oxidizing agents: Woodward-Prevost hydroxylation, Chloranil, and hydrogen peroxide. Swern oxidation. PCC (Corey's reagent), PDC (Cornforth reagent), Baeyer-Villiger oxidation. Dakin oxidation, Ceric Ammonium Nitrate (CAN), Sodium Hypochlorite, Babler Oxidation, Corey Kim Oxidation, Wacker Oxidation, NaIO4 and HIO4, Etard oxidation.

**Unit - IV: Reductions** **15 hrs.**

Study of following reductions- Catalytic hydrogenation using homogeneous and heterogeneous catalysts. Study of the following reducing reagents and reactions: Metal complex hydrides, Wolff-Kishner, Birch, Sodium in alcohol, Fe in HCl, Adam's catalyst, Lindlar catalyst, TBTH, Corey-Bakshi-Shibata reduction (CBS reagent), Zinc borohydride, Luche reduction (CeCl3, NaBH4, MeOH).

**Reference Books**

1. Modern Synthetic Reactions-(Benjamin) H. O. House.
2. Reagents in Organic Synthesis-(John Wiley) Fieser and Fieser
3. Principles of Organic Synthesis-(Methuen) R. O. C. Norman
4. Hydroboration- S. C. Brown.
5. Advances in Organometallic Chemistry- (A.P.)F. C. A. Stone and R. West.
6. Organic Chemistry (Longman)Vol. I & Vol. II- Finar
7. Oxidation by-(Marcel Dekker) Augustin
8. Advanced Organic Chemistry 2nd Ed. R R. Carey and R. J. Sundburg
9. Organic Synthesis-(Prentice Hall)R. E. Ireland.
10. Homogeneous Hydrogenation-(J. K.) B. R. James.
11. Comprehensive Organic Chemistry- (Pargamon) Barton and Ollis.
12. Organic Reactions- R. Adams.
13. Some Modern Methods of Organic Synthesis-(Cambridge) W. Carruthares.
14. Organic Chemistry- Jonathan Clayden

## Organic Chemistry Practical Course

## Practical-VII: OCHP404 (4 Cr, 120 hrs)

## Course Outcomes (COs):

CO1: Demonstrate the ability to estimate heteroatoms such as nitrogen and sulfur in organic compounds through classical quantitative methods, interpreting experimental results with accuracy and precision.

CO2: Perform multi-step organic syntheses (minimum three) such as the preparation of anthranilic acid, p-aminobenzoic acid, Sandmeyer products, and benzimidazole, while understanding reaction mechanisms, purification, and yield optimization.

CO3: Develop problem-solving skills in organic chemistry by analyzing and interpreting IR, NMR, and mass spectral data for the structure elucidation of unknown organic compounds.

CO4: Apply principles of green and safe laboratory practices in synthetic and analytical organic chemistry experiments, promoting environmental consciousness and laboratory safety.

1. **Estimation of Sulphur and Nitrogen.**

2. **Three Step preparations (Any Five)**
    a) Preparation of Anthranilic acid.
    b) Preparation of p- Amino benzoic acid.
    c) Preparation of p- Chloro nitrobenzene by Sandmeyer reaction.
    d) Preparation of p- Iodonitrobenzene by Sandmeyer reaction.
    e) Preparation of Benzylamine
    f) Preparation of Benzimidazole
    g) Preparation of 2-acetyl cyclohexanone
3. **Structure elucidation by using given spectral data.**

**Note: Any other experiments may be added when required.**

**REFERENCE BOOKS:**


1. A Textbook of Practical Organic Chemistry – A. I. Vogel.
2. Practical Organic Chemistry – Mann & Saunders
3. A Handbook of Quantitative & Qualitative Analysis- H. T. Clarke

4. Organic Synthesis Collective Volumes.

**RP-405 Research Project (06 Cr, 180 Hrs)**

**See Annexures II for details (In the end of this document).**

**Note:** Study tour is compulsory for M. Sc. Part- II Students to visit Chemical Industries in India.

# Shivaji University Kolhapur

## Syllabus as per NEP-2020

**For**

**M. Sc. Part- II Physical Chemistry**

**Semester III & IV**

## Under the Faculty of Science and Technology

**To be implemented with effect from Academic Year 2026-2027**

This is applicable for University Department and Affiliated College PG Centres

# Name of Program: M.Sc. II Physical Chemistry

***About PG Degree Program of Master of Science (M.Sc.) in Physical Chemistry*:**

The Master of Science (M.Sc.) in Physical Chemistry is a postgraduate degree that delves into the fundamental principles governing the physical and chemical properties of matter. This specialised field bridges the gap between physics and chemistry, offering a comprehensive understanding of molecular behaviour, reaction mechanisms, and thermodynamic principles. In the Indian and global context, pursuing an M.Sc. in Physical Chemistry holds significant academic, professional, and societal value.

Physical Chemistry is often regarded as the backbone of chemical sciences, providing the theoretical framework that underpins other branches such as organic, inorganic, and analytical chemistry. An M.Sc. in this discipline equips students with in-depth knowledge of topics like quantum chemistry, kinetics, spectroscopy, thermodynamics, and statistical mechanics. The programme enhances analytical thinking, problem-solving skills, and experimental techniques, preparing graduates for doctoral studies and research-intensive roles in academia or industry.

The knowledge and skills gained through an M.Sc. in Physical Chemistry are highly sought after in various industries, including pharmaceuticals, petrochemicals, materials science, energy, environmental science, and nanotechnology. Graduates are adept at handling advanced instrumentation, data analysis, and computational modelling, making them valuable assets in research and development (R&D), quality control, and technical consultancy roles. In India, with the growing focus on innovation and indigenisation, physical chemists play a pivotal role in developing new materials, energy solutions, and sustainable technologies.

Physical Chemistry drives scientific innovation by enabling the development of new theories, materials, and technologies. Postgraduates contribute to cutting-edge research in fields such as catalysis, surface science, biophysical chemistry, and environmental monitoring. Their work often leads to advancements in drug design, renewable energy, pollution control, and nanomaterials, addressing critical challenges faced by society.

## Opportunities in Academia and Education

An M.Sc. in Physical Chemistry opens avenues for teaching and academic careers at colleges and universities. Postgraduates can inspire future generations of scientists by imparting knowledge and fostering curiosity. They also contribute to curriculum development, academic research, and mentoring, strengthening the educational ecosystem in India and abroad.

### Global and Societal Impact

Physical Chemistry is at the heart of many global challenges, such as climate change, clean energy, and sustainable development. Professionals in this field contribute to international collaborations and policy making, influencing how science addresses pressing issues. The skills and insights gained through an M.Sc. programme empower graduates to make meaningful contributions to society, both in India and on the global stage.

## Programme Educational Objectives (PEOs):

**PEO-1** To provide students with advanced theoretical and practical knowledge in physical chemistry, enabling them to understand and solve complex chemical problems in both academic and industrial settings.

**PEO-2:** To cultivate a strong foundation in physical subject with advanced laboratory techniques, instrumentation, and computational tools for research and analysis in physical chemistry, thereby preparing students for research, innovation, and higher studies (Ph.D., Postdoctoral Research, etc.).

**PEO-3**: To in still professional ethics, scientific temper, teamwork, and effective communication skills necessary for careers in academia, pharmaceutical industries, chemical manufacturing, or entrepreneurship.

**PEO-4:** To encourage lifelong learning, critical thinking, and application of physical chemistry knowledge to address societal and environmental challenges through green chemistry and sustainable practices.

## Programme Outcomes (POs):

- PO1: Demonstrate comprehensive knowledge of physical chemistry principles and their application to solve complex scientific problems.
- PO2: Employ advanced laboratory techniques, instrumentation, and computational tools for research and analysis in physical chemistry.
- PO3: Critically evaluate scientific literature, formulate hypotheses, and design experiments to explore new areas in chemical science.
- PO4: Communicate scientific concepts and research findings effectively through written, oral, and digital means.
- PO5: Exhibit ethical and professional behaviour in scientific practice, recognising the societal and environmental implications of chemical research.

- PO6: Collaborate effectively in multidisciplinary teams and contribute to innovative solutions in academia, industry, and public policy.
- PO7: Pursue lifelong learning and adapt to emerging trends in chemistry and related fields.

## Programme Specific Outcomes (PSOs):

- PSO1: Apply advanced physical chemistry concepts to analyse chemical kinetics, thermodynamics, quantum chemistry, and spectroscopy.
- PSO2: Utilise computational modelling and simulation techniques to investigate molecular structures, reactions, and properties.
- PSO3: Conduct independent and collaborative research projects in areas such as catalysis, materials science, nanotechnology, and energy solutions.
- PSO4: Address real-world challenges by developing sustainable chemical processes and technologies relevant to Indian and global contexts.
- PSO5: Mentor and guide students or colleagues in academic or industrial settings, fostering scientific curiosity and analytical thinking.

### M. Sc. II (SEM - III) Physical Chemistry

**MANDATORY PAPERS**

Paper VII: PCHT301 (4 Cr): Advanced Quantum Chemistry

Paper VIII: PCHT302 (4 Cr): Electrochemistry and Chemical Kinetics

PCHP404 (4 Cr): Practical-V

PCHP405 (2 Cr): Practical-VI

RP-306 (4 Cr): Research Project

**ELECTIVE PAPERS**

Paper IX: E-PCHT303 (A) (4 Cr): Solid State Chemistry

Paper IX: E-PCHT303 (B) (4 Cr): Physical Chemistry for Pharmaceutical Industries

Paper IX: E-PCHT303 (C) (4 Cr): Physical Chemistry for Green and Clean Energy

Paper IX: E-PCHT303 (D) (4 Cr): Colloidal, Surface and Interface Chemistry

## DETAILED SYLLABUS:

### Paper-VII, PCHT301: Advanced Quantum Chemistry (4 Credits, 60 hrs)

This course is tailored to leverage the current strengths of computational science for deepening our molecular-level understanding and developing new technologies. A grounding in basic quantum mechanics aids in grasping concepts like spectral selection rules, atomic orbitals, and electronic transitions. Knowledge of advanced topics—such as *ab initio* methods, electron correlation techniques, and density functional theory—enables students to solve for electronic structures in atoms and molecules. These skills empower learners to predict reaction mechanisms, analyse transition states, design new molecules, and calculate spectral and molecular properties. When combined with computational lab experience, students gain the expertise needed to conduct cutting-edge scientific research using both experimental and computational tools.

### Course Outcomes (COs)

- CO1: To grasp atomic orbitals, their shapes, and related spectroscopic rules and to learn advanced quantum methods like HF-SCF and post-HF for accurate electronic calculations.
- CO2: To use course concepts to simulate molecular properties and various spectra and to select appropriate basis sets and apply electron correlation corrections.
- CO3: To understand and apply Density Functional Theory (DFT) for electron structure analysis and to calculate transition states and reaction pathways with DFT.
- CO4: To predict molecular-level material properties for a range of applications and to employ semiempirical and parameterization methods for complex molecules to ease computations and to acquire knowledge and skill for independent work in global R&D and academic settings.

## Unit I: Basic Quantum Chemistry (15 hrs)

Covers the fundamentals, including exact solutions of the Schrödinger equation for rigid rotators, harmonic oscillators, hydrogen, and hydrogen-like atoms. Topics also include atomic orbitals and their radial/angular characteristics, ground and excited state energies, and ionization potentials. Discusses transition dipole moment integrals, as well as selection rules for rotational, vibrational, and electronic transitions.

## Unit II: Ab Initio Methods (15 hrs)

Explores self-consistent field (SCF) theory, Hartree-Fock (HF) method, quantum particles and spin, Slater determinants, and HF equations. Reviews both restricted (RHF) and unrestricted (UHF) models, Fock matrices, Roothan-Hall equations, Koopman's theorem, and various basis sets (STO, GTO). Examines basis set classifications, minimal and split-valence sets, error types, and correction strategies. Covers correlation energy and post-HF methods like configuration interaction, many-body perturbation theory, Møller-Plesset perturbation, and coupled cluster methods. Introduces software packages for ab initio calculations.

## Unit III: Density Functional Theory (15 hrs)

Introduces DFT fundamentals, including functionals, electron density, fermi/coulomb holes, Thomas-Fermi model, Slater's approximation, and the Hohenberg-Kohn theorems. Addresses energy functionals, minimizing energy, non-interacting reference systems, Kohn-Sham equations, and total energy computations. Discusses exchange-correlation functionals, basis sets, pseudopotentials, plane waves, self-consistency cycles, and density functional perturbation theory (including first- and second-order derivatives and atomic forces).

## Unit IV: Semiempirical Methods (15 hrs)

Provides an overview of semiempirical methods and zero differential overlap (ZDO) approximation. Covers variational principles, secular determinants/equations, Hamiltonians in semiempirical approaches, Hückel molecular orbital (HMO) theory, $\pi$-electron approximation, aromaticity, HMO calculations, reactivity predictions, and symmetry utilization. Reviews neglect of differential overlap (NDO), complete/intermediate modifications, and popular methods like AM1, PM3, PM5, PM6, along with their limitations. Introduces relevant software for semiempirical calculations.

## Recommended Books:


1. K. Chandra, Introductory Quantum Chemistry, 4th Edition, Tata McGraw-Hill, New Delhi, 1994.
2. D. A. McQuarrie, Quantum Chemistry, Viva Books, New Delhi, 2003.
3. P. Atkins and R. Friedman, Molecular Quantum Mechanics, 4th Edition, Oxford University Press, New York, 2005.
4. Leach, A.R. Molecular Modelling. Principles and Applications, 2nd Edition, Prentice-Hall, Harlow, England, 2001.
5. K.I. Ramachandran, G. Deepa and K. Nimboori, Computational Chemistry and Molecular Modelling: Principles and Applications, Springer-Verlag, Berlin, 2008.
6. Becker, O.; MacKerell, A.D.; Roux, B.; Watanabe, M. eds. Computational Biochemistry and Biophysics, Marcel Dekker, New York, 2001.
7. F. Jensen, Introduction to Computational Chemistry, 2nd Edition, John Wiley & Sons Ltd, West Sussex, England, 2007.
8. D.B. Cook, Handbook of Computational Chemistry, Oxford University Press, New York, 1998.

9. Fabio Finocchi, Density Functional Theory for Beginners: Basic Principles and Practical Approaches, 2011
10. Wolfram Koch, Max C. Holthausen, A Chemist's Guide to Density Functional Theory, 2nd Edition, Wiley-VCH, Weinheim, 2001.
11. Fiolhais F. Nogueira M. Marques (Eds.), A Primer in Density Functional Theory, Springer-Verlag, Berlin, 2003.
12. P. Geerlings, F. De Proft, and W. Langenaeker, Conceptual Density Functional Theory, *Chem. Rev.* **2003,** *103,* 1793–1873.

## Paper-VIII, PCHT302: Electrochemical Kinetics (4 credits, 60hrs)

Electrochemical Kinetics are fundamental disciplines that enable a detailed understanding of reaction rates and mechanisms within both simple and complex chemical systems. This advanced course is meticulously structured to provide students with a robust foundation in reaction kinetics, encompassing essential principles as well as specialised topics pertinent to biological systems and industrial applications. The curriculum places significant emphasis on state-of-the-art experimental methodologies, theoretical models, and practical implementations, particularly in areas such as enzymatic catalysis, electrochemical synthesis, corrosion control, and fuel cell technologies.

### Course Outcomes

- CO1: To impart a comprehensive understanding of the principles and methodologies of electrochemistry, with a focus on both equilibrium properties and ion-solvent interaction of electrolytes.
- CO2: To facilitate an in-depth understanding of various types of electrode reactions and fuel cell batteries applications in various battery industries and to examine the kinetics of electrochemical processes such as corrosion, passivation, and industrial electrolysis, with particular attention to reactor design and process scale-up.
- CO3: To study the collision and transition state theories for the applications of rate of chemical reactions. To study the various methods for the determination of thermodynamic functions for activation.
- CO4: To study the various surface kinetics reactions application in industries and in research. Different mechanistic aspects of surface reaction and industrial applications. Student can learn different methods of study of dynamics of fast reaction mechanism.

## Unit 1: Ionic equilibrium in Solutions (15 hrs)

**A) Equilibrium Properties of Electrolytes:** Debye – Huckel Theory of inter-ionic attraction, Ionic atmosphere, Time of relaxation, Relaxation and Electrophoretic effects, Debye – Huckel Onsagar equation, Validity of Debye – Huckel equation, factors influencing the degree of dissociation, Debye Huckel limiting law equation, Ionic mobility, Experimental determination of ionic mobility, Determination of dissociation constant by EMF method, osmotic coefficient, Numerical problems. (8 hrs)

**B) Ion-solvent Interactions:** Structure of water, hydration, heats of hydration of electrolytes, calculation of heats of hydration (Born, Bernal-Fowler methods), entropy of hydration. Ion transport in solutions, diffusion, chemical potential and work of transport, Ficks laws, diffusion coefficient. (7 hrs)

## Unit 2: Electrode reactions and Modern Fuel cells Applications (15 hrs)

**A) Electrode reactions:** Electrode at equilibrium, Butler-Volmer equation, Tafel equations, Multistep electrode reactions. Electrocatalysis: Influence of various parameters on water splitting, HER and OER and Application of cyclic voltammetry for characterization of various electrochemical processes. Electrochemical instrumentations: Current-time transients, potential-time transients, electrochemical impedance spectroscopy. (7 hrs)

**B) Fuel cells and corrosion:** Applications in energy storage technologies (fuel cells batteries) Hydrogen – oxygen, hydrocarbon – air, alkaline, Phosphoric acid, Solid oxide, Proton exchange membrane, Molten Carbonate, Solid Polymer Fuel Cell and applications. Corrosion: Comparison between dry and wet corrosion, Factors affecting corrosion: Nature of the metal, Nature of the corroding environment, Types of corrosion, Prevention of corrosion: Material selection & Design, protective coatings, corrosion inhibitors. (8 hrs)

## Unit 3: Collision and Transition state theory (15 hrs)

**A) Collision Theory:** Definition, Formulation of the total collision rate, p factor, Reactive collisions, Forward scattering: the stripping or grazing mechanism, Backward scattering: the rebound mechanism, Steady State Approximation Collision theory of gas reaction, collision frequency.

**B) Transition State Theory:** Transition state theory, configuration and potential energy, Use of the statistical mechanical form of transition state theory, Thermodynamic Formulations of Transition State Theory: Determination of thermodynamic functions for activation, the partition function form and the Thermodynamic form of transition state theory, Reaction rate theory of Lindemann, Hinshelwood, Kassel and Slater Theory.

**Unit 4: Applied Kinetics of Surface and Fast reaction (15 hrs)**

**A) Kinetics of Surface reaction:** Thermodynamics and statistical mechanics of adsorption, Mechanism of surface reactions: Kinetic effects of surface heterogeneity, Kinetic effects of interaction Unimolecular surface reactions: Inhibition, Activation Energies, Bimolecular surface reactions: Reaction between two adsorbed molecules reaction between a gas molecule and an adsorbed molecule, Adsorption of two gases without mutual displacement. **(7 hrs)**

**B) Fast reactions:** Hammett plots Hammett equation, substituent and reaction constants and their physical significance, calculation of k and K values, Yukawa-Tsuno equation. Taft equation, steric parameters Solvent effects, Grunwald-Winstein equation. Kinetics of Fast reactions: Relaxation techniques, pressure jump and temperature jump methods, NMR relaxation, flash photolysis and molecular beam methods. **(8 hrs)**

**Recommended Books:**

1. Chemical Kinetics and Dynamics by J.I. Steinfeld, J.S. Francisco, and W.L. Hase (2nd Edition, Prentice Hall)
2. Physical Chemistry: A Molecular Approach by D.A. McQuarrie and J.D. Simon (University Science Books)
3. Electrochemical Methods: Fundamentals and Applications by A.J. Bard and L.R. Faulkner (2nd Edition, Wiley)
4. Enzyme Kinetics: Behaviour and Analysis of Rapid Equilibrium and Steady-State Enzyme Systems by I.H. Segel (Wiley-Interscience)
5. Chemical Kinetics by K.J. Laidler (3rd Edition, Pearson Education)
6. Modern Electrochemistry by J.O'M. Bockris and A.K.N. Reddy (Springer)

## Elective Papers ( Choose any one )

## Paper-IX, E-PCHT303(A): Solid State Chemistry (4 credits, 60hrs)

Material Chemistry occupies a pivotal position at the intersection of physical chemistry, solid-state physics, and materials science, offering essential knowledge that underpins research and innovation in advanced materials. This course, designed for MSc students specialising in Physical Chemistry, seamlessly integrates theoretical foundations with practical applications. Learners are guided from fundamental atomic-level concepts to the cutting edge of contemporary materials research. Through four comprehensive modules, participants will acquire a thorough understanding of the synthesis, structure, properties, and applications of modern materials.

### Course Outcomes

- CO1: To cultivate a robust understanding of the chemical principles that form the basis of material science.
- CO2: To examine diverse classes of materials, elucidating their structures as well as their physical and chemical properties.
- CO3: To introduce advanced methods of material synthesis, state-of-the-art characterisation techniques, and the crucial relationship between structure and function.
- CO4: To promote analytical and critical thinking regarding the design, selection, and utilisation of materials in contemporary technology and to nurture research acumen through laboratory work, critical literature analysis, and project-based experiential learning.

**UNIT-I: The Solid State** **(15 hrs)**

Introduction, laws of crystallography, lattice types, X-ray diffraction, Bragg's equation, Miller indices, Bragg's Method, Debye-Sherrer method of X-ray for structure analysis of crystals, indexing of reflections, identification of unit cells from systematic absence in diffraction pattern, structure of simple lattice and X-ray intensities, structure factor and its relation to intensity and electron density, phase problem, procedure for an X-ray structure determination, Rietveld analysis, Problems.

**UNIT –II: Solid State Reactions** **(15 hrs)**

General principle, types of reactions: Additive, structure sensitive, decomposition and phase transition reactions, tarnish reactions, kinetics of solid-state reactions, Mechanochemical methods for preparations of semiconductors. Co-precipitations reactions, factors affecting the reactivity of solid-state reactions.

**UNIT –III: Band Structure of Solids** **(15 hrs)**

Metals, insulators and semiconductors, free electron theory and its applications, electronic structure of solids, band theory, band structure of metals, insulator, and semiconductors, Energy bands and band gaps of semiconductors, effective mass, Fermi surfaces, mobility, p-n junction, conducting polymers, light emitting diodes, luminous efficiency, photo-conduction and photoelectric effects, laser, principle of laser action, solid state laser and their applications, Problems.

**UNIT-IV: Preparation of Materials** **(15 hrs)**

Purification and crystal growth, kinetics of nucleation, critical radius, principle of nucleation, crystal growth during casting, zone refining, growth from solution, growth from melt and preparation of organic semiconductors for device applications.

Crystal defect and Non-Stoichiometry: Classification of defects subatomic, atomic and lattice defect in solids. Thermodynamics of vacancy in metals, Thermodynamics of Schottky defects in ionic solids, Thermodynamics of Frenkel defects in silver halides. Calculation of number of defects and average energy required for defect.

## Recommended Books:


1. A guide to laser in chemistry by Gerald R., Van Hecke, Keny K. Karokitis
2. Principles of Solid-State Chemistry, H. V. Keer, Wiley Eastern,
3. Solid State Chemistry, N. B. Hannay
4. Solid State Chemistry, D. K. Chakrabarty , New Age International
5. An Introduction to Crystallography: F. G. Philips
6. Crystal Structure Analysis: M. J. Buerger 49
7. The Structure and properties of materials: Vol. III Electronic properties by John Walss
8. Electronic processes in materials : L. U. Azroff and J. J. Brophy
9. Chemistry of imperfect crystal: F. A. Krogen
10. Elements of X-ray Diffraction by B. D. Cullity, Addison- Weily.
11. Solid State Chemistry by A.R.West (Plenum)
12. Electronics made simple by Jacobwitz.
13. Principles of Physical Metallurgy, by Abhijeet Mallick,
14. Nano Science and Nanotechnology: S. Singh 2019

Solid State Chemistry and Its Applications, Anthony R. West

**Paper-IX, E-PCHT303(B): Physical Chemistry for Pharmaceutical Industries (4 credits, 60 hrs)**

This course provides a comprehensive exploration of the fundamental principles and contemporary advancements in physical chemistry as applied to the pharmaceutical industry. It covers a wide range of topics, including colloidal systems such as suspensions, emulsions, and nanoparticles in drug delivery, and delves into the physical chemistry underlying drug action, solubility, and dissolution kinetics. Students will gain an in-depth understanding of partition coefficients, membrane transport, and the thermodynamic aspects of drug-receptor interactions, all of which are crucial for effective drug design and delivery. Through dedicated units, the course introduces quantum chemistry, spectroscopic techniques, and the nature of chemical bonding and intermolecular forces relevant to pharmaceuticals. It also addresses the significance of different states of matter, thermodynamic laws, and phase equilibria in drug formulation and stability. Further, learners will explore chemical kinetics, enzyme catalysis, and methods for predicting the shelf-life of pharmaceutical products. The curriculum is enriched with case studies, discussions on green chemistry, and insights from recent research, ensuring that students are well-versed in both foundational knowledge and emerging trends in the field.

## Course Outcomes

- CO1: To develop a comprehensive understanding of fundamental and advanced principles of physical chemistry as they apply to pharmaceutical sciences and to enable students to analyse electrolyte behaviour, ionisation, conductance, and the role of pH and buffer systems in drug formulation and delivery.
- CO2: To familiarise learners with electrochemical analysis techniques utilised in pharmaceutical quality control and to impart knowledge of surface chemistry, adsorption, surfactants, and colloidal systems relevant to innovative drug delivery methods.
- CO3: To explain the physical chemistry underpinning drug action, including solubility, dissolution kinetics, partitioning, membrane transport, and thermodynamics of drug–receptor interactions.
- CO4: To encourage critical evaluation of current advances, such as pharmaceutical nanomaterials, targeted drug delivery, and green chemistry practices, through discussion of recent research and case studies and to cultivate scientific reasoning and problem-solving skills applicable to real-world pharmaceutical scenarios.

**Unit 1: Fundamentals of Physical Chemistry (15 hrs)**

Atomic and Molecular Structure: Introduction to quantum chemistry fundamentals, overview of spectroscopic techniques relevant to pharmaceutical analysis. Chemical Bonding and Intermolecular Forces: Types of chemical bonding, intermolecular interactions in pharmaceutical compounds, their implications for drug properties and formulation. States of Matter: Detailed discussion of solids, liquids, and gases; pharmaceutical significance of different states of matter.

**Unit 2: Thermodynamics and Pharmaceutical Applications (15 hrs)**

Laws of Thermodynamics: Comprehensive study of the first, second, and third laws and their relevance to pharmaceutical systems. Gibbs Free Energy and Spontaneity: Application of thermodynamics in predicting spontaneity of pharmaceutical reactions. Phase Equilibria and Colligative Properties: Role of phase transitions and colligative properties in drug formulation and stability.

**Unit 3: Chemical Kinetics, Reaction Mechanisms, and Electrochemistry (15 hrs)**

Chemical Kinetics: Rate laws, reaction order determination, enzyme kinetics, catalysis in pharmaceuticals, and drug stability studies; methods of shelf-life prediction. Electrochemistry and Ionic Equilibria: Electrolyte behaviour, ionisation, conductance in drug solutions; principles of pH and buffer systems in drug formulation and delivery; electrochemical analysis techniques in pharmaceutical quality control.

**Unit 4: Surface Chemistry, Colloids, and Advanced Topics in Drug Action (15 hrs)**

Surface Chemistry and Colloids: Adsorption phenomena, surfactants in pharmaceuticals, colloidal systems (suspensions, emulsions, nanoparticles) in drug delivery. Physical Chemistry of Drug Action: Solubility and dissolution kinetics, partition coefficients, membrane transport, thermodynamics of drug–receptor interactions. Case Studies and Current Advances: Exploration of pharmaceutical nanomaterials, targeted drug delivery, green chemistry initiatives, and discussion of recent research articles and real-world applications.

**Recommended Books:**

1. Atkins' Physical Chemistry for the Life Sciences, Peter Atkins & Julio de Paula
2. Physical Chemistry: Principles and Applications in Biological Sciences, Tinoco et al.

3. Remington: The Science and Practice of Pharmacy
4. Relevant current research articles and review papers (to be provided during the course)

## Paper-IX, E-PCH303(C): Physical Chemistry for Green and Clean Energy (4 credits, 60 hrs)

Physical Chemistry for Green and Clean Energy is designed to provide students with a comprehensive understanding of the physical chemical principles underpinning sustainable energy technologies. Through a focus on green and clean energy solutions, the course will equip learners with essential knowledge of chemical thermodynamics, kinetics, electrochemistry, and materials science as applied to renewable energy systems, energy storage, and environmental sustainability. The curriculum will integrate foundational theory with current advances in green chemistry, highlighting real-world applications and innovation in sustainable energy. The curriculum includes the study of nanomaterials, colloidal systems, and membrane transport processes as applied in modern energy devices. Key advances such as the hydrogen economy, $CO_2$ capture, biofuels, and solar photovoltaics are discussed through case studies and recent research. Emphasis is placed on the practical application of physical chemistry concepts, including thermodynamics, phase equilibria, and chemical kinetics, in both renewable and non-renewable energy systems. Special attention is given to the role of ionic liquids in enhancing energy efficiency and facilitating phase transitions. The course also incorporates problem-solving sessions and real-world examples, preparing students to contribute to innovative solutions in the field of green and clean energy. Through a blend of theory and application, learners gain the skills required for research and development in sustainable energy materials.

### Course Outcomes

- CO1: To impart a solid foundation in physical chemistry concepts relevant to green and clean energy technologies.
- CO2: To explore the role of chemical thermodynamics and kinetics in renewable energy systems such as solar cells, fuel cells, and batteries.
- CO3: To analyse electrochemical processes for energy conversion and storage, including water splitting, hydrogen production, and supercapacitors.
- CO4: To understand the principles of green chemistry and their applications in designing environmentally benign energy solutions and to examine current advances in clean energy technologies, including the hydrogen economy, $CO_2$ capture, biofuels, and solar photovoltaics, through case studies and recent research and to develop

critical thinking through case studies, recent research articles, and real-world problem-solving in sustainable energy.

**Unit 1: Fundamentals of Physical Chemistry in Energy Systems (15 hrs)**

Core thermodynamic principles and their role in energy transformations. Phase equilibria and chemical kinetics in energy-related processes. Overview of renewable and non-renewable energy sources, including their physical chemistry foundations. Introduction to ionic liquids: definitions, unique properties, and applications in energy systems. Role of ionic liquids in enhancing thermodynamic efficiency and facilitating phase equilibria. Case studies on the use of ionic liquids in thermal energy storage and transfer. Problem-solving sessions and examples from current research articles

**Unit 2: Electrochemistry and Energy Conversion (15 hrs)**

Electrochemical cells: batteries, fuel cells, and solar cells—principles and mechanisms. Ion transport, electrolyte behaviour, and electrode reactions in energy conversion devices. Electrochemical techniques and instrumentation in energy research. In-depth exploration of ionic liquids as electrolytes: their advantages in batteries, fuel cells, and supercapacitors. Conventional electrolytes versus ionic liquids in terms of stability, conductivity, and environmental impact. Recent advances in the use of ionic liquids for energy conversion and storage technologies. Laboratory demonstrations and literature-based exercises.

**Unit 3: Green Chemistry and Sustainable Energy Materials (15 hrs)**

Principles of green chemistry as applied to energy production and environmental sustainability. Design and synthesis of sustainable catalysts, materials, and their lifecycle analysis. Environmental impact assessment and strategies for minimising ecological footprint. Ionic liquids as green solvents: eco-friendly synthesis routes for energy materials. Applications of ionic liquids in the development of recyclable and non-toxic catalysts. Case studies on lifecycle analysis of materials involving ionic liquids. Critical discussion of recent research articles and real-world applications.

**Unit 4: Advanced Topics and Applications in Clean Energy (15 hrs)**

Nanomaterials and colloidal systems: synthesis, characterisation, and energy device applications. Membrane transport and separation processes in clean energy technologies. Current advances: hydrogen economy, $CO_2$ capture, biofuels, and solar photovoltaics. Innovative uses of ionic liquids in advanced energy applications: hydrogen production, $CO_2$ capture, and biofuel processing. Membrane processes enhanced by ionic liquids: separation, purification, and energy efficiency. Case studies and recent research in green and clean energy, with a focus on ionic liquids as enabling materials. Integrated problem-solving and critical analysis of cutting-edge literature.

**Recommended Books**:

1. Atkins' Physical Chemistry for the Life Sciences, Peter Atkins & Julio de Paula
2. Physical Chemistry: Principles and Applications in Biological Sciences, Tinoco et al.
3. Green Chemistry: Theory and Practice, Paul T. Anastas & John C. Warner
4. Electrochemical Energy Storage for Renewable Sources and Grid Balancing, Patrick T. Moseley & Jürgen Garche
5. Relevant current research articles and review papers
6. Introduction to Green Chemistry, Albert Matlack
7. Ionic Liquids in Synthesis, Peter Wasserscheid & Thomas Welton
8. Nanostructures for Energy Conversion, Tetsuo Soga
9. Membrane Technology and Applications, Richard W. Baker
10. Handbook of Clean Energy Systems (6 Volumes), Jinyue Yan (Ed.)

## Paper-IX, E-PCH303(D): Colloidal, Surface and Interface Chemistry (4 credits, 60hrs)

This course provides an in-depth study of the fundamental principles and contemporary applications of colloidal, surface, and interface chemistry. Students will explore the physical and chemical phenomena that occur at interfaces, the properties of colloids, and the role of surface chemistry in biological, environmental, and technological contexts. The course integrates theoretical concepts with practical examples, drawing from current research and industrial innovations, with a special emphasis on applications relevant to green chemistry, nanotechnology, and energy systems.

## Course Outcomes

- CO1: To understand the fundamental principles governing surfaces, interfaces, and colloidal systems.
- CO2: To apply thermodynamic and kinetic concepts to surface and interfacial phenomena.
- CO3: To analyse the role of surface and colloidal chemistry in biological, environmental, and technological processes.

- CO4: To gain practical experience with experimental techniques used in surface and interface studies and to evaluate current research and industrial applications, including green chemistry and clean energy.

**Unit 1: Fundamentals of Colloids and Interfaces (15 hrs)**

Introduction to Colloids and Interfaces. Definitions and classifications of colloids. Types of interfaces: solid/liquid, liquid/liquid, solid/gas, liquid/gas. Historical perspectives and significance in nature and technology. Thermodynamics of Surfaces and Interfaces. Surface tension and interfacial free energy. Wettability, contact angle, and adsorption phenomena. Gibbs adsorption isotherm.

**Unit 2: Colloidal Systems: Properties, Forces, and Stability (15 hrs)**

Colloidal Dispersions. Types of colloidal dispersions: sols, emulsions, foams, aerosols. Intermolecular Forces in Colloidal Systems. van der Waals, electrostatic, and steric forces. Colloidal Stability. DLVO theory and factors influencing stability.

**Unit 3: Surface and Interfacial Phenomena & Experimental Techniques (15 hrs)**

Surface and Interfacial Phenomena. Adsorption at solid/liquid interfaces. Surfactants and micelle formation. Adsorption isotherms: Langmuir and Freundlich models. Experimental Techniques. Surface area determination (BET method). Spectroscopic and microscopic techniques: AFM, SEM, TEM. Electrokinetic phenomena: zeta potential and electrophoresis.

**Unit 4: Applications and Recent Advances (15 hrs)**

Applications in Green Chemistry and Energy. Role in catalysis and environmental remediation. Colloids in renewable energy and nanotechnology. Membrane technology and clean energy systems. Biological and Biomedical Applications. Colloids and interfaces in biological systems. Biological membranes and surface-active agents. Drug delivery, biosurfactants, and bio-colloids. Recent Advances and Current Research. Emerging materials: ionic liquids and nanostructures.

Recommended books:

1. Atkins' Physical Chemistry for the Life Sciences, Peter Atkins & Julio de Paula
2. Physical Chemistry: Principles and Applications in Biological Sciences, Tinoco et al.
3. Green Chemistry: Theory and Practice, Paul T. Anastas & John C. Warner

4. Electrochemical Energy Storage for Renewable Sources and Grid Balancing, Patrick T. Moseley & Jürgen Garche
5. Introduction to Green Chemistry, Albert Matlack
6. Ionic Liquids in Synthesis, Peter Wasserscheid & Thomas Welton
7. Nanostructures for Energy Conversion, Tetsuo Soga
8. Membrane Technology and Applications, Richard W. Baker
9. Handbook of Clean Energy Systems (6 Volumes), Jinyue Yan (Ed.)
10. Relevant current research articles and review papers (to be provided during the course)

# Physical Chemistry Practicals

## PCHP304: Practical V (4 Credits, 120 hrs)

### List of Experiments

1. Determination of stoichiometry and instability constant silver ammonia complex.
2. Determination of transport number of $H^+$, $Na^+$, $K^+$ etc. ions using moving boundary method.
3. Determination of the critical micelle concentration of a given surfactant in aqueous and aqueous salt solutions.
4. Determination of equivalent conductance at infinite dilution and dissociation constant for weak acid using Kohlrausch Law of independent ionic mobility.
5. pH-metric determination of dissociation constant of carbonic acid.
6. Structure drawing, Geometry optimization and Single-point energy calculations for small molecules using minimal basis sets.
7. Electronic structure calculations for small molecules and their aggregates
8. Calculation of vibration spectra using *ab initio* techniques.
9. Structure and properties of transition states from DFT calculation
10. Semi-empirical and quantum mechanical determination of thermochemical properties of small molecules.
11. Determination of exchange current density ($i_0$) and transfer coefficient ($\alpha$) for a reversible redox couple ($Fe^{3+}/Fe^{2+}$ or $[Fe(CN)_6]^{3-/4-}$) using Tafel plot and linear polarization method, Butler–Volmer equation, Tafel equation, low & high overpotential limits, calculation of kinetic parameters

12. Cyclic Voltammetric investigation of a quasi-reversible system and determination of heterogeneous rate constant ($k^0$) using Nicholson method Cyclic voltammetry diagnostics, reversibility criteria, peak separation vs scan rate, Nicholson working curve
13. Electrocatalytic hydrogen evolution reaction (HER) on transition metal (Ni, Co, Cu) electrodes in alkaline medium: Construction of Tafel plot and comparison of catalytic activity Multistep electrode reactions, Volmer–Heyrovsky mechanism, Tafel slope interpretation (30, 60, 120 mV/dec), pH effect
14. Fabrication of Ni–Fe layered double hydroxide (LDH) on nickel foam and evaluation of its OER activity in 1 M KOH using LSV and Tafel analysis; Calculation of overpotential at 10 mA $cm^{-2}$Modern electrocatalysis, OER mechanisms (AEM/LOM), benchmark comparison with literature, volcano plot concept

**Any other experiments may be added when required.**

# PCHP305: Practical VI (2 Credits, 60 hrs)

## List of Experiments

1. Determination of Thermodynamic Parameters for electrochemical reactions: To determine $\Delta G^0$, $\Delta H^0$ and $\Delta S^0$ for the formation of 1 mole of cadmium in 1 wt. % amalgam at 25 °C.
2. Study of the effect of ionic strength on the reaction between persulphate and iodide by visual method.
3. Statistical representation of given experimental data: Estimation of errors in measured and derived properties, reporting data with appropriate significant figures, graphical representation of data with x- and y-error bars.
4. Determination of order of reaction for iodination of acetone catalysed by acid with reference to acetone, iodine and acid catalyst.
5. Determination of electrochemical active surface area (ECSA) of electrocatalysts using three methods: (a) Double-layer capacitance, (b) Cu-UPD, (c) CO-stripping voltammetry Practical application of CV for catalyst characterization, importance of ECSA normalization, real vs geometric area
6. Electrochemical Impedance Spectroscopy (EIS) study of a catalyst-coated electrode: Fitting of Randles circuit, extraction of charge-transfer resistance (Rct) and correlation with exchange current density EIS fundamentals, Nyquist/Bode plots, equivalent circuit modelling, link between $R_s$ and $i_0$

7. Rotating Disk Electrode (RDE) study of oxygen reduction reaction (ORR) on carbon-supported catalyst: Koutecky–Levich analysis and determination of number of electrons transferred Mass-transport correction, Levich equation, kinetic current density, distinction between $2e^-$ and $4e^-$ pathways.

**Any other experiments may be added when required.**

## Reference Books

1. **Electrochemical Methods: Fundamentals and Applications** Allen J. Bard & Larry R. Faulkner 3rd Edition, Wiley (2022 or latest reprint) → The Bible for all 7 experiments. Detailed theory + experimental protocols for CV, Tafel, EIS, RDE, ECSA, etc. → Every calculation (Nicholson method, Koutecky–Levich, Randles circuit fitting) is derived step-by-step.
2. **Electrocatalysis: Fundamentals and Applications** Richard C. Alkire, Dmitry A. Kuznetsov, Jacek Lipkowski (Editors) Wiley-VCH (2023) → Latest book dedicated to HER, OER, ORR mechanisms, volcano plots, Tafel slope interpretation, NiFe LDH, $MoS_2$, etc. → Directly relevant for Experiments 3, 4, and 7.
3. **Instrumental Methods in Electrochemistry** Southampton Electrochemistry Group (R. Greef, C.M.A. Brett et al.) Horwood Publishing (Reprinted 2021) → Excellent practical guide with real EIS Nyquist plots, RDE hydrodynamics, and catalyst preparation methods.
4. **Modern Electrochemistry 2A & 2B: Fundamentals of Electrodics** John O'M. Bockris & Amulya K.N. Reddy Springer (Kluwer) – Latest reprint 2022 → Classic but still unbeatable for Butler–Volmer derivation, multistep mechanisms, exchange current density, and overpotential concepts.
5. **Electrochemical Impedance Spectroscopy** Mark E. Orazem & Bernard Tribollet 2nd Edition, Wiley (2017) – still the gold standard in 2025 → Complete guide to EIS fitting, constant phase element (CPE), transmission line models for porous electrodes (very useful for Ni foam/LDH catalysts).

## RP-306: Research Project (4 Cr, 120 Hrs)

**See Annexture II for details (In the end of this document).**

# M. Sc. II (SEM - IV) Physical Chemistry

## MANDATORY PAPERS

Paper X: PCHT401 (4 Cr): Thermodynamics and Molecular Modeling

Paper XI: PCHT402 (4 Cr): Molecular Structure: Spectroscopic Approaches

PCHP404 (4 Cr): Practical-VII

RP-405 (6 Cr): Research Project

## ELECTIVE PAPERS

Paper XII: E-PCHT403 (A) (4 Cr): Surface Chemistry

Paper XII: E-PCHT403 (B) (4 Cr): Biophysical Chemistry

Paper XII: E-PCHT403 (C) (4 Cr): Modern Electroanalytical Techniques

Paper XII: E-PCHT403 (D) (4 Cr): Radiation and Nuclear Chemistry

## Paper-X, PCHT 401: Thermodynamics and Molecular Modeling (4 credits, 60 hrs)

This advanced course offers a comprehensive exploration of thermodynamics and its application to molecular modeling. It is designed for postgraduate students seeking both theoretical knowledge and practical expertise in the field. Through a blend of experimental and computational approaches, participants will investigate how individual molecular forces contribute to overall thermodynamic properties. The syllabus covers essential industrial processes, including thermoelectricity and osmosis, and emphasizes the study of irreversible phenomena, microscopic reversibility, and Saxen's relations. By integrating modern thermodynamics, statistical mechanics, and molecular simulation techniques, the course equips students with the analytical skills necessary for independent research and professional careers in chemical and pharmaceutical industries.

### Course Outcomes

- CO1: Enable students, including those with diverse mathematical backgrounds, to interpret scientific concepts through mathematical modeling, thereby deepening their understanding of physical chemistry and develop proficiency in applying statistical methods to estimate and analyse the bulk thermodynamic properties of various substances.

- CO2: Foster comprehension of the relationship between microscopic (quantum) and macroscopic (classical) properties using ensemble theories and statistical distribution laws and train students to evaluate thermodynamic characteristics of quantum systems, encompassing both bosons and fermions.
- CO3: Introduce classical and statistical thermodynamic principles for computer-based simulations, focusing on molecular dynamics to model real-life processes and to provide advanced instruction in molecular dynamics (MD) simulation techniques for assessing molecular structures and properties, with applications spanning drug design, material science, protein chemistry, and polymer science to deliver practical training in simulation methodologies, preparing students for research roles in premier laboratories and R&D departments within the pharmaceutical sector.
- CO4: Examine the application of thermodynamic principles to systems characterized by irreversible effects and near-equilibrium conditions and impart fundamental knowledge of industrially relevant phenomena such as thermoelectric generation, Peltier effects, electrophoresis, osmosis, thermo-diffusion, and thermo-conductivity and to develop an understanding of entropy production and flow in chemical and biological contexts, enhancing insight into coupled reactions in living systems.

## Unit I: Contemporary Theoretical Foundations in Thermodynamics

**(15 hrs)**

This unit introduces students to advanced mathematical tools essential for thermodynamic analysis, including exact and inexact differentials, total and partial differentiation, and transformations of variables. Emphasis is placed on optimisation techniques (maxima and minima), integrating factors, and the application of Paff differential equations. The Carathéodory theorem and Legendre transformations are explored for their roles in deriving and interpreting thermodynamic identities. The classical and modern interpretations of the second law of thermodynamics are discussed, with focus on entropy changes, Clausius inequality, and free energy concepts. The unit culminates in a comprehensive examination of equilibrium conditions and thermodynamic potentials, incorporating recent advancements in the understanding of non-equilibrium states and their practical significance in physical chemistry.

### Unit II: Statistical Thermodynamics and Quantum Statistics (15 hrs)

This unit provides a modern perspective on statistical thermodynamics, beginning with the foundational concepts of ensembles, ensemble and time averages, and the ergodic hypothesis. Students analyse the role of partition functions in determining thermodynamic properties, bridging classical and quantum statistics. The properties of photon gases, bosonic and fermionic systems, and quantum statistics for absolute entropy are explored, including current research on helium condensation, Fermi energy, and electron behaviour in metals. The heat capacity of solids is addressed through both classical (Einstein, Debye) and advanced models, with discussion on characteristic temperatures and the Debye $T^3$ law. Recent applications in materials science, nanotechnology, and quantum computing are integrated to reflect contemporary developments in the field.

### Unit III: Molecular Modelling and Advanced Simulation Techniques (15 hrs)

Students will explore the distinction between microscopic and macroscopic properties, with an emphasis on timescales relevant to chemical and biological systems. The unit covers potential energy surfaces, including Morse potential and harmonic oscillator models, as well as the construction and parameterisation of modern force fields. Key topics include non-covalent interactions, Lennard-Jones and truncated potentials, and the evaluation of various force field methodologies. Advanced molecular dynamics (MD) simulation methods are introduced, including algorithms for neighbour searching, integration (Verlet, Leap-frog, Velocity Verlet, Beeman's), constraint handling (SHAKE, LINCS), and energy minimisation (steepest descent, conjugate gradient, L-BFGS). The curriculum incorporates solvent models (implicit and explicit), simulation protocols (heating, equilibration, production), and trajectory analysis. Cutting-edge topics such as enhanced sampling (replica exchange), free energy calculations, protein folding, and protein-ligand binding are discussed. Students gain hands-on experience with state-of-the-art MD software and visualisation tools, reflecting current best practices in computational chemistry and biophysics.

### Unit IV: Non-equilibrium Thermodynamics and Applications (15 hrs)

This unit delves into the principles of non-equilibrium thermodynamics, focusing on mass and energy conservation in both closed and open systems, and the modern understanding of entropy production. Students examine non-adiabatic processes, steady-state phenomena, and the generalised thermodynamic equations of motion. The curriculum covers chemical and electrochemical affinities, reaction coupling, rates, and the transformation of generalised fluxes and forces. Phenomenological equations, transport coefficients, and Onsager's reciprocity relations are discussed in depth, with attention to the theorem of microscopic reversibility. The generation and flow of entropy in closed and open systems are analysed, with applications to heat flow, chemical potentials, diffusion, electromotive forces, electro-osmosis, and thermoelectric effects. Recent advances in the study of cross-effects and coupled reactions, including their implications for biological and energy systems, are highlighted to ensure alignment with contemporary research and industrial relevance.

**Recommended Books:**


1. S. N. Blinder, Advanced Physical Chemistry, The Macmillan Company, 1967.
2. L. K. Nash, Elements of Statistical Thermodynamics, 2nd Edition, Addison Wesley, 1974.
3. T.L. Hill, An Introduction to Statistical Thermodynamics, Addison-Wesley, 1960.
4. S. Glasstone, Theoretical Chemistry: An Introduction to Quantum Mechanics, Statistical Mechanics, and Molecular Spectra for Chemists, D. Van Nostrand Company, Inc., 1944.
5. D. A. McQuarrie and J. D. Simon, Physical Chemistry: A Molecular Approach, Viva Books, New Delhi, 1998.
6. Allen, M. P., Tildesley, D. J., Computer Simulations of Liquids, Oxford: Oxford Science Publications, 1987.
7. Frenkel, D.; Smit, B., Understanding Molecular Simulation: From Algorithms to Applications, 2nd Edition, Academic Press, San Diego, 2002.
8. K.I. Ramachandran, G. Deepa, and K. Nimboori, Computational Chemistry and Molecular Modelling: Principles and Applications, Springer-Verlag, Berlin, Germany, 2008.
9. F. Jensen, Introduction to Computational Chemistry, 2nd Edition, John Wiley & Sons Ltd, West Sussex, England, 2007.
10. Schlick, T., Molecular Modelling and Simulation: An Interdisciplinary Guide, Springer-Verlag, New York, Inc., Secaucus, NJ, USA, 2002.
11. D.B. Cook, Handbook of Computational Chemistry, Oxford University Press, New York, 1998.
12. Online Manuals for simulation and visualization packages (GROMACS, VMD, NAMD, AMBER, TINKER, etc.).
13. Prigogine, Introduction to Thermodynamics of Irreversible Processes, Wiley, New York, 1968.
14. R.P. Rastogi, Introduction to Non-equilibrium Physical Chemistry: Towards Complexity and Non-linear Science, Elsevier, Oxford, 2008.

## Paper-XI, PCHT402: Molecular Structure: Spectroscopic Approaches (4 credits, 60hrs)

This advanced course offers a comprehensive and critical examination of molecular structure with a focus on state-of-the-art spectroscopic techniques. Designed for postgraduate science students, it emphasises both theoretical underpinnings and practical applications, fostering analytical skills for independent research. Students will engage deeply with the principles, instrumentation, and emerging trends in spectroscopy, preparing them for advanced research or professional roles in academia and industry.

### Course Outcomes

- CO1: To provide an in-depth understanding of the fundamental and advanced principles of molecular spectroscopy and its pivotal role in elucidating molecular structure.
- CO2: To critically analyse and compare a range of spectroscopic techniques employed in contemporary chemical, physical, and interdisciplinary research.
- CO3: To cultivate advanced practical skills in acquiring, interpreting, and critically evaluating spectroscopic data for molecular identification, structural analysis, and material characterisation.
- CO4: To explore and assess recent innovations, interdisciplinary applications, and cutting-edge research in spectroscopy, including its integration with other scientific methods.

### Unit 1: Rovibrational and Raman Spectroscopy (15 hrs)

Advanced theory of molecular rotation and vibration; energy level quantisation and anharmonicity. In-depth exploration of infrared absorption: quantum mechanical selection rules, transition intensities, and isotopic effects. Raman spectroscopy: Stokes/anti-Stokes processes, depolarisation ratios, and advanced polarizability concepts. Instrumentation: high-resolution FTIR, advanced Raman spectrometers, and sample handling for complex systems. Applications: detailed functional group analysis, advanced material characterisation, and in situ monitoring.

### Unit 2: Electronic Absorption and Emission Spectroscopy (15 hrs)

Comprehensive analysis of electronic transitions: singlet/triplet states, vibronic coupling, and selection rules. Advanced absorption spectroscopy: quantitative methods, spectral deconvolution, and computational approaches. Emission spectroscopy: time-resolved fluorescence, phosphorescence lifetimes, and quantum yields. Instrumentation: tunable lasers, advanced detectors, integration with computational tools. Applications: photophysics, photochemistry, environmental sensing, and advanced quantitative analysis.

## Unit 3: Nuclear and Electron Spin Magnetic Resonance Spectroscopy (15 hrs)

Advanced NMR: quantum mechanical principles, multidimensional techniques (2D, 3D NMR), and dynamic NMR. ESR/EPR spectroscopy: advanced principles, g-tensor analysis, and hyperfine interactions in complex systems. Instrumentation: superconducting magnets, cryogenic techniques, high-frequency sources, and probe design. Interpretation: structure elucidation of complex organic, inorganic, and biological molecules; paramagnetic systems. Applications: biomolecular structure, catalysis, and materials science.

## Unit 4: Advanced Topics in Molecular Spectroscopy (15 hrs)

Fourier-transform methods, ultrafast and time-resolved spectroscopies, and non-linear techniques. Laser-based spectroscopy: pump-probe, transient absorption, and multi-photon processes. Multidimensional NMR/ESR, solid-state techniques, and integration with computational modelling. Interdisciplinary applications: spectroscopy in nanoscience, environmental studies, medicine, and materials innovation. Critical analysis of recent literature, case studies, and research-led seminars.

**Recommended Books:**

1. Principles of Molecular Spectroscopy by C.N. Banwell and E.M. McCash
2. Introduction to Spectroscopy by Donald L. Pavia, Gary M. Lampman, George S. Kriz
3. Fundamentals of Molecular Spectroscopy by C.N. Banwell
4. Spectrometric Identification of Organic Compounds by Robert M. Silverstein et al.
5. Recent research articles and review papers
6. Online resources: NPTEL lectures, Royal Society of Chemistry Spectroscopy tutorials, open-access databases, and relevant postgraduate-level MOOCs.

## Electives Papers (Choose any one)

## Paper-XII, E-PCHT403(A): Surface Chemistry (4 credits, 60hrs)

### Course Outcomes

- CO1: Understand concepts of solid-liquid, solid-gas, liquid-gas interfaces.
- CO2: Apply fundamental principles of chemistry to chemical processes occurring at interfaces.
- CO3: Apply spectroscopic methods to study interfaces and interfacial phenomena and learning and understanding the importance, applications, and basic aspects of surface chemistry.
- CO4: The course focuses on the fundamentals of surface chemistry, with the main emphasis on solid surfaces in contact with gas phase and Adsorption, desorption, and colloidal applications of surface chemistry are able to apply this knowledge in understanding and designing surface chemistry processes.

### UNIT-I: Surface Chemistry of Interfaces 15 hrs.

Types of interfaces, liquid-vapour interface, surface tension and interfacial tension, surface tension across curved surfaces, capillary action, methods of determination of surface tension, vapor pressure of droplet ( Kelvin equation ) ,surface activity and adsorption phenomenon, Trube's rule, liquid-liquid interfaces, work of cohesion and adhesion, surface spreading , spreading of one liquid on the surface of other liquid, spreading coefficient and derivation for its relation with surface tension, surface films on liquids, criteria for spreading of one liquid on another. Experimental techniques for the study of monomolecular films, states of monomolecular films reaction on monomolecular films, heterogenous catalysis.

### UNIT –II: Solid-Liquid and Solid - Solid interfaces 15 hrs.

Solid-liquid interfaces, Introduction, wetting phenomenon, contact angle and wetting, heat of wetting, methods of determination of contact angle, contact angle hysteresis, wetting agents, selective wetting, applications in detergency, and pesticide affectivity, solid-solid interfaces, introduction, surface energy of solids, adhesion, and adsorption, sintering and sintering mechanism, Tammann temperature, importance of impurities, surface structure and surface composition. Friction and lubrication, mechanism of lubrication, solid state lubricants.

## Unit-III: Solid-Gas Interfaces 15 hrs.

Adsorption, mechanism of adsorption, adsorption of gases by solids, surface area measurement, factors affecting on adsorption, experimental methods of determining gases adsorption, adsorption of solutes from solution, heat of adsorption, measurement of heat of adsorption, Chemisorption: kinetics of chemisorption, heat of chemisorption, surface film, Catalysis of gases reaction by solid surface, One reactant gases slightly/ strongly/ moderately adsorbed, Retarded reaction, ion exchange adsorption, Applications.

## UNIT- IV: Colloids and Emulsion 15 hrs.

Colloidal solution, classification of colloids, Theories of origin of charge on sol particles, determination of charge on a colloidal particle, stability of sols, properties of colloids, spontaneous ageing of colloids, factors affecting on the spontaneous ageing, theories of spontaneous ageing, coagulation, kinetics of coagulation. Emulsion: Types of emulsion, preparation, properties, characteristics, identification test between two types of emulsions, emulsifiers, demulsification. Gels: classification, methods for the preparation of gels, properties of gels, applications of colloids.

Recommended Books:


1. Physical chemistry of surfaces: A. W. Adamson.
2. Introduction to colloid and surface chemistry by D. J. Shaw. 58
3. Surface chemistry by J. J. Bikermann
4. The Surface Chemistry of Solids,by S.J.Gregg, Second Edition, Chapman & Hall Ltd. London.
5. Advanced Physical Chemistry, by Gurdeep Raj, Goel Publishing House, Krishna Prakashn Media (P) Ltd., Meerut-250001(UP)
6. Physical Chemistry by Pahari S. New Central Book Agency (P) Ltd. Kolkata.
7. Advanced Physical Chemistry J.N. Gurtu, A. Gurtu. 11th Edition Pragati Prakashan.
8. Advanced Physical Chemistry D N Bajpai S Chand Publications
9. Essentials of Physical Chemistry by Arun Bahl, B S Bahl, G D Tuli . S Chand Publications
10. Principles of Physical Chemistry by S H Maron and C F Prutton
11. Physical Chemistry, P. W Atkin.

## Paper-XII, E-PCHT403(B): Biophysical Chemistry (4 credits, 60hrs)

Biophysical Chemistry bridges the disciplines of biology, physics, and chemistry to provide a molecular understanding of biological systems. This introduces students to the fundamental principles and experimental techniques essential for analysing the structure, dynamics, and functions of biological molecules. Special emphasis is placed on the quantitative and physical-chemical aspects of biomolecular systems.

### Course Outcomes

- CO1: To understand the foundational principles of biophysical chemistry as applied to biological macromolecules.
- CO2: To gain familiarity with the major experimental and computational techniques used in biophysical research.
- CO3: To develop quantitative reasoning and problem-solving skills in the context of biomolecular systems.
- CO4: To explore the physical basis behind biomolecular structure, stability, dynamics, and interactions and to connect theoretical concepts to real-world biological and biomedical problems.

### Unit I: Foundations of Biophysical Chemistry and Biological Macromolecules (15 hrs)

Scope and interdisciplinary nature of biophysical chemistry. Overview of biological macromolecules: proteins, nucleic acids, lipids, carbohydrates. Hierarchy of biological structure: primary, secondary, tertiary, quaternary. Non-covalent interactions: hydrogen bonding, hydrophobic effect, van der Waals forces, ionic interactions. Structure-function relationships: allostery, molecular recognition, and signal transduction.

### Unit II: Thermodynamics and Kinetics of Biomolecular Systems (15 hrs)

First, second, and third laws of thermodynamics. Enthalpy, entropy, free energy, and spontaneity. Thermodynamic properties of macromolecules and assemblies. Phase transitions: protein denaturation, micelle/lipid bilayer formation. Ligand binding and cooperativity (Hill equation, Scatchard analysis). Basic principles of chemical kinetics. Rate laws and mechanisms relevant to biomolecular processes. Enzyme kinetics: Michaelis–Menten theory, steady-state and pre-steady-state kinetics. Inhibition and regulation of enzymes.

## Unit III: Dynamics, Folding, and Analytical Techniques (15 hrs)

Folding and misfolding of proteins and nucleic acids: kinetic and thermodynamic considerations. Relaxation kinetics and stopped-flow techniques. UV/Visible absorption, fluorescence, and phosphorescence spectroscopy. Circular dichroism (CD) and optical rotatory dispersion (ORD). Infrared (IR) and Raman spectroscopy for biomolecule analysis. Nuclear Magnetic Resonance (NMR) spectroscopy: principles and applications in biomolecular structure. Electron Paramagnetic Resonance (EPR) spectroscopy. X-ray diffraction and crystallography: basics and applications to macromolecules. Light scattering, analytical ultracentrifugation, and mass spectrometry.

## Unit IV: Computational and Advanced Topics in Biophysical Chemistry (15 hrs)

Theoretical methods and models for biomolecular systems. Molecular mechanics, dynamics, and Monte Carlo simulations. Bioinformatics and structural databases (PDB, GenBank). Energy landscapes and protein folding funnels. Introduction to molecular docking and drug design. Protein structure: motifs, domains, folding, and stability. Nucleic acid structure: DNA/RNA conformations, topology, and dynamics. Lipid assemblies and biological membranes: structure and phase behaviour. Carbohydrate structure and recognition in biological systems.

Recommended books:

1. van Holde, K.E., Johnson, W.C., & Ho, P.S. Principles of Physical Biochemistry
2. Lehninger, A.L., Nelson, D.L., & Cox, M.M. Principles of Biochemistry
3. Atkins, P. & de Paula, J. Atkins' Physical Chemistry
4. Creighton, T.E. Proteins: Structures and Molecular Properties
5. Cantor, C.R. & Schimmel, P.R. Biophysical Chemistry (Volumes I–III)
6. Davidson, V.L. & Sittman, D.B. Biochemistry
7. Current literature and review articles (as provided during the course)

## Paper-XII, E-PCHT403(C): Modern Electroanalytical Techniques (4 credits, 60hrs)

This course aims to provide an in-depth understanding of modern electroanalytical techniques, their underlying principles, instrumentation, and applications in analytical chemistry. Students will gain theoretical knowledge and practical skills necessary for research and industrial applications involving electrochemical analysis.

### Course Outcomes (COs)

- CO1: Develop a rigorous understanding of the principles governing modern electroanalytical techniques and acquire practical skills in the use, calibration, and maintenance of electrochemical instrumentation.
- CO2: Cultivate the ability to design, execute, and interpret electroanalytical experiments, including data analysis and troubleshooting and understand the thermodynamic and kinetic principles underlying electrode processes and their applications.
- CO3: Interpret and critique primary literature and contemporary research in electroanalysis.
- CO4: Prepare for advanced research, professional, or teaching roles in analytical and physical chemistry.

### Unit 1: Fundamentals of Electroanalytical Chemistry (15 hrs)

Introduction to electroanalytical chemistry: Scope and significance. Electrochemical cells: Galvanic and electrolytic cells. Electrode types: Reference, working, and auxiliary electrodes. Electrochemical thermodynamics and kinetics: Nernst equation, electrode potentials, overpotential. Basics of mass transport: Diffusion, migration, and convection. Instrumentation and measurement systems in electroanalysis.

### Unit 2: Voltametric and Amperometric Techniques (15 hrs)

Principles of voltammetry: Polarography, cyclic voltammetry, linear sweep voltammetry. Amperometry: Constant potential measurements and applications.

Pulsed techniques: Differential pulse, square wave, and stripping voltammetry. Electrode materials and surface modification. Applications in environmental, pharmaceutical, and biochemical analysis.

**Unit 3: Potentiometric, Conductometric, and Coulometric Methods (15 hrs)**

Potentiometry: Ion-selective electrodes, pH measurement, potentiometric titrations. Conductometry: Principles, instrumentation, conductometric titrations. Coulometry: Principles, constant current and constant potential coulometry. Microelectrodes and miniaturised systems. Analytical applications and method validation.

**Unit 4: Advanced and Emerging Electroanalytical Methods (15 hrs)**

Electrochemical impedance spectroscopy (EIS): Principles and applications. Electrochemical sensors and biosensors: Design and working. Lab-on-a-chip and microfluidic electrochemical devices. Recent advances: Nanomaterials in electroanalysis, in-situ and Spectro-electrochemical techniques. Indian contributions and case studies in modern electroanalysis.

**Recommended Books:**

1. Allen J. Bard and Larry R. Faulkner, Electrochemical Methods: Fundamentals and Applications
2. Joseph Wang, Analytical Electrochemistry
3. David Harvey, Modern Analytical Chemistry
4. Relevant research articles and review papers (will be provided during the course)

## Paper-XII, E-PCHT403(D): Radiation and Nuclear Chemistry (4 credits, 60 hrs)

This course provides a comprehensive understanding of radiation and nuclear chemistry, focusing on the fundamental principles, applications, and implications of nuclear processes. The course is structured into four units, each of 15 hours, tailored for students pursuing an M.Sc. in Physical Chemistry. Emphasis will be placed on both theoretical concepts and practical applications relevant to modern research and industry in India and globally.

### Course Outcomes (COs)

- CO1: Explain the basic principles of radioactivity, nuclear reactions, and the structure of atomic nuclei.
- CO2: Apply the concepts of radiation detection and measurement techniques in laboratory and industrial settings.
- CO3: Analyse the chemical effects of radiation and understand radiochemical methods in analytical chemistry.

- CO4: Evaluate the applications and societal impact of nuclear chemistry in medicine, energy, agriculture, and environmental science.

**Unit 1: Fundamentals of Nuclear Chemistry (15 hrs)**

Atomic nucleus: Composition, properties, and nuclear forces. Isotopes, isobars, isotones, and nuclear stability. Types of radioactive decay: Alpha, beta, gamma, positron emission, electron capture. Radioactive series and decay kinetics. Binding energy, mass defect, and packing fraction. Q-value of nuclear reactions and their calculations. Fundamentals of fission and fusion processes.

**Unit 2: Radiation Detection and Measurement (15 hrs)**

Interaction of radiation with matter. Principles and functioning of detectors: Geiger-Müller counter, scintillation counter, proportional counter, semiconductor detectors. Measurement of radiation: Units (Becquerel, Curie, Gray, Sievert, Roentgen). Radiation dosimetry and safety standards. Counting statistics and error analysis. Pulse height analysis and spectroscopy. Shielding and protection from radiation.

**Unit 3: Radiochemical Methods and Applications (15 hrs)**

Principles of radiochemical separation techniques. Isotope dilution analysis and radiotracer techniques. Activation analysis: Neutron activation, photon activation. Applications of radioisotopes in analytical chemistry. Radiolysis of water and radiation chemistry of organic and inorganic compounds. Hot atom chemistry and recoil techniques. Radioimmunoassay and autoradiography.

**Unit 4: Applications and Impact of Nuclear Chemistry (15 hrs)**

Nuclear energy: Reactors, fuel cycle, and waste management. Applications in medicine: Diagnostic imaging (PET, SPECT), radiotherapy. Industrial applications: Radiography, thickness gauging, tracer techniques. Agricultural and environmental applications: Food irradiation, pest control, radiotracers in soil and water studies. Nuclear accidents and their environmental impact. Societal, ethical, and regulatory issues in nuclear chemistry. Recent advances and future directions in nuclear chemistry.

Recommended books:

1. G. Friedlander, J. W. Kennedy, and J. M. Miller, "Nuclear and Radiochemistry"
2. H. J. Arnikar, "Essentials of Nuclear Chemistry"
3. J. N. Lal and S. B. Manohar, "Nuclear Chemistry: Principles and Applications"
4. Indian Atomic Energy Regulatory Board (AERB) Guidelines

## Physical Chemistry Practicals

### PCHP404, Practical VII (4 Credits, 120hrs)

List of Experiments

1. Determination of stability constant of ferric thiocyanate complex.
2. To determine stoichiometry and stability constant of ferric-salicylate complex by Job's Method and mole ratio method spectrophotometrically.
3. Determination of molecular properties of small gaseous molecules from rovibrational spectra.
4. Determination of apparent and partial molar volumes of 1:1 electrolyte in aqueous solutions using pyknometric method of density measurements.
5. Determination of indicator constant and isosbestic point of an indicator.
6. Determination of molar enthalpy of solution, molar enthalpy of dilution and partial molar heat content of components in aqueous solutions.
7. Determination of thermodynamic properties from Molecular dynamic simulations of some simple systems.
8. UV/Visible quantification of proteins and nucleic acids.
9. Enzyme kinetics using spectrophotometric methods.

**Any other experiments may be added when required.**

### RP-405 Research Project (06 Cr, 180 Hrs)

**See Annexture II for details (In the end of this document).**

**Note:** Study tour is compulsory for M. Sc. Part- II Students to visit Chemical Industries in India.

# Shivaji University Kolhapur

## Syllabus as per NEP-2020

**For**

**M. Sc. Part- II Analytical Chemistry**

**Semester III & IV**

## Under the Faculty of Science and Technology

**To be implemented with effect from Academic Year 2026-2027**

This is applicable for University Department and Affiliated College PG Centers

## M.Sc. Part- II Analytical Chemistry

Analytical Chemistry is a pervasive and a key subject not only for Chemistry, but all the branches of Science, Engineering and Technology which involves Chemistry. It is an experimental science and students need to be trained in theory and practical dealing with fundamental and advanced analytical skills of conventional analysis and instrumental analysis so as to get expertise in doing fine experiments and handle sophisticated instruments.

The M.Sc. Analytical Chemistry program offered by Shivaji University is a Two Years full time program. The first and second semester gives general background of analytical chemistry and its importance to all the branches of Chemistry to make a good theoretical background of students. The semester third and fourth is totally assigned to analytical chemistry and it covers most of the fundamental and advance aspects of modern analytical chemistry. In order to make students more careers oriented and nurturing their scientific temperaments, students will get exposure to the depth of core understanding of various dimensions of analytical chemistry during these two years the study.

## Programme Educational Objectives (PEOs):

PEO-1: To provide students with advanced theoretical and practical knowledge in Analytical chemistry, enabling them to understand and solve complex chemical problems in both academic and industrial settings.

PEO-2: To cultivate a strong foundation in Analytical subject with advanced laboratory techniques, instrumentation, and computational tools for research and analysis in analytical chemistry, thereby preparing students for research, innovation, and higher studies (Ph.D., Postdoctoral Research, etc.).

PEO-3: To in still professional ethics, scientific temper, teamwork, and effective communication skills necessary for careers in academia, pharmaceutical industries, chemical manufacturing, or entrepreneurship.

PEO-4: To encourage lifelong learning, critical thinking, and application of analytical chemistry knowledge to address societal and environmental challenges through green chemistry and sustainable practices.

## Program Outcomes (POs):

PO1: The M.Sc. analytical chemistry program at Shivaji University, Kolhapur provides the key knowledge base and laboratory resources to prepare students for careers as professionals in the field of chemistry and particularly in analytical chemistry enabling them to interface not only with various branches of chemistry (organic, inorganic, physical, biological, industrial, environmental, pharmaceuticals etc) but also with the related fields, and for professional courses and areas of research including medical, forensic, food, agriculture, dental, law, intellectual property, business programs etc.

PO2: Students will be able to solve various problems by identifying the essential parts of a problem, formulate strategy for solving the problem, applying appropriate techniques to arrive at a solution, test the precision and accuracy of the solution and interpret the results.

PO3: Students will be able to acquire domain specific knowledge and technical skills needed for employment in industries, teaching fields and pursue research. Students will be skilled in problem solving, critical thinking and analytical reasoning

PO4: Students will be able to apply the fundamental knowledge to address the cross-cutting issues such as sustainable development

PO5: Students will get perfect insight into qualitative and quantitative analytical chemistry and research ethics for production of quality research.

PO6: Students will be able to communicate effectively i.e. being able to articulate, comprehend and write effective reports, make effective presentations and documentation and capable of expressing the subject through technical writing as well as through oral presentation.

## Program Specific Outcomes (PSOs):

PSO1: Students will be able to prepare and qualify subject specific competitive exams like NET, SET and GATE and also other general public administration exams like M.P.S.C. and U.P.S.C. etc. exams.

PSO2: Student will be able to utilize the knowledge and analytical skills in QA-QC and R&D departments in almost all the industries enabling them to secure jobs where analytical chemistry is the core requirement to ensure and ascertain the quality of the product.

PSO3: Students will have opportunity for higher education leading to Ph.D. program.

PSO4: Students will be able to explore contemporary research in chemistry and allied fields of science and technology, collaborate in team projects, communicate the results of scientific work in oral, written and electronic formats to both scientists and the public at large.

## M. Sc. Part II: Analytical Chemistry

## SEMESTER- III

**MANDATORY PAPERS**

Paper-VII, ACHT301 (4 Cr): Advanced Analytical Techniques

Paper-VIII, ACHT302 (4 Cr): Electroanalytical Techniques in Chemical Analysis

ACHP304 (4 Cr) : Practical-V

ACHP305 (2 Cr) : Practical-VI

RP-306 (4 Cr): Research Project

**ELECTIVE PAPERS**

Paper-IX, E-ACHT303 (A) (4 Cr): Organo Analytical Chemistry

Paper-IX, E-ACHT303 (B) (4 Cr): Environmental Chemical Analysis and Control

Paper-IX, E-ACHT303 (C) (4 Cr): Recent Advances in Analytical Chemistry

Paper-IX, E-ACHT303 (D) (4 Cr): Automation and Sensor

## SEMESTER- IV

**MANDATORY PAPERS**

Paper-X, ACHT401 (4 Cr): Modern Separation Method in Analysis

Paper-XI, ACHT402 (4 Cr): Advanced Methods in Chemical Analysis

ACHP404 (4 Cr): Practical-VII

RP-405 (6 Cr): Research Project

**ELECTIVE PAPERS**

Paper-XII, E-ACHT403 (A) (4 Cr): Organic Industrial Analysis

Paper-XII, E-ACHT403 (B) (4 Cr): Industrial Analytical Chemistry

Paper-XII, E-ACHT403 (C) (4 Cr): Quality Assurance and Accreditation

Paper-XII, E-ACHT403 (D) (4 Cr): Food, Fertilizer and Pesticides Analysis

# M.Sc. Part-II (SEM- III): Analytical Chemistry

## Detailed Syllabus:

**MANDATORY PAPERS**

## Paper-VII, PCHT301: Advanced Analytical Techniques (4 Cr, 60 hrs.)

## Course Outcomes (COs):

CO1: Develop knowledge of fundamental, instrumentation and working of state of art instrumental analytical techniques, effective use and choice of technique, written and/or oral communication of the concepts of analytical chemistry which will be useful as analytical chemist and R&D.

CO2: Acquire knowledge of mass spectrometry, type of MS, ionization types and specific practical applications of MS.

CO3: Acquire knowledge of basics of nanochemistry, nanomaterials and nanotechnology and application orientated synthesis and characterization of nanomaterials.

CO4: This course gives wide understanding about the instrumental analytical techniques (SEM, TEM, EDS, STM, AFM, Raman, XFS, ESR, XPS, AES, SIMS etc.) employed for qualitative and quantitative analysis for contemporary research.

**UNIT-I: Advances in Mass Spectrometry 15 hrs.**

Introduction to Mass spectrometry, diagram of a mass spectrometer and Instrumentation, principles, history, concept of ion free path, classification of mass spectrometry based on nature of compound to be analyzed and the ion sources viz. Electron impact (EI), chemical ionization (CI), Fast ion or atom bombardment ionization (FID/FAB), field desorption (FD), laser desorption ionization (LDI), plasma desorption ionization (PDI), thermospray ionization (TSI), electrospray (ESI), atmospheric pressure ionization, Inductively couple plasma (ICP) etc. Mass Analyzers, Quadrupolar Analyzers, Quadrupole ion trap or Quistor, Ion trap detector, development of high –Mass, High-resolution ion trap, tandem mass spectrometry in the ion trap, time of flight analyzer, magnetic and electromagnetic analyzer, ion cyclotron resonance and FTMS, and detectors.

**UNIT-II: Introduction to Nanotechnology and Nano Chemistry 15 hrs.**

Definition of nanomaterials and nanotechnology, significance of nanotechnology, size and properties, types of nanomaterials like 0D (quantum dots), 1D, 2D and 3D, introduction to physical, chemical and biological synthesis of nanomaterials with suitable examples, top down and bottom-up approach, chemical synthesis of nanomaterials- Different types and processes for synthesis of nanomaterials using wet chemical approaches. Fabricating nanomaterials with different morphology intended for specific applications. Applications of Nanotechnology.

**UNIT-III: Advanced Instrumentation Techniques-A** **15 hrs.**

Scanning Electron Microscope (SEM) - Introduction, principle, instrumentation, applications
Transmission Electron Microscope (TEM) - Introduction, principle, instrumentation, applications,
Energy Dispersive X-ray Analysis (EDAX) - Introduction, principle, instrumentation, applications.
Scanning Tunneling Microscopy (STM) - Introduction, principle, instrumentation, applications
Atomic Force Microscopy (AFM) - Introduction, principle, instrumentation, applications
Practical applications and examples in analytical chemistry and research.

**UNIT-IV: Advanced Instrumentation Techniques-B** **15 hrs.**

Raman Spectroscopy- Introduction, principle, instrumentation, applications.
X-Ray Fluorescence Spectroscopy (XFS) - Introduction, principle, instrumentation, applications
Electron Spin Resonance Spectroscopy (ESR) - Introduction, principle, instrumentation, applications.
Secondary Ion Mass Spectrometry (SIMS) - Introduction, principle, instrumentation, applications, Practical applications and examples in analytical chemistry and research.

## Recommended Books:

1) E. De. Hoffmann, J. Charette, V. Stroobant, Mass Spectroscopy: Principles and Applications, John Wiley & Sons, Masson, Paris 1996.
2) J. H. Gross, Mass Spectroscopy: A Text book, Springer-Verlag Berlin 2004.
3) C. G. Herbert, R. A. W. Johnstone, Mass Spectrometry Basics, CRC Press, Boca Raton, Florida, 2002.
4) K. Benjamin: Mass Spectrometry
5) A. I. Vogel: A text book of Quantitative inorganic Analysis, Lonqmans.
6) G. H. Morrison and H, Freise: Solvent Extraction in Analytical Chemistry (John Wiley

New York), 1958.
7) Willard, Merrit and Settle: Instrumental Methods of analysis.
8) Principles of instrumental analysis- Holler, Skoog and Crouch.
9) Instrumental methods of Chemical analysis-H. Kaur
10) Bhushan, Bharat 2004. Handbook of Nanotechnology. Springer.
11) Niemeyer, C.M. & Mirkin, C.A. 2004. Nanobiotechnology- Concepts, Applications and Prespectives. Wiley-VCH Verlag.
12) Zander, C., Enderlein, J. & Keller, R.A. 2002 Single Molecule Detection in Solution. Wiley VCH Verlag.
13) Avouris, P, Klitzing, K. Von, Sakaki, H. & Wiesendanger,R .2003 NanoScience and Technology Series.
14) Scanning Probe Microscopy- Analytical Methods (R. Wiesendanger eds), Springer.
15) Nanochemistry, a chemical approach to nanomaterials, G. A. Ozin, and A. C. Arsenault, RSC Publishing, Cambridge, 2005. ISBN 0-85404-664-X.

## Paper-VIII, ACHT302: Advanced Methods in Chemical Analysis (4 Cr, 60 hrs.)

## Course Outcomes (COs):

CO1: Fundamental knowledge of electrochemistry, electrodes, types of electrodes, its construction will lay foundation for the course.

CO2: Students will gain knowledge and skill in electroanalytical techniques like cyclic voltammetry and its types, polarography, coulometry and dynamic light scattering technique for qualitative and quantitative analysis.

CO3: Students will be familiar with the advanced electrodes used for chemical analysis, liquid-liquid membrane electrodes, enzymes and gas electrodes.

CO4: Students will learn about electrophoretic techniques, advances in electrophoresis techniques and its analytical applications.

**UNIT-I: Voltammetry Techniques** **15 hrs.**

Introduction, Principle, excitation signals in voltammetry, basic instrumentation based on operational amplifiers, voltametric electrodes. Cyclic Voltammetry: Instrumentation, Determination of analytes using cyclic voltammetry, Applications. Pulse voltammetry:

Introduction, Normal Pulse Voltammetry, Reverse pulse voltammetry, Differential pulse voltammetry, Square wave voltammetry. Stripping voltammetry: Cathodic and Anodic stripping voltammetry, Electrodeposition step, Voltammetric completion of the analysis, adsorptive striping methods, voltammetry with microelectrodes. Practical applications in analytical chemistry and research.

**UNIT-II:** **15 hrs.**

**a) Ion selective electrodes & electrochemical sensors:**

Introduction, types and construction of electrodes, glass electrode, solid state and precipitate electrodes, liquid – liquid membrane electrodes, enzyme and gas electrodes, chemically modified electrode, Enzyme based electrode, catalytic electrodes, ultramicroelectrodes and applications.

**b) Electrogravimetry:**

Introduction, Types of electrogravimetric techniques, Diffusion Migration, Convection, instrumentations, applications.

**UNIT –III: Particle Size Analysis** **15 hrs.**

Introduction, Low angle LASER light scattering: Instrumentation, theoretical models, Mie theory, Fraunhofer diffraction theory, particle size distribution analysis, Applications. Dynamic Light Scattering: Introduction, Instrumentation, photodetector sample cell and sample handling, Applications, Photosedimentation: Setting velocity and particle size, Stokes equation, Instrumentation, sedimentation modes, Particle size distribution analysis, photometric measurements and applications. Comparison with particle size measurements using XRD, SEM and TEM. Practical applications in analytical chemistry and research.

**UNIT –IV: Electrophoresis:** **15 hrs.**

Introduction, Paper electrophoresis Principle, Factors governing migration of ions, Supporting media (gel, paper, cellulose, acetate, starch, polyacrylamide, agarose, sephedax and thin layers) Techniques of electrophoresis: Low and high voltage, iso electric focusing, continuous electrophoresis, capillary electrophoresis, Zone, gel, isotaechophoresis and micellar electro kinetic capillary chromatography, instrumentation, detection and applications and Applications, Numericals.

**Reference Books:**

1) R.D. Braun, Introduction to Instrumental Analysis.
2) D. A. Skoog, F. J. Holler, Principles of Instrumental Analysis, 6th edition.
3) Willard, Deritt, Dean and Settle, Instrumental methods of Analysis.
4) F. J. Welcher, Standard Methods of chemical Analysis Vol.3, Part A & B.
5) G.W. Ewing, Instrumental Methods of Analysis 4th and 5th editions.
6) Chatawal and Anand, Instrumental Methods of Analysis.
7) Bassett, Denney-Jeffer and Mendham, Vogel's Textbook of Quantitative Inorganic Analysis, (5th edition).
8) Electro-analytical chemistry, edited by H.W. Nurnberg.
9) Stulic, Ion selective electrodes (John Wiley).
10) Introduction to instrumental analysis by R. D. Broun, Mc Graw Hill (1987)
11) Instrumental methods of chemical analysis by H. Willard, D. Merrit, J.A. Dean and F.A. Settle. Sixth edition CBS (1986)
12) Fundamentals of Analytical Chemistry by D. A. Skoog, D. M. West and H. J. Holler sixth edition (1992) and Principles of Instrumental Analysis Skoog, West, Niemann
13) Vogel Text Book of quantitative analysis 6th Ed.

## ELECTIVE PAPERS

## Paper-IX, E-ACHT303(A): Organo Analytical Chemistry (4 Cr, 60 hrs.)

## Course Outcomes (COs):

CO 1: Students will gain knowledge of the instruments used at the interface of Analytical-Organic chemistry useful for R&D and structural elucidation using UV-Visible, IR, 1H & 13C NMR, Mass spectrometry data and interpretation of the same.

CO 2: Students will acquire knowledge about the drug, their classification, sources of impurities (chemical, atmospheric and microbial contamination) in pharmaceutical raw materials and analysis of the same.

CO 3: Students will gain knowledge about the conventional and advanced analytical approaches for analysis of drug, vitamin, body fluids and clinical samples.

CO 4: Students will have an idea of commonly used pesticides and their analysis and also about forensic science and forensic sample analysis.

**UNIT–I: Hyphenated Techniques** **15 hrs.**

Advanced techniques of analysis: UV-Visible, IR, 1H-NMR (Recapitulation), 13CNMR, Mass spectrometry (Basic fundamentals of mass spectrometry, ionization, advanced organic analysis examples); Problems related to structure determination and applications of spectroscopic techniques as analytical tools.

**UNIT-II: A) Drug Analysis** **10 hrs.**

Introduction to drugs, their classification, sources of impurities in pharmaceutical raw materials such as chemical, atmospheric and microbial contaminants etc. Limit tests: Limit test for impurities for Pb, As, Fe, Se, etc. Estimation of moisture (K-F method), halide (Schnoiger's oxygen flask method), sulphate, boron, etc. Analysis of commonly used drugs such as antihistamines, sulpha drugs, barbiturates, etc. using non-aqueous titrations, sodium nitrite titrations, differential UV methods, colorimetric and fluorimetric methods of analysis.

**B) Analysis of vitamins** **05 hrs.**

Analysis of vitamins (thiamine, ascorbic acid, Vit. A, Vit. B6, Vit. K) and hormones (progesterone, oxytocin, insulin) chemical, instrumental and biological assay, wherever applicable.

**UNIT – III: A) Clinical Analysis** **08 hrs.**

Biological significance, analysis of assay of enzymes (pepsin, monoamine, oxidase, tyrosinase), Composition and detection of abnormal level of certain constituents leading to diagnosis of diseases. Sample collection and preservation of physiological fluids, analytical methods to the constituents of physiological fluids (blood, urine and serum). Blood- Estimation of glucose, cholesterol, urea, haemoglobin and bilirubin, Urine- urea, uric acid, creatinine, calcium, phosphate, sodium, potassium and chloride.

**B) Body fluid analysis** **07 hrs.**

Composition and detection of abnormal level of certain constituents leading to diagnosis of diseases. Sample collection and preservation of physiological fluids, analytical methods to the constituents of physiological fluids (blood, urine and serum) Blood-Estimation of glucose, cholesterol, urea, haemoglobin and bilirubin Urine- urea, uric acid, creatinine, calcium, phosphate, sodium, potassium and chloride.

**UNIT–IV: A) Pesticides Analysis** **07 hrs.**

Introduction, classification of pesticides, sampling, sample pretreatment and processin g, analysis of DDT, gammexane, endosulphan, zinab, ziram, malathion, thiram, thiometon, simazine and chlordane. Applications of colorimetric and chromatographic techniques (GC-MS, HPLC-MS) in analysis of pesticide residue. Introduction to EPA regulatory body. Practical applications and examples in analytical chemistry and research.

**B) Forensic Analysis** **08 hrs.**

Special features of forensic analysis, sampling, sample storage, sample dissolution, classification of poisons, lethal dose, significance of LD-50 and LC-50. General discussion of poisons with special reference to mode of action of cyanide, organophosphate and snake venom. Estimation of poisonous materials such as lead, mercury and arsenic in biological samples. Practical applications and examples in analytical chemistry and research.

## Reference Books:

1) F. J. Welcher: Standard methods of Chemical analysis, 6th Ed. Vol. I and II( D. Van Nostard Comp.)
2) I. M. Kolthoff: Treatise on Analytical Chemistry Vol. I & II.
3) F. D. Snell: Encyclopedia of industrial Chemical Analysis Vol. 1 to 20 ( John Wiley) Riech: Outline of Indutrial Chemistry.
4) K. H. Buchel: Chemistry of Pesticides (John Wiley) Indian, Pharmacopoeia, British Pharmacopoeia and U. S. Pharmacopoeia.
5) V. M. Parikh: Absorption spectroscopy of organic molecules (Addision Wesley) Willard, Merrite, Dean and Settle: Instrumental methods of analysis (CBS).
6) D. H. Williams and J. Fleming: Specroscopic methods in organic chemistry (McGraw Hill).
7) Silverstein: Spectroscopic Identification of organic compounds (John Wiley).
8) Jackmann and Sternhill: Applications of NMR spectroscopy of organic Chemistry (Pergamon Press).
9) J. D. Roberts : Nuclear Magnetic Resonance ( McGraw Hill)
10) K. Benjamin: Mass Spectrometry.
11) Nicholas: Aids to the Analysis of foods and Drugs.
12) A. H. Beckett and J. B. Stanlake; Practical Pharmaceutical Chemistry Vol. I & II (CBS publishers).

**Paper-IX, E-ACHT303(B): Environmental Chemical Analysis and Control (4 Cr, 60 hrs.)**

## Course Outcomes (COs):

CO1: Students will acquire knowledge about sampling, criteria of good sampling, handling, preservation and storage of the samples, pretreatment and post treatment of samples.

CO2: Students will acquire knowledge of conditions and strategies required during sampling and electrochemical and spectral methods for analysis of environmental samples.

CO3: Students will learn about the air and water pollution, sources of pollution, typical parameters and properties (physical, chemical and biological) to be measured in air and water pollution with relevance to specific case studies.

CO4: Students will be acquainted with organic pollutants and their analysis with special reference to pesticide analysis.

**UNIT-I: Sampling in analysis 15 hrs.**

Definition, theory and techniques of sampling, sampling of gas, liquids and solids, Criteria of Good sampling, Minimization of Variables, transmission and storage of samples, high pressure ashing techniques (HPAT), particulate matter, its separation in gas stream, Filtering and gravity separation. Analysis of particulate matter like asbestos, mica, dust and aerosols etc

**UNIT-II: Electrochemical and spectral methods Environmental analysis 15 hrs.**

Introduction to instrumental techniques, principle instrumentation and applications with respect to environmental analysis of Conductometry, Potentiometry, Ion selective electrodes, Amperometry, Coulometry, Atomic absorption spectrometry, Atomic fluorescence pectrometry, Inductively coupled plasma spectrometry, Turbidimetry, Non Dispersive Infrared Analysis (NDIR).

**UNIT-III: Air and Water Pollutant Analysis 15 hrs.**

Chemistry of Air pollutants, characterization. source, methods of analysis of air pollutants;CO, CO2, NOX, NH3, H2S, SO2 etc. Monitoring Instruments, Potable and Industrial water, major and minor components, dissolved oxygen (DO) Chemical oxygen demand(COD) Biochemical oxygen demand (BOD) and their measurements. Analysis of Pd, Cd, Hg, Cr, As and their physiological manifestations. Quality of industrial waste water analysis for organic and inorganic constituents. Chemistry of odour and its measurements.

**UNIT-IV: Organic Pollutants and Their Analysis** **15 hrs.**

Sources, disposal, treatment and analysis of phenolic residues, methods of recovery of phenols from liquid effluents, Organomercurials and its analysis, Analysis of organochlorine pesticides, volatile organic pollutants and their analysis.

## Recommended books:


1) A.K. De: Standard Methods of Waste and Waste water analysis.
2) P. M. S. Monk Fundamentals of Electroanalytical chemistry-John Wiley & Sons (2001)
3) Instrumental methods of chemical analysis H. Kaur.
4) S.M. Khopkar, Environmental Chemistry; Environmental pollution analysis.
5) M.S. Creos and Morr, Environmental Chemical Analysis, American publication (1988).
6) A.K. De, Environmental Chemistry, New Age International publishers.
7) Moghe and Ramteke, Water and waste water analysis: (NEERI).
8) A.C. Stern, Air pollution: Engineering control Vol. IV (AP).
9) P.N. Cheremisinoff and R.A.Young, Air Pollution control and Design. Hand Book Vol. I &II (Dekker).
10) R. B. Pohasek, Toxic and Hazardous waste disposal, Vol.I & II (AAS).
11) M. Sitting, Resources Recovery and Recycling, Handbook of industrial Waste.
12) 10) B.K.Sharma, Industrial Chemistry.
13) S.P. Mahajan, Pollution Control in Process Industries.
14) R.A. Horne, Chemistry of our Environment.

## Paper-IX, E-ACHT303(C): Recent Advances in Analytical Chemistry (4 Cr, 60 hrs.)

## Course Outcomes (COs):

CO1: Students will be acquainted with ultra-purity and ultra-trace analysis required in electronic and semiconductor processing.

CO2: Students will learn Radio-Analytical techniques for analysis.

CO3: Student will be well versed with C13, P15 and O17 NMR Spectroscopy applications.

CO4: Student will learn about ESR spectrometry and its applications quantitative analysis.

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**UNIT-I: Ultra Purity and Ultra trace Analysis** **15 hrs.**

Ultra purity and ultra-trace analysis, laboratory dosing, purification of reagents, Preconcentration Techniques, Methods of trace analysis such as NAA, XRF, AAS and ICP, High purity materials for electronic industry, contamination control during analytical operations.

**UNIT-II: Radio-analytical Chemistry** **15 hrs.**

Separation methods, Precipitation, solvent extraction and chromatographic methods. Activation analysis, basic principles, fast neutron activation analysis, radiochemical methods in activation analysis, Applications if Geo-chemistry, oxygen in metals. Isotope dilution analysis: Principles and applications. Sub-stoichiometric determination of traces of metals: Principles, techniques and experimental methods in the determination of As, Pb and Hg.

**UNITS-III: Advanced Techniques in Analysis** **15 hrs.**

Nuclear Magnetic Resonance Spectroscopy ($^1$H NMR): Elementary ideas (Recapitulation); Different types of couplings, factors affecting on coupling constants, Karplus equation, Spin systems (AB, AX, ABX, AMX), Rate processes, spin decoupling, shift reagents, Nuclear Overhauser effect (NOE), INEPT and INADEQUATE.

$^{13}$C Nuclear Magnetic Resonance Spectroscopy: Elementary ideas, instrumental problems, chemical shifts (aliphatic, olefinic, alkyne, aromatic, heteroaromatic and carbonyl carbons); Effect of substituents on chemical shifts.

**UNIT-IV: Electron Spin Resonance Spectroscopy** **15 hrs.**

Electron behavior, ESR spectrometer, Spectra, Hyperfine interaction, free radical and interpretation of the spectra, Applications in quantitative analysis. Numerical problems.

## References:


1) Garen W. Ewing, Analytical Instrumentation, Handbook, Marcel Dekker Inc. (1997).
2) Mereitt, Dean, Settel, Instrumental methods of Chemical Analysis.
3) M. Zeif and J.W.Mitchell, Contamination Control in trace elemental analysis. Ajuja, Ultrapurity.
4) Minczewski,Chwastowska and Dycozynski, Separation and pre-concentration methods in Inorganic trace analysis.Ellis Haward.
5) Cali, trace Analysis of semiconductor Materials Pergamon.
6) Overman and Cleark, Radioisotopes techniques MGH.
7) Tolgyessy, Brown and Kyrs, Isotope dilution analysis.
8) Leniham and Thomson, Activation Analysis (AP).
9) Ruzica and Stary, Substopchiometry in Radiochemical Analysis. Pergamon.
10) Ladd and Lee, Radiochemistry.
11) Clerk, Handbook of Radiochemical methods.
12) Price, Nuclear radiation detections.

## Paper-IX, E-ACHT304 (D): Automation and Sensor (4 Cr, 60 hrs.)

## Course Outcomes (COs):

CO-1. Study the various terms used and methods in sensors and automation.

CO-2. Describe application of automation in analytical laboratory and sensors.

CO-3. Explain importance sensors and automation in analytical chemistry.

CO-4. Explain principles of different types of sensors in analytical chemistry.

**UNIT-I: Introduction to laboratory Automation: 15 hrs.**

Introduction, automation, miniaturization and simplification, lab automation, flow injection analysis, miniaturized analytical systems, fast response analytical systems, chemical sensors, screening systems, process on-line systems.

Laboratory Automation: Definition and concept, objective of automation in analytical chemistry, automation of analytical tools and process, automation of preliminary operations, automation of calibration, automation of measuring and transducing of analytical signals, automation of data acquisition and processing, analysers, automated management system, advantages and shortcomings of automated system.

**UNIT-II: Flow Injection Analysis 15 hrs.**

Batch and continuous flow analysis, principles, basic FIA instrumentation, dispersion in FIA, FIA for reproducible and precise sample preparation, FIA system with enzymes, flow injection hydride generation scheme, online sample conditioning, and preconcentration, exploiting the physical dispersion process, FIA gradient technique, Process control, process control analysers.

**UNIT-III: Miniaturized Analytical systems 15 hrs.**

Introduction, Concept, theory of miniaturization, microfabrication, silicon and glass micro-matching, polymer replication technology, miniaturized analytical components, sampling and sample pre-treatment, system integration, serial integration, parallel integration, commercialization.

Biosensors in analysis Introduction, producing biological surface, methods of immobilization, Achievement of bio transduction (amperometry, potentiometric, optical).

**UNIT-IV: Chemical Sensors** **15 hrs.**

Introduction, definitions, Classification of chemical sensors, descriptions of chemical sensors (electrochemical sensors, potentiometric sensors, Volta- metric chemical sensors, sensors based on conducting properties), Optical sensors (light guides, the evanescent wave, design of fibre optic sensor, indicator mediated sensor), Calorimetric sensors (catalytic gas sensor, thermal conductivity sensor), mass sensor (piezoelectric quartz crystal resonator, surface acoustic wave sensor).

## References:


1) Analytical Chemistry, Ed. by Kellner, Mermet, Otto, Valcarcel, Widmer, Second Ed. Wiley –VCH
2) Garen W. Ewing, Analytical Instrumentation, Handbook, Marcel Dekker Inc. (1997).
3) Mereitt, Dean, Settel, Instrumental methods of Chemical Analysis.
4) M. Zeif and J.W.Mitchell, Contamination Control in trace elemental analysis. Ajuja, Ultrapurity.
5) Minczewski,Chwastowska and Dycozynski, Separation and pre-concentration methods in Inorganic trace analysis.Ellis Haward.
6) Cali, trace Analysis of semiconductor Materials Pergamon.
7) Overman and Cleark, Radioisotopes techniques MGH.
8) Tolgyessy, Brown and Kyrs, Isotope dilution analysis.
9) Leniham and Thomson, Activation Analysis (AP).
10) Ruzica and Stary, Substopchiometry in Radiochemical Analysis. Pergamon.
11) Ladd and Lee, Radiochemistry.
12) Clerk, Handbook of Radiochemical methods.
13) Price, Nuclear radiation detections.

# Analytical Chemistry Practical Course

## Practical-V: ACHP304 (4 Cr, 120 hrs.)

## Course Outcomes (COs):

CO1: In-depth training on laboratory solution preparations on all concentration scales

CO2: Training on laboratory safety and lab ethics in scientific work

CO3: Training on planning, design and execution of experiments

CO4: Training on uncertainty estimations for experimentally measured and derived properties of solutions

## List of Experiments:

**Major:**

1. Estimation of Sn, Zn, Cu and Pb from Bronze alloy (volumetric, gravimetric or colorimetric techniques can be used)
2. Estimation of Ca and Fe from milk powder
3. Analysis of Galena ore
4. Analysis of Benzoic acid and salicylic acid from medicated powder
5. Analysis of vitamin A in food products
6. Estimation of Aspirin
7. Kjeldahl's method of protein estimation in foods and feeds
8. Analysis of Lindane in BHC powder.

**Minor:**

1. Analysis of plaster of Paris for calcium content
2. Fertilizer analysis for P (colorimetrically), K (Flame photometrically).
3. Determination of Barium ions by Turbidimetry.
4. Analysis of iodized table salt.
5. Analysis of soda ash.
6. Estimation of copper fungicide
7. Analysis of sulpha drug
8. Analysis of vitamin-C in juices and squashes.
9. Analysis of ethambutol
10. Identification of organic compounds by their IR spectra

**Any other experiments may be added when required.**

**Practical-VI: ACHP305 (2 Cr, 60 hrs.)**

## Course Outcomes (COs):

CO1: Training on scientific literature search, defining the objective of the work, research skills, data representation in tabular and graphical form etc.

CO2: Training on experimental verification of fundamental theories, comparison of data with literature and scientific discussion on any deviation of data from expected theoretical values or reported literature.

CO3: Developing analytical skills

CO4: Training on qualitative and quantitative analysis of analyte

**Major:**

1. Analysis of Lindane in BHC powder.
2. Determination of pK value of an indicator.
3. Polarographic estimation of traces of Cu, Cd, Ni, Zn and Fe in sample solution.
4. To study the complex formation between Fe(III) and salicylic acid and determine the stability constants of the complex by Job's variation method.
5. To determine the equivalence conductance and dissociation constant using Kolharach Law at infinite dilution independent of ionic mobility of weak electrolyte.
6. Any other suitable experiment may be added when required.

**Minor:**

7. Determination of strength of acetic acid in commercial vinegar by conductometric method.
8. Determination of chloride content from saline water by Potentiometry.
9. Estimation of bicarbonate and carbonate by potentiometric method.
10. Estimation of Fe by ceric sulphate and potassium dichromate titration potentiometrically.
11. XRD and Thermal analysis Kaolinite, cobalt oxalate and zinc oxalate.
12. Estimation of vitamin B2 in the medicinal tablets fluorimetrically.
13. Kinetic study of hydrolysis of ethyl acetate in presence of $OH^-$ ions conductometrically.
14. Determination of pKa of given dibasic acid pH-metrically.
15. Determination of relative strength of acetic acid, chloroacetic acid and trichloro acetic acid by conductometrically.

**Any other experiments may be added when required.**

## RP-306: Research Project (4 Cr, 120 hrs)

**See Annexure-I for details. (In the end of this document).**

## M.Sc. Part-II (SEM- IV) Analytical Chemistry

## MANDATORY PAPERS

### Paper-X, ACHT401: Modern Separation Method in Analysis (4 Cr, 60 hrs.)

### Course Outcome (COs):

CO1: Students will learn about modern separation and chromatographic used for analysis of different type of samples.

CO2: The student will understand instrumentation and mechanism of various separation techniques.

CO3: Student will acquire knowledge regarding various choice of instrument and detectors to be used for analysis depending on the sample and matrix.

CO4: Student will learn fundamentals of extractive chromatography, types of extraction techniques, advances in extraction methods and their hyphenations with chromatography leading to addressing challenging problems in analytical chemistry.

**UNIT-I: Advanced Gas Chromatographic Techniques 15 hrs.**

Principles, Plate theory, Instrumentation and working of a Gas Chromatograph, sampling, sample pretreatment, sample injection types, columns, Detectors, programmed temperature G.C., Applications. Pyrolysis gas and vapour phase chromatography-instrumentation and techniques, advantages and applications. Gas chromatography-Mass Spectrometry, interface, instrumentation and applications. Introduction to TGA-MS/TGA-GC-MS and significance. Practical applications and examples in analytical chemistry and research.

**UNIT-II: Advanced Liquid Chromatographic Techniques 15 hrs.**

High Performance Liquid Chromatography (HPLC) and Ultra Performance Liquid Chromatography (UPLC)-Principle, instrumentation, mobile phase, Stationary support in HPLC, detectors and applications. Super critical fluid chromatography (SCFC), characteristics, instrumentation and applications. Comparison of HPLC and GLC with SCFC. Liquid Chromatography-Mass Spectrometry interface, instrumentation, advantages and applications. Practical applications and examples in analytical chemistry and research.

**UNIT-III: Ion Chromatography** **15 hrs.**

Principles, structure and characteristics of resins, eluent, supressor columns and detectors used in Ion Chromatography, commercial scope, analytical applications, environmental speciation by Ion Chromatography. Practical applications and examples in analytical chemistry and research.

**UNIT –IV: A) Modern extraction and separation techniques** **08 hrs.**

Basic principles, classification of solvents extraction systems, extraction equilibria, factors affecting extraction process , application of β- diketones , δHydroxyquinoline , dithicarbamaes xanthenes, Thio, separation of non-metals and metals. Separation of transition metal ions using ion exchangers. Solid phase extraction, solid phase microextraction, sonic extraction, accelerated solvent extraction, soxhlet extraction.

**B) Extractive Chromatographic Separations** **07 hrs.**

Introduction, Theoretical aspects of extraction chromatography, solvent extraction and extraction chromatography with chelating ligands, extraction chromatography by ion pair formation, extraction chromatography by solvation, extraction equilibria, nature of stationary phase in extraction chromatography, inert support, techniques in extraction chromatography, extraction chromatography with tributyl phosphate and other applications. Practical applications and examples in analytical chemistry and research.

## Recommended Books:

1) A.I.Vogel, a text Book of Quantitative Inorganic Analysis.

2) W H Willard, L L Merritt and J A Dean, Instrumental Methods of Analysis.

3) S. M.Khopkar, Basic Concepts in Analytical Chemistry.

4) LR. Shyder and C.H.Harvath, An Introduction to separation Science. Wiley Interscience.

5) James S Fritz and George H.Schenk Jr. Quantitative Analytical Chemistry, 2nd editions Allyn and Bacon Inc. Bosten.

6) J.G. Dick, Analytical Chemistry.

7) R.L. Pescok and L.D.Shield, Modern Methods of Chemical Analysis.

8) O. Samuelson: Ion Exchange separation in analytical chemistry (Jhonwiley , 1963)

9) Y. Marcus and A. S. Kertes: Ion Exchange and solvent Extraction of metal complexes (Wiley – Interscience, 1969)

10) J. A. Marinsky and Y. Marcus: Ion exchange and solvent Extraction (Marcel Dekker, INC,

New York, 1973)
11) G. H. Morrison and H, Freiser: Solvent Extraction in Analytical Chemistry (John Wiley, New York, 1958)
12) A. K. Da, S. M .Khopkar and R. A. chalmers: solvents Extraction of metals (Von Nostrant Ravinhold, 1970)

## Paper-XI, ACHT402: Advanced Methods in Chemical Analysis (4 Cr, 60 hrs.)

## Course Outcome (COs):

CO1: Students will be skilled in the techniques like fluorescence, phosphorescence, types of quenching, FRET and applications of the same in Analytical Chemistry and for addressing research problems.
CO2: Students will gain knowledge of the kinetic methods of analysis supporting the analysis and data procured in research.
CO3: The students will acquire the knowledge of advanced method of chemical analysis XPS, XRF, fluorescence and phosphorescence spectroscopy which will be beneficial in research.
CO4: Students will acquire knowledge of identifying types of plastic and will also be able to and determination of metallic impurities in plastics.

**UNIT-I: Fluorescence and Phosphorescence Spectrophotometry 15 hrs.**

Fluorimetry, types of luminescence, Instrumentations, theories of fluorescence and phosphorescence, electronic transition, structural factors, solvatochromism, solvation dynamics, faith of excited molecules, solvent effect on fluorescence, effect of intermolecular process, fluorescence anisotropy and time domain fluorescence life time measurements. Relation between concentration with fluorescence and phosphorescence intensity, fluorescence quenching mechanism, resonance energy transfer. Chemiluminescence, Fluorescence sensing, Synchronous spectrum, Fluorescent nanomaterials. Practical applications, examples and problems in analytical chemistry and research.

**UNIT-II: Kinetic Methods of analysis 15 hrs.**

Theoretical basis of kinetic methods of analysis, methods of determining amount of the substance, Tangent Method, Fixed Time and Concentration method. Addition Method, Oxidation Reactions of H2O2 with thiosulphate, iodide and amino, Enzyme catalyzed reactions. Inhibitors and Activators.

**UNIT – III: Photoelectron spectroscopy 15 hrs.**

Basic principles, photoelectric effects, Photoionization process, Koopman's theorem, photoelectron spectra of simple molecules, ESCA, chemical shift, Auger electron spectroscopy basic idea.

**UNIT-IV: X-ray spectroscopy 15 hrs.**

Introduction, X-Ray generation, Properties of X-radiation, X-Ray, Instrumentation, X-Ray Absorption, Fluorescence and Diffraction methods of analysis and their applications.

## Recommended Books:

1) Gary D Christian,Analytical chemistry 6 th edition.John Willey and sons INC (2003) H.
2) Kaur, Instrumental Methods of Chemical Analysis. Pragati Prakashan, Meerut.
3) W H Willard, L L Merritt and J A Dean, Instrumental Methods of Analysis.
4) S. M.Khopkar, Basic Concepts in Analytical Chemistry.
5) D. Skoog and D. West, Principle of Instrumental Analysis.Holl Seamlers.
6) E. Berlin, Principles and Practice of X-Ray Spectrometric Analysis, Plenum, New York.
7) J. Winefordner, S. Schulman and T O Haver: Luminescence Spectrometry in Analytical Chemistry. Wiely Interscience New York.
9) H. Mark and G Rachnitz, Kinetics in Analytical chemistry.
10) Interscience NY. Gary D Christian,Analytical chemistry 6 th edition.John Willey and sons INC (2003)
11) Engineering chemistry, R Gopalan, G. S. Nagrajan.
12) Engineering chemistry B. K. Sharma

## ELECTIVE PAPERS

## Paper-XII, E-ACHT403(A): Organic Industrial Analysis (4 Cr, 60 hrs.)

## Course Outcome (COs):

CO1: Acquire knowledge of handling and investigating the characteristics of the oils, fats, detergents and soap samples and analysis of the same providing opportunity in cosmetic, pharmaceuticals, dyes and polymers industries.

CO2: Student will gain knowledge and importance of food quality, probe for food adulteration and adulterants, food preservative, food flavors and analysis of their components.
CO3: Students will also gain knowledge about the animal food stuff and the additives added in the animal food stuff as antibiotics, dietary supplements and growth promoting drugs, preservatives etc. and analysis of the same.
CO4: Student will learn about the analysis of cosmetics, face powder, hair dyes and hair care products, types of cosmetics, precautionary measures and composition of the cosmetics and specific roles of the ingredients. Will acquire knowledge about the paints, pigments and petroleum products, composition and analysis of the same using conventional and instrumental techniques.

**UNIT – I: Industrial Analysis A) Analysis of oils, fats and Soaps 08 hrs.**

Introduction to natural fats and oils; isolation of oils from natural resources and their purification. Analysis of oils and fats: Softening point, Congeal point, Titre point, Cloud point, Iodine, saponification, acid, hyroxyl, R-M and Polenske value, Elaiden test, etc. Introduction to soaps, manufacture of soaps (in brief), analysis of soaps: total anhydrous soap and combined alkali, potassium, water, free fatty acids, saponifiable and non-saponifiable matter in soaps, estimation of phenol, copper and germicidal agents in soaps, determination of inorganic fillers and soap builders, and other additives, estimation of soap in detergents (THAM method)

**B) Analysis of Detergents 07 hrs.**

Classification of detergents, analysis of raw materials, separation as alcohol soluble and alcohol insoluble matter, additives in detergent formulation (chlorides, sulfates, phosphates, silicates, borates, oxygen releasing substances, CMC, EDTA, etc.), their role and analysis; analysis of active ingredients in detergents (methylene blue and Hyamine-1622 method).

**UNIT – II: Food and Food Additive Analysis**

**A) Food Analysis 08 hrs.**

Food flavors, food colors, food preservatives, analysis of milk and milk products, adulterants in milk and their identification, analysis of honey, jam and their major component. Practical applications and examples in analytical chemistry and research.

**B) Food Additive Analysis 07 hrs.**

Additives in animal food stuff: Antibiotics: penicillin, chlorotetracyclin, oxytetracyclin in diet supplements; Identification and estimation of growth promoting drugs such as.

sulfaquinoxaline, methyl benzoquate, sulfanitran, pyrimethamine, nitrovin, nitrofurazone, acinitrazole, etc

**UNIT-III: Analysis of cosmetics products** **15 hrs.**

**A) Analysis of cream and lotions** **08 Hrs**

Introduction to cosmetics, definition, types of cosmetics, background, and development in cosmetic industry, issues in cosmetic industries (contamination and adulteration), future scope and role of analytical chemistry.

Composition of creams and lotions, determination of water, propylene glycol, non-volatile matter and ash content; estimation of borates, carbonates, sulphates, phosphates, chlorides, ammonia, nitromethane, oxalic acid, 4- hydroxy benzoic acid, sodium iodate, free formaldehyde, H2O2, mercatoacetic acid, titanium and zinc oxides. Practical applications and examples in analytical chemistry and research.

**B) Analysis of face powder** **07 hrs.**

Composition of face powder, estimation of boric acid, Mg, Ca, Zn, Fe, Al and Ba. Analysis of deodorants and antiperspirants-composition, analysis of fats and fatty acids, boric acid, magnesium, calcium, zinc, iron, titanium, aluminium, phenol, methanamine, hexachlorophenone, sulphonates, urea, etc. Practical applications and examples in analytical chemistry and research.

**UNIT-IV: Analysis of Paints, pigments and petroleum products** **15 hrs.**

**A) Analysis of Paints and pigments** **08 hrs.**

Composition of paint, preliminary inspection of sample, test on the total coating, separation and estimation of pigments, binder and thinner of latex paints; modification of binder, flash point of paints. Practical applications and examples in analytical chemistry and research.

**(B)Analysis of petroleum products** **07 hrs.**

Introduction, constituents and petroleum fractionation, quality control; - specific gravity, viscosity, Cloud point, pour point, flash point, vapor pressure, Doctor test, sulphuric acid absorption, aniline point, and colour determination, cloud point, pour point. Determination of water, neutralization value (acid and base numbers), ash content, sulphur and mercaptan sulphur. Determination of lead in petroleum; Analysis of coal and coke: Types, composition, preparation of sample, proximate and ultimate analysis calorific value by Bomb Colorimetry.

## Reference Books:

1) S. R. Junk and H. M. Pancoast: Hand book of sugars (AVI)
2) B. Bilot and B. V. Well: Perfumary technology (JW)
3) I. M. Kolthoff: Treatise on Analytical Chemistry Vol. I and II
4) D. Pearson: Laboratory techniques in food analysis.
5) S. Ranganna: Handbook of Analysis and Quality control for fruits and vegetable products, 2nd Ed. (Mc Graw Hill.)
6) Nicholls: Aids to the analysis of foods and drugs.
7) G. J. Mountrey: Poultry product technology (AVI)
8) Karamer Twig: Quality control for food industry (AVI)
9) G. F. Longonan: the analysis of detergents and detergent products (JW)
10) A. Davidsohn & B. M. Mlwidaky : Synthetic detergents (Book center, Mumbai)
11) M. Ash and L. Ash: A formulary of cosmetic preparations. (G. Goodwin)
12) Kurl Bauer, Dorothea Garhe, Horst Surburg: Common fregrance and flavour materials, (VCH publisher, New York)
13) F. J. Welcher: Standard Methods of Chemical analysis Vol. I & II (6th Ed.)
14) S. N. Mahendru: Analysis of food products (Swan Publishers).

## Paper-XII, E-ACHT403(B): Industrial Analytical Chemistry (4 Cr, 60 hrs.)

## Course Outcome (COs):

CO1: The students will acquire knowledge of analysis of metals, alloys, minerals and ores commonly used in the industry.

CO2: The students will be acquainted with the analysis of real samples like cement, plaster of Paris, different commercial ores, soil composition, soil fertility, fertilizers etc using conventional and instrumental methods of analysis.

CO3: Students will also gain the knowledge of analysis of commercial materials, explosives, polymers, resins, rubber, luminescent paints, lubricants and adhesives.

CO4: These would offer opportunity to the students to get employment in industries for quality assurance and quality control (QA-QC) of the product.

**UNIT-I: Spectrochemical Methods of Analysis** **15 hrs.**

Introduction to Spectrochemical methods. Electronic spectra and molecular structure, NIR spectrometry for non-destructive testing. Solvents for spectrometry, FTIR spectrometer, fluorometry, optical sensors. Analysis of ores –bauxites, dolomites, monazites. Analysis of Portland cement.

**UNIT-II: Analysis of metals and alloys** **15 hrs.**

Foundry materials, ferroalloys, and special steels, slags, fluxes. Analysis of alloys, bronze, brass, Alnico and Nichrom.

**UNIT-III: Analysis of soil and fertilizers** **15 hrs.**

Method of soil analysis, soil fertility its determination, determination of inorganic constituents of plant materials, Chemical analysis as measure of soil fertility, analysis of fertilizers.

**UNIT-IV: Analysis of Commercial materials** **15 hrs.**

Analysis of explosive materials, TNT, RDX, lead azide, EDNA (ethylene dinitramine). Analysis of conducting polymer, resins and rubber. Analysis of luminescent paints, Analysis of lubricants and adhesive.

## Recommended Books:

1) Hillebrand Lhundel, Bright and Hoffiman, Applied Inorganic Analysis, John Wiley.
2) Snell and Biffen, Commercial Methods of Analysis.
3) P.G. Jeffery, Chemical Methods of Rock Analysis, Pergamon.
4) Buchel, Chemistry of Pesticides. J Wiley.
5) Rieche, Outlines of Industrial Organic Chemistry, ButterWorth.
6) F.A.Henglein, Chemical Technology, Pergamon.
7) Kent, Riegl's Industrial Chemistry,Rainhold.
8) Chopra and Kanwar,Analytical Agriculture Chemistry, Kalyani Publishers.
9) Aubert and Pintes, Trace Elements in Soils.
10) Bear, Chemistry of Soil.
11) Hauson, Plant Growth Regulators, Noyes.
12) P.G. Jeffery and D.J. Hatchinson, Chemical Methods of Rock Analysis.
13) F.J. Weleher, Standard Methods of Chemical Analysis, A Series of Volumes Robert and Krigeger Publishing Company.
14) I. M. Kolthoff and PJ Ewing, Treatise o Analytical Chemistry, A series of Volumes.

15) R.D. Reeves and R.R. Brooks, Trace element Analysisof Geological Materials, John Wiley & Sons NewDehli.
16) W.M. Johnson and J.A.Maxwell,Rock and Mineral Analysis, John Wiley and Sons, NewYork.
17) W. F. Hildebrand, G H C Landell and HABrighot, Applied Inorganic Analysis, John Wiley 2nd Edition.
18) K. J. Das, Pesticide Analysis (MD).

## Paper-XII, E-ACHT403(C): Quality Assurance and Accreditation (4 Cr, 60 hrs.)

## Course Outcome (COs):

CO1: Students will acquire knowledge of QA-QC which in essential for analytical chemist, This covers a variety of chemical fields and this knowledge would help students working on various materials, understanding the basics of samples, sampling, sample storage, and pre-post treatment of samples.

CO2: Students will acquire knowledge of good laboratory practices, professional ethics, and instrumental analytical chemistry, awareness of health hazards, remedial measures, analytical method development and validation.

CO3: The students would be aware of the importance of documentation for raw materials and finished products, their monitoring, maintenance and management. World-wide agencies involved in regulating the analytical protocols and establishing standards.

CO4: Students will gain knowledge about the quality assurance and accreditation, evolution and significance of quality management, available accreditation agencies and advantages of accreditation.

**UNIT-I: Quality Assurance** **15 hrs.**

Introduction to Quality Control and quality assurance: Concepts and significance. Quality control and statistical techniques: Quality control charts, the X-quality control chart, the R-quality control chart and its interpretation, spiked sample control charts, use of blind samples in quality control, use of proficiency evaluations in quality control. Calibration and maintenance of Instruments / Equipment: Instrument calibration – linear calibration curves, equipment calibration, frequency of calibration, calibration of common laboratory instrument and equipment (Analytical balances, volumetric glassware, ovens, furnaces, UV / Visible spectrophotometer, pH meter, conductivity meter, IR spectrophotometers, AAS, GC, HPLC etc.,). Maintenance of instruments and equipment.

**UNIT-II: Documentation for Quality Assurance: Raw Data 15 hrs.**

Type of notebooks, control of notebook distribution and data entry. General Reagents and volumetric reagents. Sampling – sampling methods, sample labelling, and sample login/register. Sample analysis, reporting, recording and personal training. Instrument calibration and maintenance. Analytical report, Personnel, training, records - professional personnel, technician personnel. Filing quality assurance documentation. Good laboratory practices and personnel, Quality Programme, Instrument and Organisation calibration, Customer Satisfaction.

**UNIT-III: Documentation for Quality Assurance: Raw Data 15 hrs.**

Computers and quality assurance: Sample handling. Data Acquisition. Quality control data and calculations. Computer generated analytical reports. Security considerations. Hardware and software. Establishing a Quality Assurance program: Management commitment. Define the quality assurance program. Writing standard operating procedures. Topics for standard operating procedures. Consolidating the programme.Monitoring the program – monitoring quality assurance data, reporting quality assurance problems. Writing the quality assurance manuals.

**UNIT-IV Quality Accreditation 15 hrs.**

Laboratory Accreditation: Need for laboratory accreditation. International aspects of laboratory accreditation and in India. Criteria for laboratory accreditation. Benefits of laboratory accreditation, Evolution and significance of Quality Management, Background to ISO 9000, comparison between ISO-9001, ISO-9002 & ISO-9003., ISO 9000-2000 series of standards on quality managament system,- evolution of series of standards, introduction to ISO organization, Registration/ certification- benefits of QMS certification. Structure of ISO 9000-2000 family of standards. Advantages of ISO 9000-2000. Requirements of ISO 9001-2000 QMS and applications, Steps for effective implementations. Significance of ISO - 9001, 9002, 9003 & 9004. Requirements of ISO9000/ IS14001. Concepts of OHSMS (BS 8800) Quality Managament Principles in QMS, QMS documentation, Quality Manual, Quality policy, conformities and Nonconformities.

## Recommended Books:

1) Handbook of Quality Assurance for the analytical chemistry laboratory, James P. Dux, Van Nostrand Reinhold, New York, 1986.
2) Applying ISO-9000 Quality Management Systems, International Trade Centre Publishing, UNCTAD/WTO. Geneva, Switzerland, Indian Edition Printed by D.L. Shah Trust.
3) How to practice GLP, PP Sharma, Vandana Publications, 2000, New Delhi
4) Training manuals on ISO 9000 / 2000 PQM, Girdhar J Gyani, Raj Publishing House, 2001
5) Quality Assurance in Analytical Chemistry, B.W. Wenclawiak, Springer, India, 2004.

## Paper-XII, E-ACHT404(D): Food, Fertilizer and Pesticides Analysis (4 Cr, 60 hrs.)

## Course Outcome (COs):

CO1: Acquire knowledge of handling and investigating the characteristics of the food analysis. Students will also gain knowledge about the animal food stuff and the additives added in the animal food stuff as antibiotics, dietary supplements and growth promoting drugs, preservatives etc. and analysis of the same.
CO2: Student will gain knowledge and importance of food quality, probe for food adulteration and adulterants, food preservative, food flavors and analysis of their components.
CO3: Student will gain knowledge of analysis of fertilizers and Pesticides and their characterization techniques. Acquire knowledge of determination of micronutrients in fertilizers.
CO4: Student will learn about the analysis of vitamins including microbiological techniques. Biological values and estimation of enzymes, Carbohydrates, essential amino acids, proteins and lipids.

**Unit-I: General concepts of food analysis** **15 hrs.**

Nutrient value of food. Physical characteristics & chemical constituents' Proximate composition of food Legislation related to food and recent amendments, Standards and public health a. General idea regarding food processing and preservation b. Food contamination and spoilage c. Food safety considerations. d. Adulteration-Introduction, Types, Tests for adulterants, control.

**Unit-II: Analysis of food** **15 hrs.**

Study of followings with their estimation methods: Food preservatives, emulsifiers. Food stabilizers, Food thickener. Introduction, Standard composition and Analysis of the following foods: Milk and milk products, Tea, Coffee, Cereals & Flour, Honey, Soft drinks & Alcoholic beverages.

**Unit-III: Analysis of fertilizers and Pesticides** **15 hrs.**

Classification of fertilizer, NPK value, Chemical composition of superphosphate, Lime and Potash fertilizer, Analysis of commercially available fertilizers for N, P & K.

Legislation and recent amendments with respect to pesticides materials. Names of pesticides and their chemical structures. Application dosage of different pesticides. Analysis of specific pesticides.

**Unit-IV: Analysis of Vitamins** **15 hrs.**

Analytical techniques of determination of water and fat soluble vitamins including microbiological techniques. Human nutrition: Biological values and estimation of enzymes, Carbohydrates, essential amino acids, proteins and lipids.

## Reference Books: -

1. Chemical analysis of food By Pearson.

2. Introductions to food science and technology, series by G.F.Stewart and M.A.Amerine Academic process.

3. Applied chemistry A Text book for Engineers and technologists by H.D. Gesser.

4. Food analysis by Nielson.

5. Food additives by S.N.Mahindry (APH) publication

6. Jacob (M.B) chemical Analysis of food and food products (Van Nostrand co. New York)

7. Analytical chemistry of foods (C.S. James) Blackie Academic and professional

8. Food Analysis principles and techniques D.W. Gruenwedel, J.R. Whitaker, Mercel Dekker.

## Analytical Chemistry Practical Course

## Mandatory

## Practical-VII: ACHP404 (4 Cr, 120 hrs.)

## Course Outcomes (COs):

1. The students will acquire hands on training for conducting the representative experiments for the analysis of wide variety of samples of inorganic, organic and physical approaches by qualitative and quantitative analysis. Demonstrate professional and ethical attitude to serve the society
2. Students will have knowledge of safety signs on container of chemicals, safety in handling of chemicals, MSDS sheets, learn sample preparation and characterization for confirming the purity.
3. Students would acquire knowledge about the separation and estimation of amount of metal, metal ions, organic compounds etc. in given samples.
4. Based on the experience of project work, students will have ability to start their R & D laboratory.

**List of Experiments:**

**Major**

1. Cement analysis
2. Analysis of Chrome steel alloy for Cr and Ni content
3. Analysis of bauxite ore to estimate the amount of silica, aluminium and iron. -VIII
4. Estimation of salicylic acid and zinc oxide from medicated powder
5. Determination of saponification value and iodine value of oil
6. Estimation of amount of copper (II) with EDTA spectrophotometrically.
7. Simultaneous spectrophotometric determination of Cr and Mn
8. Analysis of milk.
9. Analysis of some common pesticides, insecticides, plastics and detergents.
10. Estimation of Urea, Uric acid and creatinine in Urine.
11. Estimation of blood sugar, calcium and total nitrogen and non-protein nitrogen in blood.
12. Studies on the effect of substituent at ortho position of benzoic acid on its equilibrium constant pH metrically.
13. Agricultural analysis of soil sample, animal feeds, soil micronutrients, milk powder for Ca, Fe and P content.

**Minor**

1. Estimation of Fe from soil sample
2. Analysis of Na and K from soil sample
3. Determination of chemical oxygen demand of water sample (dye solution)
4. Estimation of lactose from milk sample
5. Determination of flash point of oil/fuel
6. To estimate the amount of glycine from amino acid
7. To determine the amount of alkali content of antacid tablet titrimetrically
8. Determination of dissociation constant of weak acid pH-metrically.
9. Estimation of Zn in the given solution fluorometrically.
10. Determination of pKa of tribasic acid by potentiometry.
11. Determination of critical micelle concentration of given surfactants conductometrically
12. Estimation of acetyl salicylic acid in the given aspirin tablet by titrating against 0.1N alcoholic KOH potentiometrically.
13. To determine the acid base dissociation constant and isoelectric point of amino acid pH metrically

**Any other experiments may be added when required.**

**Note:** Study tour is compulsory for M.Sc. Part- II Students to visit Chemical Industries in India

## RP-405 Research Project (06 credit, 180 Hrs)

**See Annexure II for details (In the end of this document).**

# Shivaji University Kolhapur

## Syllabus as per NEP-2020

**For**

**M. Sc. Part- II Industrial Chemistry**

**Semester III & IV**

## Under the Faculty of Science and Technology

**To be implemented with effect from Academic Year 2026-2027**

This is applicable for University Department only

# M. Sc. Part II: Industrial Chemistry

## (SEM-III and SEM-IV)

The M.Sc. in Industrial Chemistry is a two-year postgraduate program (typically spanning four semesters) that delves into both theoretical foundations and practical applications across areas like organic chemistry, polymer science, analytical techniques, and industrial processing. The program prepares students not only in education but to work in sectors such as government, petrochemicals, pharmaceuticals, polymers, textiles, food, and paints. During the course, students explore methods such as instrumental analysis, computational chemistry, process control, and research methodology. Our institution include industrial training or internships, along with dissertations or project work in the final semester, to provide real-world experience. This degree opens up various career paths—ranging from research and development, quality control, and production to academic roles or further doctoral studies. Students are in demand in industries such as pharmaceuticals, petrochemicals, agrochemicals, cosmetics, food processing, paints, and ceramics.

The program offers a dynamic blend of science, technology, and industry relevance, preparing students for specialized roles in chemical manufacturing and innovation.

**Programme Educational Objectives (PEOs):**

**PEO1:** Students will be equipped to excel in diverse sectors including industries, research laboratories, quality control, analytical services, and academia at both national and international levels.

**PEO2:** Through rigorous instruction in synthesis, separation, analysis, computational chemistry, and product development, Students will design and develop innovative industrial solutions.

**PEO3:** Empowered with interdisciplinary knowledge and ethical awareness, Students will lead teams, adapt to evolving industrial contexts, and pioneer as innovators or entrepreneurs.

**PEO4:** Students will demonstrate adaptability and a continuous pursuit of emerging techniques and technologies to tackle real-world chemical challenges effectively.

**Program Outcomes (POs):**

**PO1**: Students will apply in-depth knowledge of Industrial Chemistry across organic, inorganic, physical, analytical, and polymer domains to identify, formulate, and solve complex scientific problems (e.g., using literature review and logical reasoning).

**PO2**: Students will efficiently design and conduct experiments, analyze and interpret data, and leverage modern instruments and computational tools (e.g., modeling, software) to draw meaningful, research-based conclusions.

**PO3**: Students will understand and assess the broader implications of chemical practices including environmental, health, societal, and ethical dimensions and promote sustainable and responsible solutions.

**PO4**: Students will communicate complex scientific concepts effectively (through reports, presentations, technical writing), collaborate within multidisciplinary teams, manage projects, and pursue continuous learning in evolving technological contexts.

**Program Specific Outcomes (PSOs):**

Upon completion of the M.Sc. Chemistry program, students will possess the ability to:

**PSO1**: Students will be able to synthesize, separate, characterize, and analyze industrially relevant chemical compounds using both classical laboratory protocols and modern instrumentation in areas such as pharmaceutical chemistry, analytical chemistry, and formulation science.

**PSO2**: Students will apply chemistry knowledge responsibly within quality control, quality assurance, and process management in sectors like polymers, paints, agrochemicals, ceramics, and food, upholding professional ethics.

**PSO3**: Students will demonstrably apply their chemical expertise to excel in higher studies such as doctoral-level research and academic inquiry by designing and conducting research with integrity and rigor.

**PSO4**: Students will be equipped to pursue careers in education or academic mentorship, thus contributing to capacity-building and national development through teaching and scholarly engagement.

## Industrial Chemistry: SEMESTER- III

**MANDATORY PAPERS**

Paper VII: INDCHT301 (4 Cr): Organic Chemical Industries -I

Paper VIII: INDCHT302 (4 Cr): Inorganic Chemical Industries -I

INDCHP304 (4 Cr): Practical-V

INDCHP305 (2 Cr): Practical-VI

RP306 (4Cr): Research Project

**ELECTIVE PAPERS: (Choose any one)**

Paper IX: E-INDCHT303 (A) (4 Cr): Methods of Analysis in Industries

Paper IX: E-INDCHT303 (B) (4 Cr): Chemical analysis in food, Agro, and Pharmaceuticals

Paper IX: E-INDCHT303 (C) (4 Cr): General Chemical Technology

Paper IX: E-INDCHT303 (D) (4 Cr): Advances in Metal Complexes

# M.Sc. Part-II (SEM- III): Industrial Chemistry

## Detailed Syllabus:

**MANDATORY PAPERS**

**Paper VII: INDCHT301 (4 Cr): Organic Chemical Industries-I**

## Course Outcomes (COs):

On completing the module, students will be able to:

**CO1:** Classify various types of dyes (e.g., azo, triphenylmethane, fluorescent, photosensitive, natural dyes, etc.) and explain their key characteristics.

**CO2:** Explain the chemical composition and nutritional value of major foodstuffs, and the physicochemical basis for their properties and spoilage.

**CO3:** Describe the manufacturing processes for cane-sugar derived compounds such as acetic acid, oxalic acid, citric acid, acetic anhydride, furfural, and anhydrous alcohol, with a focus on production from bagasse.

**CO4:** Articulate the refining processes for edible oils and explain the chemistry underlying the production of soaps (solid and liquid), detergents, and ophthalmic solutions.

**Unit –I: Dyes and Pigments (15 Hrs)**

Dyes, Pigments and Intermediates: Classification of dyes, preparation of important dye intermediates, methods of preparation of commercial dyes of different classes with suitable examples. Typical manufacturing processes of few dyes, fluorescent brightening agents, special dyes, photosensitive dyes, dyes as food additives, and natural dyes.

**Unit – II: Food Processing and Food Additives (15 Hrs)**

Classification, chemical composition, and nutritional value of common food stuffs, properties of foods, food preservation and processing, food deterioration, methods of preservation and processing by heat, cold, chill storage, deep freezing, drying, concentration, fermentation, and radiation. Permitted food additives and their role: antioxidants, colouring agents, sweeteners.

**Unit – III: Cane Sugar Based Chemistry (15 Hrs)**

Introduction, manufacturing processes of acetic acid, oxalic acid, citric acid, acetic anhydride, furfural from bagasse, anhydrous alcohol, sugar-based chemical industries in India. Preparation and Analysis of organic jaggery.

**Unit – IV: Soap and Detergents (15 Hrs)**

**Oils, soaps, and Detergents:** Refining of edible oils, manufacturing of soaps, Detergents, Liquid soaps, and Ophthalmic solutions. Manufacturing of glycerol from fatty acids, greases from fatty acids, and turkey–red oil.

**Paints:** Introduction, properties, manufacture of paint, and applications

**Varnishes and Inks:** Constitutions, examples of preparation, and applications.

**REFERENCE BOOKS**


1. Klöckl, Ingo. Handbook of Colorants Chemistry: Dyes and Pigments Fundamentals. De Gruyter, Berlin.
2. Chauhan, O. P. (Ed.). Advances in Food Chemistry: Food Components, Processing and Preservation. Springer, Singapore.
3. Madhu, M. Textbook of Food Processing and Preservation, Vol. I. Integrated Publications, New Delhi.
4. Allan, J. Color Chemistry. Springer, Berlin.
5. Kent, J. A. Riegel's Industrial Chemistry. Van Nostrand Reinhold, New York.
6. Ash, M., & Ash, I. A Formulary of Paints and Other Coatings. Gower Publishing, Aldershot.
7. Ash, M., & Ash, I. A Formulary of Cosmetic Preparations. Godwin, London.
8. Groggins, P. H. Unit Processes in Organic Synthesis. McGraw-Hill, New York.
9. Kirk, R. E., & Othmer, D. F. Encyclopedia of Chemical Technology. Wiley, New York.
10. Aurand, L. W., & Woods, A. E. Food Chemistry. AVI Publishing, Westport.
11. Mayer, L. H. Food Chemistry. Affiliated East-West Press, New Delhi.
12. Manay, N. Shakuntala., & Swamy, M. Shadakshara. Foods: Facts and Principles. New Age International, New Delhi.
13. DeMan, J. M. Principles of Food Chemistry. Springer, Cham.


**Paper VIII: INDCHT302 (4 Cr): Inorganic Chemical Industries-I**

## Course Outcomes (COs):

Upon course completion, the student is able to:

**CO1:**Explain the chemical composition and structure of milk, including key constituents like proteins, vitamins, minerals, and the physicochemical properties such as density and viscosity.

**CO2:** Identify and discuss the formulation and function of various cosmetic products such as hair dyes, shampoos, lotions, creams (cold, vanishing, and shaving), face powders, lipsticks, antiperspirants, and artificial flavourswithin the context of their chemistry and usage.

**CO3:** Describe synthesis methods for nanomaterialsincluding gas and liquid phase techniques and high-energy ball millingfor diverse materials such as metals, semiconductors, ceramics, and composites.

**CO4:** Define applications of nanotechnology in agriculture, particularly concerning precision farming, intelligent delivery systems, and nanofertilizer strategies (e.g., nanourea, mixed fertilizers, fertigation).

**Unit –I: Dairy and Leather Chemistry (15 Hrs)**

**Dairy Chemistry:** Milk and milk products, composition and structure of milk, milk proteins, enzymes, vitamins, minerals, density and viscosity of milk, effect of heat on milk, milk processing, basic milk categories, butter, ghee and clarified butter. **Leather Chemistry:** Introduction; constituents of animal skin; manufacture and preparation of hides; cleaning, soaking, liming, and degreasing; finishing and shaving; tanning (leather, vegetable, chrome); tanning effluents, pollution, and control.

**Unit – II: Cosmetics and Perfumes (15 Hrs)**

A general study including preparation and uses of the following: Hair dye, hair spray, Shampoo, Sun-tan lotions, face powder, lipsticks, talcum powder, nail enamel, creams (cold, vanishing and shaving creams), antiperspirants and artificial flavours. Water: Special consideration for cosmetics use. Surfactants: Classification and application in cosmetics as foaming agents, emulsifiers, and solubilizers. Classification and application in cosmetics as antioxidants, antimicrobial and chelating agents used as preservatives. Factors affecting effectiveness of antimicrobial preservatives.

**Unit–III: Nanoscience and Nanocrystal Technology (15 Hrs)**

Introduction, Nano and nature, synthesis of solid state materials, conventional methods-Electrodeposition, Spray Pyrolysis, Sol-gel, Hydrothermal synthesis, Chemical bath deposition, Preparation of ultra pure elements of Gallium, Indium and Germanium, $TiO_2$, ZnO, and their composites for semiconductors.

Characterization techniques: Thickness measurement, Optical absorption study, XRD, SEM, EDAX, AFM. Applications of nanotechnology.

**Unit – IV: Importance of Nanotechnology in Agriculture (15 Hrs)**

Nano-fertilizers: Nano-urea and mixed fertilizers, nanofertigation, nanopesticides, nano seed science, organic manures, micronutrients, biopesticides, biofertilizers, and agrochemicals. General introduction and applications in pest management.

**REFERENCE BOOKS**


1. Henglein, F. A. Chemical Technology. Pergamon, Oxford.
2. Thomas, R. W., & Farago, P. Industrial Chemistry. Heinemann Educational Books (HEB), London.
3. Stocchi, E. Industrial Chemistry (Vol. I). Ellis Horwood Ltd., Chichester, UK.
4. Jain, P. C., & Jain, M. Engineering Chemistry. Dhanpat Rai & Sons, Delhi.
5. Gabor, L., et al. Introduction to Nanoscience and Nanotechnology. CRC Press, Boca Raton.
6. Hornyak, G. L., Tibbals, H. F., & Dutta, J. Fundamentals of Nanotechnology. CRC Press, Boca Raton.
7. Vollath, D. Nanomaterials: An Introduction to Synthesis, Properties and Application. Wiley-VCH, Weinheim.
8. Frewer, L. J., Norde, W., Fischer, R. H., & Kampers, W. H. Nanotechnology in the Agri-Food Sector. Wiley-VCH Verlag, Weinheim.
9. Sharma, B. K. Industrial Chemistry. Goel Publishing House, Meerut.

## ELECTIVE PAPERS: Choose Any One

## Paper IX: E-INDCHT303 (A): Methods of Analysis in Industries (4 Cr, 60 hrs)

## Course Outcomes (COs):

On completing the module students will be able to:

**CO1:** Apply chromatographic, spectroscopic, and surface analytical techniques in industrial problem-solving.

**CO2:** Interpret $^{1}$H, $^{13}$C, and 2D NMR spectra for structural elucidation of organic and industrially relevant compounds.

**CO3:** Demonstrate understanding of modern surface analysis tools for quality control and materials characterization.

**CO4**: Evaluate fuel quality and calorific value using calorimetric and flash point analysis methods.

**Unit-I: Chromatographic Techniques in Industry (15 hrs)**

Gas Chromatography (GC): Principle, instrumentation, detectors (FID, TCD, ECD, MS); industrial applications in petrochemicals, pharmaceuticals, food quality control, and environmental monitoring. High Performance Liquid Chromatography (HPLC): Principle, instrumentation, detectors (UV, PDA, RI); applications in drug testing, purity analysis, polymers, and the food industry. Ion Chromatography (IC): Principle and industrial applications in water analysis, cement, fertilizers, and pharmaceuticals. Supercritical Fluid Chromatography (SFC): Principles and Industrial Relevance. Numerical problems: Retention time, resolution, column efficiency, and related calculations

**Unit-II: NMR Spectroscopy (15 hrs)**

Principles of Nuclear Magnetic Resonance (NMR) spectroscopy, including chemical shift, shielding and deshielding effects, spin–spin interactions, coupling constants, and stereochemical applications such as the Karplus curve, hindered rotation, and conformational analysis.

Proton NMR ($^{1}$H NMR) -Relation to chemical shift values for protons attached to different carbon and heteroatom environments, along with simplification methods such as double resonance, shift reagents, solvent effects, chemical exchange, and deuteration. Carbon-13 NMR ($^{13}$C NMR) is explained with emphasis on proton decoupling, chemical shift ranges, DEPT experiments, the Nuclear Overhauser Effect (NOE), and its application in structural elucidation.

**Unit-III: Chemical Analysis of Surfaces (15 hrs)**

Introduction to photoelectron spectroscopy, Ion Scattering Spectroscopy, Secondary Ion Mass Spectrometry, Auger Electron Spectroscopy, Electron Spectroscopy for Chemical Analysis. Basic principles, Instrumentation, and applications of these techniques.

**Unit-IV: Gas and Fuel analysis (15 hrs)**

Modern concept of fuels, classification of fuels, characteristics of good fuels, Orsat apparatus and its use in gas analysis, Instrumentation and working of bomb calorimetry, boy's calorimeter and numerical, coal analysis, calorific value of fuels, determination of calorific value of a solid or liquid fuel, Flash point, determination of flash point by Abel's method.

**REFERENCE BOOKS**


1. Welder, F. J. Standard Methods of Chemical Analysis, Vol. III, Part A & B. Van Nostrand, New York.
2. Strobel, H. A. Chemical Instrumentation. Addison-Wesley, Reading.
3. Willard, H. H., Merritt, L. L., & Dean, J. A. Instrumental Methods of Analysis. Van Nostrand Reinhold, New York.
4. Snell, F. D. Encyclopedia of Industrial Chemical Inorganic Analysis, Vol. 1–20. John Wiley, New York.
5. Hillebrand, W. F., Lundell, G. E., & Hoffman, J. I. Applied Inorganic Analysis. Interscience, New York.
6. Chakrabarty, D. K. Solid State Chemistry. New Age International, New Delhi.
7. Kaur, H. Instrumental Method of Analysis. Pragati Prakashan, Meerut.
8. Parikh, V. M. Application Spectroscopy of Organic Molecules. Mehta, Mumbai.
9. Williams, D. W., & Fleming, I. Spectroscopic Methods of Organic Compounds. McGraw-Hill, London.
10. Silverstein, R. M., & Bassler, G. C. Spectroscopic Identification of Organic Compounds. John Wiley, New York.
11. Parikh, V. M. Absorption Spectroscopy for Organic Molecules. John Wiley, New York.
12. Kalsi, P. S. Spectroscopy of Organic Compounds. New Age International, New Delhi.

13. Jackman, L. M., & Sternhell, S. Applications of NMR Spectroscopy. Pergamon, Oxford.
14. Roberts, J. D. Nuclear Magnetic Resonance. John Wiley, New York.
15. Pavia, D. L., Lampman, G. M., & Kriz, G. S. Introduction to Spectroscopy. Cengage, Stamford.
16. Chatwal, G. R. (Ed. Madhu Arora). Analytical Chemistry. Himalaya Publishing House, Mumbai.

## Paper IX: E-INDCHT303 (B): General Chemical Technology (4 Cr, 60 hrs.)

**Course Outcomes (COs):** By the end of this paper, students will be able to:

**CO1:** Differentiate between various reactors types, such as continuous and batch reactors, and discuss their design considerations and chemical compositions.

**CO2:** Discuss the role of sulphonating agents and elucidate the kinetics, mechanism, and thermodynamics involved in sulphonation reactions.

**CO3:** Understand the kinetic and mechanistic fundamentals of halogenation, and summarize various industrial methods, including catalytic and photo-assisted halogenation.

**CO4:** Explain the kinetics and mechanism of esterification reactions, including addition to unsaturated systems and derivatives of carboxylic acids.

**Unit-I: Chemical reactors and Unit Processes:** **(15 hrs)**

Classification of chemical reactors, continuous reactor and batch reactor, chemical composition of the reactor.

**Nitration:** Nitrating agents, Kinetics and mechanism of nitration of aromatic compounds, Nitration of paraffinic hydrocarbons, Nitrate esters, N-nitro compounds, Process equipment. Typical industrial manufacturing processes.

**Unit-II: Important Industrial Processes** **(15 hrs)**

**Sulphonation:** Sulphonating agents, Kinetics and mechanism. Desulphonation Workup Procedures, Industrial equipment and technique, Batch and continuous processes, **Amination by reduction and amminolysis:** Methods of reduction to give amino compounds, Aminating Agents, Manufacture of amino compounds by reduction as well as by amminolysis.

**Unit-III: Application-based Industrial Processes (15 hrs)**

**Halogenation:** Kinetics and mechanism. Survey of methods, Catalytic chlorination, photohalogenation, Manufacturing processes for chlorohenzene, Chlorinated methanes, monochloroacetic acid, chloral

**Oxidation:** Oxidising agents with typical applications of each, Liquid phase oxidation with oxidising compounds, typical manufacturing processes.

**Unit-IV: Esterification and Petrochemicals (15 hrs)**

**Esterification:** Kinetics and mechanism. Esterification of carboxylic acid derivatives, Esters by addition to unsaturated systems, Industrial esterifications, Ethyl acetate, butyl acetate, Vinyl acetate, methyl methacrylate.

**Petrochemicals:** petroleum refining, outline of chemicals derived from ethylene, xylene and naphthalene.

**REFERENCE BOOKS**


1. Groggins, P. H. Unit Processes in Organic Synthesis. McGraw-Hill, New York.
2. Henglein, F. A. Chemical Technology. Pergamon, Oxford.
3. Rao, M. G. & Sittig, M. Outlines of Chemical Technology. East-West Press, New Delhi.
4. Clausen, C. A. & Mattson, G. Principles of Industrial Chemistry. Wiley, New York.
5. Lowenheim, F. A. & Moran, M. K. Industrial Chemicals. Wiley-Interscience, New York.
6. Kirk, R. E. & Othmer, D. F. Encyclopedia of Chemical Technology. Wiley, New York.
7. Kent, J. A. Riegel's Industrial Chemistry. Van Nostrand Reinhold, New York.
8. Shukla, S. D. & Pandey, G. N. A Textbook of Chemical Technology, Vol. II. Vikas Publishing House, New Delhi.
9. Stille, J. K. Industrial Organic Chemistry. Prentice Hall International, London.
10. Newman, E. B. Chemical Reactor Design, Optimization, and Scaleup (2nd ed.). McGraw-Hill, New York.

**Paper IX: E-INDCHT303 (C): Chemical Analysis in Agro, Food and Pharmaceutical Industries (4 Cr, 60 hrs.)**

**Course Outcomes (COs):**

**CO1:** Students can understand the basic principles of kinetics, proton transfer and the effect of proton ion on the rates of reaction

**CO2:** Various electron transfer processes, like inner sphere and outer sphere reactions

**CO3:** Different models to study catalysis and reaction mechanisms

**CO4**: Different methods of catalysis, like micellization and pseudo-ion exchange

**Unit –I: Analysis of soil (15 Hrs)**

Moister, pH, total nitrogen, phosphorous, silica, lime, Magnesia, Manganese, sulphur& alkali salts. Fuel analysis: Solid, liquid and Gas, ultimate and proximate analysis heating values, grading of cool, liquid fuels, flasks points, aniline point, octane number and carbon residue, gaseous fuels producer gas and water gas – calorific value.

**Unit –II: Clinical Chemistry and Drug Analysis (15 Hrs)**

Composition of blood collection, and preparation of samples, clinical analysis serum electrolytes, blood glucose, blood urea nitrogen, uric acid, albumin, globulin, barbiturates, acidic and alkaline phosphates, Immunoassay, principles of radioimmunoassay and applications, The blood gas analysis – trace elements in the body.

Drug analysis: Narcotics and dangerous drugs, classification of drugs, screening by gas and thin-layer chromatography and spectrophotometric analysis.

**Unit – III: Food analysis (15 Hrs)**

Moisture, ash, crude protein, fat, crude fiber, carbohydrate, calcium, potassium, sodium, and phosphates, food adulteration common adulteration in food, contamination of food stuffs, microscopic examination of foods for adulterants, pesticide analysis in food products, extraction and purification of sample, HPLC, gas chromatography for organophosphates, thin layer chromatography for identification of chlorinated pesticides in food products.

**Unit –IV: Fluorescence in Biological, Medical and Drug Development (15 Hrs)**

Fluorescence in biological, medical, and drug development: fluorescence instrumentation for analysis of fluorophores and their modification, pH-indicators, membrane potential probes, lipid membranes, protein labelling of protein and DNA.

**REFERENCE BOOKS**


1. Skoog, D. A., West, D. M., & Holler, F. J. Fundamentals of Analytical Chemistry. W. B. Saunders, Philadelphia.
2. Bamfield, P. Chromic Phenomena: The Technological Application of Colour Chemistry. Royal Society of Chemistry, Cambridge.
3. Sharma, V. Soil Chemical Analysis: A Practical Manual. Springer, Singapore.
4. Burtis, C. A., Bruns, D. E., & Sawyer, B. G. Tietz Fundamentals of Clinical Chemistry and Molecular Diagnostics. Elsevier, St. Louis.
5. Nagavi, B. G. Laboratory Handbook of Instrumental Drug Analysis. PharmaMed Press, Hyderabad.
6. Picó, Y. Chemical Analysis of Food: *Techniques and Applications.* Academic Press, London.
7. Heinze, K. G., & Jahnz, M. (Eds.). Fluorescence Microscopy: From Principles to Biological Applications (2nd ed.). Wiley-VCH, Weinheim.
8. Sudharmai Devi, C. R., & Somani, L. L. Analytical Procedures in Soil Science and Agricultural Chemistry. Scientific Publishers, Jodhpur


## Paper IX: E-INDCHT303 (D): Advances in Metal Complexes (4 Cr, 60 hrs.)

**Course Outcomes (COs):** Students will be able to:

**CO1:** Analyse and interpret the energy profiles of reactions involving transition metal complexes, distinguishing between inert and labile complexes using Valence Bond Theory (VBT) and Crystal Field Theory (CFT).

**CO2:** Explain mechanistic pathways for ligand substitution in octahedral complexes, including acid and base hydrolysis, and distinguish between conjugate base and other mechanisms.

**CO3:** Explain the Trans effect and its theoretical interpretations; predict substitution behaviour in square planar complexes.

**CO4:** Analyse photochemical behaviour in metal complexes, including substitution, rearrangement, and redox reactions.

**Unit-I: Reaction Mechanism of Transition Metal complexes-I (15 Hrs)**

Energy profile of the reaction. Inert and labile complexes, interpretation of liability and inertness of transition metal complexes based on VBT and CFT. Factors affecting the liability of a complex, transition state, or activated complex, substrate, attacking reagents, electrophilic and nucleophilic, Nature of the central atom. Reactions of metal complexes, ligand substitution reaction, Kinetics of octahedral substitution, acid hydrolysis, factors affecting acid hydrolysis, base hydrolysis, conjugate base mechanism, direct & indirect evidence in favour of conjugate mechanism.

**Unit-II: Reaction Mechanism of Transition Metal complexes-II (15 Hrs)**

Substitution reaction in square planar complexes: the trans effect, theories of trans effect, uses of trans-effect, and cis effect. Electron transfer reactions. Types of electron transfer reactions, conditions of electron transfer, and mechanism of one-electron transfer reactions, outer sphere and inner sphere mechanisms, two-electron transfer reactions, complementary and non-complementary electron transfer reactions. Marcus's theory, Cross reactions, Inner sphere reactions, racemization, and isomerisation in transition metal complexes.

**Unit-III: Photochemistry (15 hrs)**

Absorption, excitation, photochemical laws and quantum yield, electronically excited states and their life-time measurement, electronically excited states of metal complexes, type of photochemical reactions, substitution reactions, rearrangement reactions, and redox reactions. Photochemistry of coordination compounds, LMCT states and MLCT states, charge transfer spectra, charge transfer excitations, methods for obtaining charge transfer spectra.

**Unit-IV: Applications of Coordination Compounds (15 hrs)**

Metal Complexes in analytical chemistry, qualitative analysis, complexometric Titrations, Complexes in Colourimetry, and their role in Gravimetric analysis, Separation of Metals. Metal complexes in food poisoning treatment and their therapeutic applications. Heavy Metal–protein complexes in the Rasching Process, Ziegler-Natta catalysis, alkene conversions, electroplating, and metallurgical operations, including the dissolution of copper metal in aqueous potassium cyanide, as well as in water softening

**REFERENCE BOOKS**

1. Basolo, F., & Pearson, R. G. Mechanisms of Inorganic Reactions. Wiley, New York.
2. Huheey, J. E., Keiter, E. A., & Keiter, R. L. Inorganic Chemistry: Principles of Structure and Reactivity. Harper Collins, New York.

3. Cotton, F. A., & Wilkinson, G. Advanced Inorganic Chemistry. Wiley-Interscience, New York.
4. Greenwood, N. N., & Earnshaw, A. Chemistry of the Elements. Pergamon Press, Oxford.
5. Douglas, B. E., McDaniel, D. H., & Alexander, J. J. Concepts and Models of Inorganic Chemistry. Wiley, New York.
6. Jorgensen, C. K. Absorption Spectra and Chemical Bonding in Complexes. Pergamon Press, Oxford
7. J. D. Lee, Concise Inorganic Chemistry. Wiley Eastern, New Delhi.
8. R. K. Sharma, Coordination Chemistry. Krishna Prakashan Media, Meerut.
9. Satya Prakash, G. D. Tuli, S. K. Basu & Madan, Advanced Inorganic Chemistry Vol. I & II. S. Chand & Co., New Delhi.
10. Gurdeep R. Chatwal, Coordination Chemistry and Organometallics. Himalaya Publishing House, Mumbai.
11. B. R. Puri, L. R. Sharma & K. C. Kalia, Principles of Inorganic Chemistry. Vishal Publishing Co., Jalandhar.
12. R. C. Mehrotra & A. Singh, Organometallic Chemistry: A Unified Approach. New Age International, New Delhi.
13. C. N. R. Rao, Ultraviolet and Visible Spectroscopy: Chemical Applications. Tata McGraw-Hill, New Delhi.
14. R. K. Bansal, Heterocyclic Chemistry. New Age International, New Delhi.
15. R. L. Dutta & A. Syamal, Elements of Magnetochemistry. Affiliated East-West Press, New Delhi.

# Industrial Chemistry Practical Course

## INDCHP-305 (4 Cr, 120 Hrs): Practical-V

**Course Outcomes (COs):**

**Industrial Chemistry Practicals**

**CO1:** Accurately operate advanced instrumentation, including conductometer, fluorimeter, polarograph, potentiometer, pH meter, and spectrophotometer.

**CO2:** Conduct conductometric titrations to determine critical micelle concentration (CMC) and quantify acetic acid in vinegar using conductivity trends.

**CO3:** Apply fluorometric methods to estimate concentrations of quinine sulfate and riboflavin from samples. Measure the latent heat of fusion of solids via calorimetric observations. Perform polarographic analysis, including determining half-wave potentials of $Cd^{2+}$/Zn using differential and half-wave methods, and determining unknown $Cd^{2+}$ concentrations via standard addition. Experimental spectral measurements and analysis for understanding binding equilibria.

**CO4:** Construct and interpret calibration curves, titration plots, and spectral data; use regression tools to derive analytical parameters such as CMC, $pK_a$ values, solubility product, or stability constants. Apply error analysis and statistics, including identification of random and systematic errors, calculating uncertainties, significant figures, and detection limits.

(Aligned with learning objectives for data analysis in analytical chemistry)

**The practical course contains the list of experiments**

- **Physical Chemistry Practicals**

1. To determine the critical micelle concentration of sodium lauryl sulphate in aqueous Solution conductometrically.
2. Determination of the percentage of acetic acid in commercial vinegar solution.
3. To estimate the quinine sulphate in the given sample by fluorometry.
4. To determine the amount of riboflavin in a given B-complex tablet by fluorometry.
5. Determination of transport number of H+, Na+, K+ etc. ions using moving boundary method.
6. To determine unknown concentrations of $Cd^{+2}$ion in a given solution by the standard addition method.
7. To determine the Solubility of $PbI_2$ with the Ag/AgI electrode by using Potentiometry.
8. To determine the dissociation constant of tribasic acid ($H_3PO_4$) potentiometrically.
9. To determine the dissociation constant of dibasic acid pH – metrically.

10. To determine the pH value of various buffers using pH meter and determine the dissociation constant of acetic acid.

- **Inorganic Chemistry Practicals**

1. Analysis of Stainless steel Alloy [e.g. iron, chromium and nickel]
2. Analysis of Ilmenite Ore [e.g. acid-insoluble matter (combined oxides), iron and titanium]
3. Analysis of Portland cement
4. Gravimetric Estimation of Si and Ca from Plaster of Paris sample
5. Estimation of Magnesium from tablet of Milk of magnesia
6. Estimation of calcium from calcium supplementary tablet
7. Estimation of Iron and Zinc from iron-zinc supplementary Multivitamin Tablet
8. Estimation of Aluminium from alum sample
9. Estimation of Mn volumetrically from Tea leaves
10. X-ray powder diffraction analysis of cubic compound
11. Determination of lattice constants and geometry, Partical Size, Density
12. Interpretation of Mossbaur spectrum with reference to determination of
    a) isomer shift b) quadruple splitting c) Internal magnetic field d) general comment
13. Interpretation of IR spectrum with reference to stretching vibration C=N, C=O, N, M-O.
14. Interpretation of NMR spectrum with reference to calculation of chemical shifts and general comments.

- **Organic Chemistry Practicals**

1. Identification and separation of organic mixtures by physical and chemical methods.
2. Preparation of p-aminobenzoic acid from p-toluidine.
3. Preparation of p-iodonitrobenzene from p-nitroaniline.
4. Preparation of benzanilide from benzophenone.
5. Preparation of m-nitroaniline from nitrobenzene.
6. Estimation of copper from copper fungicide.
7. Estimation of Endosulfan from a given sample of a drug tablet.
8. Estimation of nitrogen by Kjeldahl’s method.

**Note: Any other advanced experiments related to organic/ analytical chemistry may be added.**

## INDCHP305 (2 Cr, 60 Hrs): Practical paper-VI

### Course Outcomes (COs):

**CO1:** The students will acquire hands on training for conducting the representative experiments for the analysis of wide variety of samples of inorganic, organic and physical approaches by qualitative and quantitative analysis.

**CO2:** Student would learn the sample preparation and characterization for purity and qualitative and quantitative analysis of samples.

**CO3:** Students will have good experimental skills for separation and estimation of amount of metal, metal ions in given samples.

**CO4:** Students will be acquainted with the separation and estimation of organic compounds in given samples.

- **Physical Chemistry Practicals**

1. To determine the hydrolysis constant of aniline hydrochloride by pH metry.
2. To determine isoelectronic point and the dissociation constant of an aminoacid (Glycine) by pH metry.
3. To determine pK value of phenolphthalein indicator by the spectrophotometric method.
4. To study the stoichiometry and stability of ferric sulphate complex by Job'smethod and Mole ratio method.
5. To determine the stability constant of Ferric thiocyanate complex by the Frank Ostwald method spectrophotometrically.
6. Determination of Latent Heat of Fusion of a Solid
7. Polarographic Analysis Using Dropping Mercury Electrode (DME)
8. Quantitative Estimation of $Cd^{2+}$ via the Standard Addition method
9. Determination of apparent and partial molar volumes in a water-ethanol mixture in aqueous solutions using a specific gravity bottle.
10. Statistical representation of given experimental data: Estimation of errors in measured and derived properties, reporting data with appropriate significant figures, and graphical representation of data with x- and y-error bars.
11. Chemical kinetics: Kinetics of iodination of acetone in the presence of strong acid.
12. Phase Equilibrium: To construct phase diagrams for a ternary system.
13. Viscosity: Determination of the radius of glycerol molecules.

- **Inorganic Chemistry Practicals**

1. Estimation of Mg and Silica from talcum powder
2. Estimation of Cu and Ca from Bordeaux mixture
3. Estimation of Vitamin C from Lemon juice
4. Estimation of Phosphate from Fertilizer sample
5. Estimation of Total Hardness of Borewell water
6. Estimation of Phosphoric acid from coca-cola sample
7. Estimation of Chemical Oxygen Demand (COD) from sewage/effluent sample
8. Interpretation of absorption spectra for
   a. Verification of position of ligands in spectrochemical series
   b. Determination of geometry (Octahedral, Square planar, tetrahedral) of a given compound.
   c. Calculation of spectral splitting parameters.
9. Interpretation of polar gram for determination of half wave potentials and unknown concentration.
10. Calculation of band gap of semiconductors with the help of plots of log Vs.10 ¾.

- **Organic Chemistry Practicals**

1. Multicomponent synthesis
2. Estimation of Vit –C
3. Estimation of Sulfur from Sulfur Fungicide
4. Preparation of NBS (N-bromo succinimide)

   Any other suitable experiment may be added with respect to the syllabus.

## RP-306: Research Project (4 Cr, 120 Hrs)

**See Annexure-I for details (In the end of this document).**

# M. Sc. II (SEM - IV) Industrial Chemistry

**MANDATORY PAPERS**

Paper X: INDCHT401 (4 Cr): Inorganic Chemical Industries- II

Paper XI: INDCHT402 (4 Cr): Selected Topics in Industrial Chemistry

INDCHP404 (4 Cr): Practical-VII

RP-405 (6 Cr): Research Project

**ELECTIVE PAPERS**

Paper XII: E- INDCHT403 (A) (4 Cr): Environmental Chemistry

Paper XII: E- INDCHT403 (B) (4 Cr): Pharmaceutical Chemistry

Paper XII: E- INDCHT403 (C) (4 Cr): Chemistry of Industrially Important Materials

Paper XII: E- INDCHT403 (D) (4 Cr): Forensic Science and Microbiological Analysis

**Paper X: INDCHT401: Inorganic Chemical Industries- II (4 Cr, 60 hrs.)**

## Course Outcomes (COs):

After completion of the course student will be able to

**CO1:** Identify and discuss major mineral resources in India and outline essential mineral processing techniques.

**CO2:** Describe and differentiate metal finishing techniques such as electrorefining, electroplating (Ni, Cr, Cu, Cd, Ag, Au), hot dipping, cladding, immersion plating, thermal spraying, vapour deposition, and organic coatings—highlighting factors affecting deposition quality and typical applications.

**CO3:** Describe the roles, preparation methods, and properties of various inorganic pharmaceutical agents, including antioxidants, gastrointestinal and topical agents, dental products, inhalants, expectorants, respiratory stimulants, and compounds of iron, iodine, and calcium, focusing on medicinal uses and assay techniques.

**CO4:** Identify and explain the preparation, properties, and industrial relevance of inorganic fine chemicals such as magnesia, alumina, aluminium chloride, calcium carbonate, sodium silicate, manganese dioxide, ferrous sulfate, lead dioxide, sodium hydrogen phosphate, and sodium hydroxide.

**Unit – I: Metallurgy and Metal Finishing Technology (15 Hrs)**

Ellingham diagrams, manufacture and applications of metal alloys and salts, and techniques for using low-grade minerals. Iron and steel (iron, steel alloy, tool steel, and stainless steel), copper and its alloys, zinc, nickel, and aluminum. Electrorefining of metals, electroplating of nickel, chromium, copper, cadmium, silver, and gold; surface treatment technology, surface coats. Introduction, electrodeposition, electroplating (factors affecting, requirements, and applications), hot dipping, metal cladding, immersion plating, metal spraying, vapour deposition, and chemical and organic coating.

**Unit – II: Role of Inorganic Chemistry in Textile Technology (15 Hrs)**

Textile Technology: A Brief history of the origin of textiles. Introduction to textile fibers and basic requirements of textile fibers. Manufacture of eco-friendly regenerated fibre. Brief study of physical & chemical properties of cotton, wool, silk & bast fibers. Importance and need of ginning. Impurities in the cotton and remedies to minimize impurities in cotton.

**Unit – III: Inorganic Pharmaceuticals (15 Hrs)**

Introduction, impurities in pharmaceutical substances and their limit tests; antioxidants, gastrointestinal agents, topical agents, dental products, inhalants, expectorants, respiratory stimulants. Compounds of iron, iodine, and calcium; antidotes in poisoning; pharmaceutical aids.

**Unit -IV: Glass and Refractory Materials (15 Hrs)**

Raw materials, Soda glass, borosilicate glass, Lead Glass, Coloured Glass, Refractory: Raw materials, clay pots, Zeolites.

**Industrial Gases:** Manufacture and industrial uses of $H_2$, $O_2$, $N_2$, $CO_2$ & acetylene.

Liquefaction of gases, production of low temperatures.

**Chemicals of Utility:** Inorganic fine chemicals, magnesia, alumina, AlCl3, calcium carbonate, sodium silicate, $MnO_2$, $FeSO_4$, $PbO_2$, $Na_2HPO_4$ and NaOH.

**REFERENCE BOOKS**


1. Lowenheim, F. A. Modern Electroplating (3rd ed.). Chapman & Hall, London.
2. Gable, D. Principles of Metal Treatment and Protection. Pergamon Press, Oxford.

3. Kenneth, G. A. Electroplating for Engineers: A Handbook (3rd ed.). Van Nostrand Reinhold Co., London.
4. Lowenbein, F. A. Modern Electroplating. Electroplating Publications, New Jersey.
5. Burke, J. E. Progress in Ceramic Science, Vol. IV. Pergamon Press, Oxford.
6. Iash, R. R. A Formulary of Paints and Other Coatings, Vol. I. Wiley, New York.
7. Gilchrist, J. D. Extraction Metallurgy. Pergamon Press, Oxford.
8. Dennis, W. H. Foundations of Iron and Steel Metallurgy. Elsevier, Amsterdam.
9. Shukla, S. D., & Pandey, G. N. A Textbook of Chemical Technology, Vol. I. Vikas Publishing House, New Delhi.
10. Henglein, F. A. Chemical Technology. Pergamon Press, Oxford.

**Paper XI: INDCHT402 (4 Cr): Selected Topics in Industrial Chemistry**

**Course Outcomes (CO)**

After completion of the course student will be able to

**CO1:** Explain the principles behind X-ray sources, including conventional X-ray tubes and synchrotron sources, and the emission spectrum characteristics fundamental to diffraction studies.

**CO2:** Describe the economic impact and scientific theories behind corrosion, including factors affecting corrosion rates, kinetics (using Evans diagrams), and thermodynamics (via Pourbaix diagrams).

**CO3:** Design and conduct sampling and monitoring of air and water pollutants, including gases (CO, $CO_2$, $NO_2$, $SO_2$, $H_2S$), heavy metals (Cd, Cr, Hg, As, Pb), and ions ($SO_4^{2-}$, $PO_4^{3-}$, $NO_3^-$), along with COD and BOD measurements.

**CO4:** Identify and classify various types of sensors—including electroanalytical, membrane electrode, ionic conductor, thin/thick film, and nano-sensors—and understand their working principles.

**Unit – I: X-ray Diffraction Techniques (15 Hrs)**

X-ray Sources (X-ray tube and synchrotron sources with their principle of working characteristics of emission spectrum), Bragg's law of diffraction, methods of diffraction (powder and single crystal), Powder diffraction: instrumentation, use of standards, characteristics of powder XRD pattern, significance of peak intensities, systematic absences of reflections, indexing of powder XRD pattern, determination of lattice parameters, and solving cubic crystal structure using powder XRD data, qualitative (identification of the phases) and quantitative analysis (phase quantification), crystallite size determination, determination of relative % crystallinity. Single crystal diffraction: Advantages of single crystal diffraction over powder diffraction, introduction to Laue, rotation photograph, and oscillation methods. Introduction to crystallographic database and file formats (raw data files, cif and pdf), Open source computer-based crystal structure building and visualization tools.

**Unit-II: Corrosion** **(15 Hrs)**

Introduction, economic aspects of corrosion, theories of corrosion, factors affecting corrosion, kinetics of corrosion, Evans diagram, thermodynamics of corrosion, Pourbaix diagram, corrosion testing techniques, Evaluation of corrosion effect: XRD, ESCA, FTIR surface techniques.

**Corrosion Prevention:** Corrosion inhibitors, protective coating, cathodic, and anodic protection. Corrosion problem in India.

**Unit-III: Industrial Pollution** **(15 Hrs)**

Introduction, Methods of monitoring and sampling of gaseous, liquid, and solid pollutants, analysis of CO, $CO_2$, $NO_2$, $SO_2$, $H_2S$, analysis of toxic heavy metals, Cd, Cr, Hg, As, Pb, analysis of anions $SO_4^{2-}$, $PO_4^{3-}$, $NO_3^-$, estimation of COD and BOD. ND-IR Spectroscopy, FTIR, AAS, ICP-AES, GC, GC-MS, HPLC, Anodic stripping voltammetry with case studies.

**Unit –IV: Sensor Technology** **(15 Hrs)**

Introduction, recent trends, classification of sensors, Elector analytical sensors, sensor, electrodes, Metal Membrane electrode sensors, Ionic Conductors, Thin film and thick Film Sensors, Nano-sensors, Application of sensors in Industry.

**REFERENCE BOOKS**


1. Adamson, A. W. Physical Chemistry of Surfaces. Wiley, New York.
2. Hannay, N. B. Solid-State Chemistry. Prentice Hall, Englewood Cliffs.
3. Glasstone, S. Physical Chemistry. Macmillan, London.
4. Bockris, J. O'M., & Reddy, A. K. N. Modern Electrochemistry, Vol. I & II. Plenum Press, New York.
5. Lee, J. D. Concise Inorganic Chemistry. Chapman & Hall, London.

6. Greenwood, N. N., & Earnshaw, A. Chemistry of the Elements. Pergamon Press, Oxford.
7. Patranabis, D. Sensors and Transducers. Prentice Hall of India, New Delhi.

**SEMESTER IV- ELECTIVE PAPERS**

Paper XII: E- INDCHT403 (A) (4 Cr): Environmental Chemistry

Paper XII: E- INDCHT403 (B) (4 Cr): Pharmaceutical Chemistry

Paper XII: E- INDCHT403 (C) (4 Cr): Chemistry of Industrially Important Materials

Paper XII: E- INDCHT403 (D) (4 Cr): Forensic Science and Microbiological Analysis

**Paper XII: E- INDCHT403 (A) (4 Cr): Environmental Chemistry**

## Course Outcomes (COs):

After completion of the course student will be able to

**CO1:** Understand and analyze the causes, sources, and impacts of water pollution, apply principles of wastewater management, and suggest remedial measures for sustainable water resource management.

**CO2:** Evaluate the sources and effects of soil pollution caused by agricultural, industrial, and domestic activities, and develop strategies for eco-friendly practices**,** biotechnological approaches, and sustainable land use systems for pollution control.

**CO3:** Identify and classify air and noise pollutants, understand their measurement standards, health impacts, and global pollution episodes, and apply scientific techniques for monitoring and controlling air and noise pollution.

**CO4:** Apply analytical techniques for the detection and quantification of toxic heavy metals in environmental samples and recommend treatment, recovery, and recycling methods for effective pollution abatement.

**Unit I: Water Pollution and Wastewater Management (15 Hrs)**

Introduction, use and conservation of water resources, water quality management, Rainwater harvesting, water management in agriculture,rain-fed systems, irrigated Systems, industries. Water pollution: Definition, types of water pollution

(Physical, Chemical, Biological, and physiological), water pollutants. Ground water pollution and its protection, Surface, river, sea, and lake water pollution, effect of excess nutrients and oil on water pollution, seawater for agriculture, and remedial measures for water pollution

**Industrial waste treatment:** Characteristics and types of industrial waste, principles of industrial waste treatment and disposal, protection of the biosphere, and surface water from industrial pollution.

**Unit -2: Soil Pollution (15 Hrs)**

Introduction, industrial, agricultural, radioactive, sewage, domestic, chemical, and metallic wastes, soil pollution by mining, by sediments and biological agents, Effect of heavy metals, diseases caused by soil pollution, and the impact of soil pollution on air Quality.

**Control of Soil Pollution:**

Control of sewage, domestic and industrial waste, eco-farming, and technology, biotechnology, integrated nutrient, pest, genetic resource, and water management, land use systems.

**Unit 3: Air pollution and Noise pollution (15 Hrs)**

Definition, composition, and reactions occurring in the atmosphere; sources of air pollution; units of measuring air pollutants. Classification and effects of air pollution: oxides of nitrogen, sulfur, and carbon; hydrocarbons; organic and inorganic particulates; and ozone as pollutants. WHO standards; indoor air pollution; occupational air pollution; outdoor air pollution. Air pollution episodes: Bhopal gas, Seveso, Chernobyl tragedies.Sources of noise; units and measurements of noise; characterization of noise from construction, mining, transportation, and industrial activities; airport noise; auditory effects; non-auditory effects; and control of noise pollution.

**Unit 4: Removal of Heavy Toxic Metals (15 Hrs)**

Chromium, mercury, lead, cadmium, arsenic, analytical methods of determination of small amounts of metal pollutants, copper recovery, treatment of wastewater to remove heavy metals, and recovery techniques. Polymer Recycling: Environment and polymer industry, recycling of polymer wastes.

**REFERENCE BOOKS**


1. Henglein, F. A. Chemical Safety Management and Engineering. Pergamon Press, Oxford.
2. Sharma, B. K. Environmental Chemistry. Goel Publishing House, Meerut.
3. Hill, M. K. Understanding Environmental Pollution: A Primer. Cambridge University Press, Cambridge.
4. Pepper, I. L., Gerba, C. P., & Brusseau, M. L. Environmental and Pollution Science. Elsevier, Amsterdam.
5. Masters, G. M. Introduction to Environmental Engineering and Science. Pearson Education, Upper Saddle River.
6. Milne, A. Noise Pollution: Impact and Countermeasures. David & Charles, London.
7. Peterson, A. P. G., & Gross, E. E. Jr. Handbook of Noise Measurement (5th ed.). General Radio Co., Concord.


**Paper XII: E- INDCHT403 (B) (4 Cr): Pharmaceutical Chemistry**

## Course Outcomes (COs):

After completion of the course student will be able to

**CO1:** Explain the entire drug development cycle from lead discovery and lead modification to the design of prodrugs and soft drugs, and understand the criteria and strategies involved in each phase.

**CO2:** Differentiate and utilize quantitative structure–activity relationship (QSAR) methodologies, including Free–Wilson and Hansch analysis, and interpret drug receptor interaction parameters such as ionization constants, steric and lipophilic influences, surface characteristics, and redox potential in predicting activity.

**CO3:** Compare theories of drug action, occupancy theory, rate theory, and the induced-fit model to molecular interactions and binding kinetics, and evaluate their applicability to real-world pharmacological scenarios.

**CO4**: Interpret basic pharmacological parameters like $LD_{50}$ and $ED_{50}$ and understand their implications in drug safety and potency discussions (mathematical derivations excluded).

**Unit – I: Drug Design** **(15 Hrs)**

Development of new drugs, procedures followed in drug design, concepts of lead compound and lead modification, concepts of prodrugs and soft drugs, structure-activity relationship (SAR), factors affecting bioactivity, Resonance, inductive effect, isosterism, non-isosterism, and special considerations. Theories of drug activity: occupancy theory, rate theory, and induced fit theory. Quantitative structure-activity relationship. History and development of QSAR. Concepts of drug receptors. Elementary treatment of drug receptor ionization Constants, steric, Shelton, and surface activity parameters and redox potentials. Free Wilson analysis, Hansch analysis, and relationships between Free-Wilson and Hansch Analysis. LD-50, ED-50 (Mathematical derivations of equations excluded).

**Unit – II: Pharmacokinetics** **(15 Hrs)**

Introduction to drug absorption, disposition, and elimination using pharmacokinetics, important pharmacokinetic parameters in defining drug disposition, and in therapeutics. Mention of uses of pharmacokinetics in the drug development process. Pharmacodynamics**:** Introduction, elementary treatment of enzyme stimulation, enzyme inhibition, sulphonamides, membrane active drugs, drug metabolism, xenobiotics, biotransformation, significance of drug metabolism in medicinal chemistry.

**Antineoplastic Agents:** Introduction, cancer chemotherapy, special problems, role of alkylating agents and antimetabolites in treatment of cancer. Mention of carcinolytic antibiotics and mitotic inhibitors. Synthesis of mechlorethamine, cyclophosphamide, melphalan, uracil, mustards, and 6-mercaptopurine. Recent developments in cancer chemotherapy. Hormone and natural products.

**Unit – III: Cardiovascular Drugs** **(15 Hrs)**

Introduction to cardiovascular diseases, drug inhibitors of peripheral sympathetic function, and central intervention in cardiovascular output.Direct-acting arteriolar dilators. Synthesis of amyl nitrate, sorbitrate, diltiazem, quinidine, verapamil, methyldopa, and atenolol. Local Antiinfective Drugs**:** Introduction and general mode of action. Synthesis of sulphonamides, furazolidone, nalidixic acid, ciprofloxacin, norfloxacin, dapsone, amino salicylic acid, isoniazid, ethionamide, ethambutol, fluconazole, griseofulvin, chlroquinprimoquin.

**Unit – IV: Psychoactive Drugs** **(15 Hrs)**

The Chemotherapy of Mind: Introduction, neurotransmitters, CNS depressants, general anaesthetics, mode of action of hypnotics, sedatives, antianxiety drugs, benzodiazepines, buspirone, neurochemistry of mental diseases. Antipsychotic drugs, the neuroleptics, antidepressants, butyrophenones, serendipity, and drug development, stereochemical aspects of psychotropic drugs. Synthesis of, diazepam, oxazepam, chlorazepam, alprazolam, phenytoin, ethosuximide, trimethadione, barbiturates, thiopental sodium, glutethimide. Antibiotics: Cell wall biosynthesis, inhibitors, β-lactum rings, antibiotics inhibiting protein synthesis.Synthesis of penicillin G, penicillin V, ampicillin, amoxicillin, chloramphenicol, Cephalosporin, tetracycline and streptomycin.

**REFERENCE BOOKS:**


1. Gringuage, A. Introduction to Medicinal Chemistry. Wiley-VCH, Weinheim.
2. Dorge, R. F. (Ed.). Wilson & Gisvold’s Textbook of Organic Medicinal and Pharmaceutical Chemistry. Lippincott Williams & Wilkins, Philadelphia.
3. Pandeya, S. S., & Dimmock, J. R. An Introduction to Drug Design. New Age International, New Delhi.
4. Wolff, M. E. (Ed.). Burger’s Medicinal Chemistry and Drug Discovery, Vol. I (Chap. 9 & Chap. 14). John Wiley, New York.
5. Goodman, L. S., & Gilman, A. The Pharmacological Basis of Therapeutics. McGraw-Hill, New York.
6. Silverman, R. B. The Organic Chemistry of Drug Design and Drug Action. Academic Press, San Diego.
7. Lednicer, D. Strategies for Organic Drug Synthesis and Design. John Wiley, New York.

## Paper XII: E- INDCHT403 (C) (4 Cr):

## Chemistry of Industrially Important Materials

### Course Outcomes (COs):

After completion of the course student will be able to learn

**CO1:** Define and classify key categories of industrial materials—including glasses, ceramics, composites, nanomaterials, thin films, Langmuir-Blodgett films, and liquid crystals—highlighting their structural differences, material components (e.g., glass formers/modifiers), and industrial applications. Supports a foundational understanding of material types and their use

**CO2:** Explain processing and fabrication techniques for these materials.Ceramics & glasses: Understand glassy state, ceramic structures, clay products, refractories, and thin-film crystallization methods.

Composites: Describe the structure and role of dispersion-strengthened, particle-reinforced, and fiber-reinforced composites.

**CO3:** Relate glass, ceramic, composite, and nanomaterial structures to performance traits like strength, brittleness, and thermal stability.

**CO4:** Choose suitable materials (glasses, ceramics, and composites) based on application constraints such as temperature, durability, or mechanical load.

**Unit – I: Industrial Materials** **(15 Hrs)**

Glasses, Ceramics, Composites, and Nonmaterial Glassystate, glass formers, and glass modifiers, applications. Ceramic structures, mechanical properties, and clay products. Refractories, characterizations, properties, and applications. Microscopic composites: dispersion-strengthened and particle-reinforced fiber-reinforced composites, macroscopic composites. Nanocrystalline phase, preparation phase, preparation procedures, special properties, applications. Thin Films and Langmuir-Blodgett Films: Preparation techniques, evaporation/sputtering, chemical processes, MOCVD, sol, etc., Langmuir-Blodgett (LB) film, growth techniques, photolithography properties, and applications of thin and L-B films. Liquid crystals: Mesomorphic behaviour, thermotropic liquid crystals, positional order, bond orientational order, nematic and smectic mesophases, smectic–nematic transition and clearing temperature, homeotropic, planar and schlieren textures, twisted nematics, chiral nematics, molecular arrangement in smectic A and smectic B phases, optical properties of liquid crystals, Dielectric Susceptibility and dielectric constants. Lytropic phases and their description of ordering in liquid crystals.

**Unit- II: Polymeric Materials (15 Hrs)**

Molecular shape, structure and configuration, crystallinity, stress–strain behaviour, thermal behaviour, polymer types and their applications, conducting and ferro-electric polymers. Ionic Conductors: Types of ionic conductors, mechanism of ionic conduction, interstitial jumps (Frenkel); vacancy mechanism, diffusion superionic conductors; phase transitions and mechanism of conduction in superionic conductors, examples and applications of ionic conductors.

**Unit – III: Superconductors (15 Hrs)**

Defect perovskites, high Tc superconductivity in cuprates, preparation and characterization of 1-2-3 and 2-1-4 materials, normal state properties; anisotropy; temperature dependence of electrical resistance; optical phonon modes, superconducting state; heat capacity; coherence length, elastic constants, position lifetimes, microwave absorption – pairing and multigap structure in high Tc materials, applications of high Tc materials.

**Unit – IV: Materials for Solid State Devices (15 Hrs)**

Rectifiers, transistors, capacitors-IV-V compounds, low-dimensional quantum structures, optical properties. Organic Solids, Fullerenes, and Molecular Devices: Conducting organics, organic superconductors, magnetism in organic materials. Fullerenes-doped, fullerenes as superconductors. Molecular rectifiers and transistors, artificial photosynthetic devices, optical storage memory and switches, sensors. Nonlinear optical materials; nonlinear optical effects, second and third order, molecular hyperpolarisability and second-order electric susceptibility, materials for the second and third harmonic generation.

**REFERENCE BOOKS:**


1. Ashcroft, N. W., & Mermin, N. D. Solid State Physics. Saunders College, Philadelphia.
2. Callister, W. D. Materials Science and Engineering: An Introduction. Wiley, New York.
3. Keer, H. V. Principles of the Solid State. Wiley Eastern, New Delhi.

4. Anderson, J. C., Leaver, K. D., Alexander, J. M., & Rawlings, R. D. Materials Science. ELBS, London.
5. Gray, G. W. (Ed.). Thermotropic Liquid Crystals. John Wiley, New York.
6. Kelker, H., & Hatz, R. Handbook of Liquid Crystals. Chemie Verlag, Weinheim.

**Paper XII:E- INDCHT403 (D) (4 Cr): Forensic Science and Microbiological Analysis**

## Course Outcomes (COs):

After completion of course student will able to learn

**CO1:** Understand and outline core principles of forensic analysis, including sampling protocols, proper sample storage, and dissolution techniques.

**CO2:** Analyze forensic detection techniques for poisonous elements (As, Sb, Pb, Cr, Hg) and other materials such as insecticide residues, gunpowder, and cement in forensic samples.

**CO3:** Classify microorganisms based on morphology, taxonomy, nutrition, and physiology, and understand their roles in pathogenesis and spoilage.

**CO4:** Monitor and assess microbial contamination across diverse domains air, food, water, and propose effective contamination control strategies.

**UNIT-I: Forensic Analysis (15 Hrs)**

Introduction to forensic analysis, scope, importance, and its special features compared with conventional analysis; principles and methods of sampling, preservation, storage, and chain of custody of different types of forensic samples; sample dissolution and extraction techniques including acid digestion, solvent extraction, microwave digestion, SPE, Soxhlet, and headspace analysis; classification of poisons natural (plant, animal, microbial), synthetic and chemical (organic, inorganic, pesticides, heavy metals, drugs), and radioactive poisons with routes of administration, absorption, metabolism, detoxification, excretion, and forensic symptoms; toxicological parameters such as lethal dose (LD), $LD_{50}$, $LC_{50}$, $ED_{50}$, and therapeutic index along with factors influencing toxicity (age, sex, genetics, synergism, antagonism); and case studies highlighting forensic applications, documentation, reporting, and legal significance of toxicological data.

**UNIT-II: Identification and Analysis of the suspects** **(15 Hrs)**

Insecticides, Analysis of metals, Gun powder Residues, Portland cement in Forensic samples. Poisoning due to cyanide, dioxins & asbestos. Physiological effects of natural poisons such as Colchicine, Morphine, Hashish, Nicotinoids. Health hazards and Remedial measures.

**Unit III: Analytical Microbiology** **(15 Hrs)**

Morphological structure and characteristics, nutrition, and physiology classification of microorganisms, Taxonomy and nomenclature, Nutritional requirements, Phathoseas and Spoilage organics Microscopy, Staining techniques, Aspatic Techniques, isolation and use of differential media, sterilization and disinfection.

**UNIT-IV: Applied Microbiology** **(15 Hrs)**

Air Microbiology with respect to contamination control, Food Microbiology, Water microbiology, Industrial microbiology with respect to quality control.

**REFERENCE BOOKS**


1. Fraser, J. Forensic Science: A Very Short Introduction. Oxford University Press, Oxford.
2. Bechky, B. A. Blood, Powder, and Residue: Behind the Scenes of Forensic Science. Princeton University Press, Princeton.
3. Hooper, M. K., & Masters, R. E. (Eds.). The Criminal Justice System (2nd ed.). Routledge, New York.
4. Fox, A., Morgan, S. L., Larsson, L., & Odham, G. Analytical Microbiology Methods. Wiley, New York.
5. Dhir, A. Textbook of Applied Microbiology. Springer, Singapore.

**Industrial Chemistry Practical Course**

**INDCHP404 (4 Cr): Practical-VII**

## Course Outcomes (COs):

After completion of the course student will be able to

**CO1:** Operate advanced analytical instruments such as conductometers, fluorimeters, polarographs, potentiometers, pH meters, and spectrophotometers—with accuracy and confidence, ensuring correct calibration and use for each experiment.

**CO2:** Execute pH metric, spectrophotometric, and stability constant determination experiments, such as determining the dissociation constant of glycine, $pK_a$ of indicators, and stoichiometry by Job's and Frank–Ostwald methods.

**CO3:** Execute advanced techniques, including soil analysis, thermal analysis, magnetic property measurements, spectrofluorimetric, and gravimetric methods.

**CO4:** Apply separation techniques for analytes in mixtures or formulations.

- **Physical Chemistry Practicals**

1. Calibration of the conductivity meter
2. Calibration of analytical balance
3. Assay by Titrimetry
4. Calibration of pH meter
5. Titration of a ternary acid mixture of acids by conductometry.
6. Verification of the Onsager Equation for a 1:1 type of strong electrolyte by conductometry.
7. Determination of $\Delta G$, $\Delta H$, $\Delta S$ of silver benzoate by the solubility product method by conductometry.
8. Determination of formal redox potential of system ($Fe^{2+}$, $Fe^{3+}$) by potentiometry.
9. Determination of binary mixture of halides by potentiometry.
10. Determination of the dissociation constant of dibasic acid by pH metry.
11. Determination of the dissociation constant of monobasic acid by pH metry.
12. Study of the adsorption of acetic acid on charcoal.
13. To verify Beer-Lambert's Law for potassium permanganate solution and hence to determine the molar extinction coefficient and unknown concentration of the given sample spectrophotometrically.
14. To determine the iron potentiometrically by titrating with potassium dichromate.

15. To determine the solubility of Calcium oxalate in the presence of different concentrations of KCl.
16. To determine the solubility of Calcium oxalate in the presence of different concentrations of HCl.

- **Inorganic Chemistry Practicals**

1. Synthesis of Zinc oxide (ZnO) nanomaterial by Co-precipitation method
2. Synthesis of Nickel oxide (NiO) nanomaterial by Hydrothermal method
3. Synthesis of Bismuth oxide ($Bi_2O_3$) nanomaterial by Sol-gel method
4. Synthesis of Silver nanoparticles by Green synthesis method using plant extract
5. Synthesis of Nickel Ferrite materials
6. Synthesis of Ferroso-ferric oxide ($Fe_3O_4$) by Co-precipitation method
7. Synthesis of Cobalt oxide ($Co_3O_4$) nanomaterial by Hydrothermal method
8. Synthesis of Lanthanum Ferric Oxide ($LaFeO_3$) nanomaterial by Sol-gel method
9. Synthesis of Cerium Oxide ($CeO_2$) by Green synthesis method using plant extract
10. Synthesis of Titanium Oxide ($TiO_2$) by Co-precipitation method
11. Synthesis of Trans-dichloro-bis(ethylene diamine) Cobalt (III) chloride
12. Synthesis of Hexa thiocyanato chromate
13. Synthesis of Tris- triphenylphosphine Nickel (II) sulphate.
14. Synthesis of Chloroaquo tetraamino cobaltic sulphate.
15. Water content by karl fisher titration
16. Assay by HPLC
17. Loss on drying ( LOD)
18. Estimate the chemical oxygen demand in water (COD).
19. Estimate the dissolved oxygen in water (DO).
20. Estimation of total hardness of water.
21. Monitoring and Analysis of Air Pollutants (PM10, PM2.5, SOx, and NOx).

- **Organic Chemistry Practicals**

1. Qualitative analysis: Identification and separation of ternary organic mixtures by physical and chemical methods.
2. Preparation of anthranilic acid.
3. Multicomponent synthesis
4. Related substances by thin-layer chromatography

5. Preparation of p-amino benzoic acid.
6. Estimation of lactose from a milk sample.
7. Preparation of p-Bromoaniline from acetanilide.
8. Synthesis of Aspirin.
9. Determination of melting point/ melting range using digital melting point apparatus
10. Assay UV spectrophotometry
11. Spectroscopic analysis of drugs- UV- Visible/ IR/ NMR spectroscopic methods.
12. Estimation of Total Organic Carbon (TOC) and Total Organic Matter (TOM) in Soil.

Any other suitable experiment may be added with respect to the syllabus.

## RP-405 Research Project (06 Cr, 180 Hrs)

**See Annexure-II for details (In the end of this document).**

**Note: Study tour is for M.Sc. Part-II: Students to visit Various Industries/academic institutes in India.**

# Shivaji University Kolhapur

## Syllabus as per NEP-2020

**For**

**M. Sc. Part- II Applied Chemistry**

**Semester III & IV**

## Under the Faculty of Science and Technology

**To be implemented with effect from Academic Year 2026-2027**

This is applicable for University Department only

# M. Sc. Part II- APPLIED CHEMISTRY

M.Sc. Course in Applied Chemistry is a potential base provided by the Shivaji University, Kolhapur on University campus to educate and prepare post graduate students from rural and urban area who will get employment on large scale in academic institutes, R & D and Quality control laboratories of Indian chemical/pharmaceutical industries as well as multinational and forensic Laboratories. The M.Sc. course in Applied Chemistry aims to provide students with broad theoretical and applied background in all specialization of Chemistry with emphasis on analytical techniques. Particular attention is given to industrial applications of applied & advanced knowledge of Chemistry so that students are completely equipped to move into careers in academic, research, industrial and commercial organizations.

The M. Sc. course in Applied Chemistry is providing broad common frame work of syllabus to expose our young graduates to the recent and applied knowledge of interdisciplinary branches of chemistry involving applied organic, inorganic, physical, analytical, industrial, pharmaceutical, polymer, nanoscience & technology. The laboratory course particularly emphasis on green chemistry approach elaborating the need for waste minimization, substitution of nontoxic chemicals and increasing the use of microscope and computational techniques. The laboratory courses are designed to provide an exhaustive and hands on working with various modern instruments. Final Semester is dedicated to project work giving students experience in solving real life problem under the supervision of faculty members involved in pursuing research and development projects usually related to industrial problem. Employment potential of the course: To provide properly qualified manpower for academic institutions R & D and QC laboratories of Indian chemical/pharmaceutical industries research organizations and forensic laboratories. M.Sc. course in Applied Chemistry can be helpful to the students to be self-employed as it not only allows for an in-depth subject specific knowledge and opportunities to specializing in number of areas at the leading edge of the subject but also encourage students to develop problem solving and reflective working practices.

## Programme Educational Objectives (PEOs):

**PEO 1:** Applied Chemistry students are well prepared for successful careers in professions such as research & innovation in industry/government organizations related to Industrial domains.

**PEO 2:** Students will be academically prepared to provide feasible and sustainable solutions for real-life problems and become licensed professional chemists in due course and will contribute effectively in serving the society.

**PEO 3:** Students will be engaged in professional activities to enhance their own achievement and simultaneously contribute in service of humankind.

**PEO 4:** Students will be successful in higher education related with industrial domain of Chemistry and management, if persuade.

**PEO 5:** Students nurtured with multidisciplinary knowledge will be a successful leader with quality to handle all kind of diverse circumstances.

## Programme Outcomes (POs)

**PO 1:** Students will have a thorough knowledge in the fundamentals and application of modern chemical and scientific theories including those in all branches of Chemical sciences.

**PO 2:** Students will be able to design and carry out scientific experiments as well as accurately record and analyze the results of such experiments.

**PO 3:** Students will be able to use the evidence based comparative chemistry approach for organic, inorganic synthesis and analysis of the chemical compounds.

**PO 4:** Students will be skilled in problem solving, critical thinking and analytical reasoning as applied to scientific problems.

**PO 5:** Applied Chemistry Students will be able to clearly communicate the results of scientific task in oral and written formats. Students will be able to function as a member of an interdisciplinary problem-solving team.

**PO 6:** Students will be able to explain the role of Applied Chemistry for addressing social, economic, and environmental problems.

## Programme Specific Outcomes (PSOs)

**PSO 1:** This course will be able to get global level research opportunities to students to pursue Ph.D. programme, targeted approach of competitive exams such as, CSIR –NET/GATE/SET, Personality Development Programs, discipline specific competitive exams conducted by service commission, etc.

**PSO 2:** The students will be able to get employment opportunities in various chemical pharmaceutical, paint and dye industries.

**PSO 3:** Understands the background of Inorganic reaction and organic reaction mechanisms and instrumental methods of chemical analysis, separation techniques and analytical methods of general purpose.

**PSO 4:** To gains complete knowledge about all fundamental aspects Inorganic, Organic, Physical and Analytical Chemistry.

# Course Structure: M.Sc. II Applied Chemistry

## Semester III

**Mandatory courses**

| Course Code | Course Title | Credits |
|---|---|---|
| Paper-VII APCHT301 | Applied Inorganic Chemistry–I | 4 |
| Paper-VIII APCHT302 | Advanced Organic Chemistry–I | 4 |
| APCHP304 | Practical-V | 4 |
| APCHP305 | Practical-VI | 2 |
| RP-306 | Research Project | 4 |

**Elective Courses (Choose any one)**

| Course Code | Course Title | Credits |
|---|---|---|
| Paper-XI E- APCHT 303 (A) | Applied Organic Chemistry-I | 4 |
| Paper-XI E- APCHT 303 (B) | Applied Physical Chemistry–I | 4 |
| Paper-XI E- APCHT 303 (C) | Applied Analytical Chemistry | 4 |
| Paper-XI E- APCHT 303 (D) | Bioorganic Chemistry | 4 |

## Semester IV

**Mandatory Courses**

| Course Code | Course Title | Credits |
|---|---|---|
| Paper-X APCHT401 | Applied Inorganic Chemistry–II | 4 |
| Paper-XI APCHT402 | Advanced Organic Chemistry–II | 4 |
| APCHP404 | Practical-VII | 4 |
| RP-405 | Research Project | 6 |

**Elective courses (Choose any one)**

| Course Code | Course Title | Credits |
|---|---|---|
| Paper-XII E- APCHT 403 (A) | Applied Organic Chemistry–II | 4 |
| Paper-XII E- APCHT 403 (B) | Inorganic Chemical Industries | 4 |
| Paper-XII E- APCHT 403 (C) | Pollution Monitoring and Control | 4 |
| Paper-XII E- APCHT 403 (D) | Chemical Engineering in Applied Chemistry | 4 |

## M.Sc. Part-II (SEM- III): APPLIED CHEMISTRY

### Detailed Syllabus:

**MANDATORY PAPERS**

### Paper-VII, APCHT 301: Applied Inorganic Chemistry – I

**Course Outcomes (COs):**

| | |
|---|---|
| CO1 | To understand basic facts and concepts in Electronic and Magnetic Properties of Transition Metal Complexes and its applications. |
| CO2 | To be familiarized with the emerging areas of emergence of nanotechnology and their applications in Applied Inorganic Chemistry. |
| CO3 | To understand basic concepts and its classifications in Nanotechnologies used in Applied Inorganic Chemistry. |
| CO4 | Student will be able to understand the theory of transition metal Complexes and nanotechnology. |

**UNIT I: Electronic Properties of Transition Metal Complexes 15 hrs.**

Energy terms, states, microstates, splitting of terms in weak octahedral and weak tetrahedral ligand field, spin selection rule, Laporte selection rule, relaxation of selection rule, band intensities and band widths, Orgel diagrams of $d^n$- configurations in octahedral and tetrahedral environments, Tanabe-Sugano diagrams($d^2$ and $d^3$configuration), calculation of Dq, B and β values, adjusted crystal field theory, MO diagrams for octahedral and tetrahedral complexes (with and without π-bonding), charge-transfer spectra, spectral properties of lanthanides and actinides.

**UNIT II: Magnetic Properties of Transition Metal Complexes 15 hrs.**

Origin of magnetism, types of magnetic behavior, energy terms, splitting of terms in weak octahedral and weak tetrahedral ligand field, magnetic behavior of transition metal complexes: valence bond approach and crystal field approach, quenching of orbital angular momentum, temperature-dependent magnetism, measurement of magnetic susceptibility using Gouy and Faraday methods, magnetic properties of lanthanides and actinides.

**UNIT III: Reaction of Transition Metal Complexes 15 hrs.**

Labile and inert complexes, ligand substitution reactions: nucleophilic substitution ($S_N1$and $S_N2$, dissociative and associative mechanism), electron transfer reactions (redox reactions): outer sphere and inner sphere mechanism, two electron transfers mechanism, reactions of coordinated ligands, isomerization reactions: isomerization involving geometrical isomers.

**UNIT IV: Nanoscience and Nanotechnology** **15 hrs.**

Introduction to nanoscience and nanomaterials and emergence of nanotechnology; Moore's law, classification of nanomaterials, 1D, 2D, 3D with their examples, experimental methods for preparation of nanomaterials: chemical and physical, synthesis of nanoparticles of gold, rhodium, silica, palladium, platinum, and silver; size dependent properties of nanoparticles: optical properties, M.P., surface to volume ratio, carbon: fullerenes and nanotubes, applications of nanotechnology and nanomaterials: nanobiotechnology, nanosensors, nanomedicines (drug delivery and diagnosis), nanophotonics, environmental remediation etc., implications of nanotechnology.

## Reference Books:


1. Cotton and Willkinsons - Advanced Inorganic Chemistry
2. J. D. Lee - Concise Inorganic Chemistry
3. Puri, Sharma and Kalia - Principles of Inorganic Chemistry
4. R. Gopalan and V. Ramalingam - Concise Coordination Chemistry
5. Asim K. Das and Madhu Das - Fundamental Concepts of Inorganic Chemistry, (Vol.5)
6. G. S. Manku- Theoretical Principles of Inorganic Chemistry
7. Datta and Shymal - Elements of Magnetochemistry
8. Alen Sharp - Inorganic Chemistry
9. Sulbha Kulkarni- Nanotechnology: Principles and Practice
10. J. Schulte - Nanotechnology: Global Strategies, Industry Trends and Applications

## Paper VIII, APCHT 302: Advanced Organic Chemistry-I

**Course Outcomes (COs):**

CO1 To get a brief idea about promising branches in chemistry like UV & IR Spectroscopy.

CO2 To understand the NMR Spectroscopy, Mass spectroscopy, Carbon-13 NMR Spectroscopy its applications.

CO3 Students would acquire the knowledge about, to learn the principles, spectroscopic problems and its applications of various spectroscopic techniques.

CO4 To know the basic aspects and idea of the spectroscopy.

**Unit I: UV and IR Spectroscopy** **15 hrs.**

UV: Introduction, principle, Woodward- Fisher rules for conjugated dines and carbonyl compounds, calculation of λmax, steric effect in biphenyls.

IR: Introduction, principle, characteristic vibrational frequencies of alkanes, alkenes, alkynes, aromatic compounds, alcohols, ethers, phenols and amines, detailed study of vibrational frequencies of carbonyl compounds (ketones, aldehydes, esters, amides, acids, anhydrides, lactones, lactams and conjugated carbonyl compounds), effect of hydrogen bonding and solvent effect on vibrational frequencies, overtones, combination bands and Fermi resonance, FT-IR of gaseous, solids and polymeric materials.

**Unit II: NMR Spectroscopy:** **15 hrs.**

General introduction and principle, definition, chemical shift, anisotropic effects and coupling constants in organic compounds, spin–spin interaction in typical systems ,analysis of 1storder spectra, simplification methods for complex spectra, use of high field NMR, shift reagents, chemical exchange and double resonance, introduction of FT that's pulse NMR NOE, DEPT and 2DNMR, Karplus curve variation of coupling constant with dihedral angle ,simplification of complex spectra, shift reagent, solvent effect, Fourier transform technique, nuclear overhauser effect (NOE).

**Unit III: Mass Spectroscopy** **15 hrs.**

Introduction and principle, ion production methods: EI, CI, and FAB, electrospray and MALDI,magnetic, TOF, quandrupole and ion cyclotron mass analyzers, MS technique,characteristic EIMS fragmentation modes and MS rearrangements.

**Unit IV: Carbon-13 NMR Spectroscopy and Structural problems 15 hrs.**

General considerations; chemical shift (aliphatic, olefinic, alkyne, aromatic, heteroaromatic and carbonyl compounds); problems associated with 13C, FT-NMR, proton decoupled off resonance, structural problems based on UV, IR, NMR, Mass and carbon-13 NMR spectroscopy.

**References:**


1. V. M. Parikh - Application spectroscopy of organic molecules (Mehta)
2. D.H. Williams and Fleming - Spectroscopic methods of organic compound.
3. Silverstein and Basslar - Spectroscopic identification of organic compounds.
4. V.M.Parikh -Aborptionspectroscipy of organic molecules (J. Wiley)
5. P.S. Kalsi - Spectroscope of organic compounds (New Age Publisher)
6. Jackman and Sterneil - Application of NMR spectroscopy
7. J.D. Roberts - Nuclear magnetic resonance. (J. Wiley)
8. Jafee and Orchin -Theory and application of U.V.
9. K. Benjamin - Mass spectroscopy.
10. Beynon J. H. -The mass spectra of organic molecules.
11. Wehli F.W, Marchand A. P. - Interpretation of carbon 13 NMR ( J. Wiley )
12. W. Kemp - Organic Spectroscopy, ELBS
13. Das and Jame -Mass Spectroscopy.
14. J. B. Lambert, S. Gronert, H. F. Shurvell, D. Lightneli, R. G. Cooks - Organic structural spectroscopy ( Prentice Hall 2nd edition)

## Elective Papers (Choose any One)

## Paper IX, E- APCHT 303 (A): Applied Organic Chemistry – I

**Course Outcomes (COs):**

| | |
|---|---|
| CO1 | To impart the students a thorough knowledge about the mechanisms of several organic reactions of some selected functional groups in organic compounds. |
| CO2 | To understand concept of Applied organic chemistry in various spheres of chemical sciences. |
| CO3 | To give an elementary idea of organic reactions, molecular orbital theory, free radical reactions and organic synthesis in Applied Organic Chemistry. |
| CO4 | Students would acquire the knowledge about the Various types of Organic reactions. |

**Unit I: Molecular Orbital Theory** **15 hrs.**

Introduction, aromaticity in benzonoids, alternant and non-alternant hydrocarbon, Huckels rule, energy level of pi molecular orbital and the concept of aromaticity, calculation of energies of orbitals in cyclic and acyclic systems and the stabilities of different systems. Calculation of charge densities, 'PMO' theory and reactivity index.

**Unit II: Organic Synthesis** **15 hrs.**

Wolff rearrangement, Sommelet-Hauser rearrangement, Stevens's rearrangement, Smiles rearrangement, Robinson ring annulations reaction, Simmon-Smith reaction, McMurry reaction, Heck reaction and Vilsmeier-Haack reaction.

**Unit III: Organic Photochemistry** **15 hrs.**

Introduction, photochemical processes. energy transfer, sensitization and quenching. singlet and triplet states and their reactivity, photoreaction of carbonyl compounds, enes, dienes, and arenes, Norrish reactions of acyclic ketones. Patterno-Buchi, Barton, photo-Fries and Di- Pi methane rearrangement reactions. photoreactions of vitamin-D. Photochemistry of vision and photosynthesis, singlet oxygen generation and reactions, applications of photoreactions and their applications for industrial synthesis.

**Unit IV: Free radical reactions** **15 hrs.**

Introduction, types of free radical reactions, detection by ESR, free radical substitution mechanism, mechanism at an aromatic substrate, neighbouring group assistance. Reactivity for aliphatic and aromatic substrates at a bridge-head, reactivity in attacking radicals, the effect of solvent on reactivity, allylic hydrogenation (NBS), oxidation of aldehydes to carboxylic acids, auto-oxidation, coupling of alkynes and arylation of aromatic compounds by diazonium salt, Sandmeyers reaction. Hunsdiecker reaction.

**Reference Books:**


1. J. March - Advanced Organic Chemistry, Wiley
2. R. O. C. Norman and A. Coxon - Modern Synthetic Reactions (Chapman and Hall)
3. M. B. Smith - Organic synthesis (McGraw-Hill)
4. Clayden, Greeves, WarrenandWoothevs - Organic Chemistry
5. R. K. Bansal - Synthetic application in organic chemistry (Narosa)
6. Peter Sykes - A Guide Book to Mechanism in Organic Chemistry (Orient-Longmans)
7. Benjomin R. Breslow - Organic Reaction Mechanism
8. B. S. Gould - Mechanism and Structure in Organic Chemistry
9. Hendrikson, Cram and Hammond - Organic Chemistry
10. J. D. Roberts and M. C. Caeserio - Basic Principles of Organic Chemistry
11. N. S. Issacs - Reactive Intermediates in Organic Chemistry (J. Wiley)
12. R. K. Bansal - Organic Reaction Mechanism (McGraw Hill)
13. K. K. Rohtgi-Mukherji - Fundamentals of Photochemistry (Wiley-Eastern)
14. J. Kagan - Organic Photochemistry (Academic press)
15. J. M. Coxon and B. Holton - Organic photochemistry (Cambridge University Press)
16. A. Gilbert and J. Baggott - Essentials of molecular Photochemistry (Blackwell Scientific publication)
17. N. J. Urro and W. A. Benjamin - Molecular photochemistry
18. Cox and T. Camp - Introductory photochemistry (McGraw-Hill)
19. R. P. Kundall and A. Gilbert – Photochemistry (Thomson Nelson)

## Paper IX, E- APCHT 303 (B): Applied Physical Chemistry-I

**Course Outcomes (COs):**

CO1 This paper will provide an insight into some of the fundamental concepts in Equilibrium Properties of Electrolytes specifically Debye – Huckel Onsagar equation, Bjerrum Theory, Debye – Falkenhagen effect, Wein effect.

CO2 To get an overview of principle and applications of catalysis and mechanism of selected reactions such as, hydrogenation, dehydrogenation olefin hydrogenation etc.

CO3 To understand the principle and applications of fuel cell and corrosion.

CO4 Students will be able to analyze and simulate the performance of different type of fuel cells.

**Unit I: Equilibrium Properties of Electrolytes 15 hrs.**

Non-ideal behavior of electrolyte solutions, Debye – Huckeltheory of inter-ionic attraction, ionic atmosphere, time of relaxation, relaxation and electrophoretic effects, Debye – Huckel-Onsagar equation, validity of Debye – Huckel equation, Debye – Falkenhagen effect, Wein effect, Debye - Huckel limiting law equation, ionic mobility, determination of dissociation constant by EMF method, experimental determination of ionic mobility, osmotic coefficient, Bjerrum theory, association constant, numerical problems

**Unit II: Catalysis: Principles and Applications 15 hrs.**

Basic principles of catalysis, adsorption isotherms, surface area pore size and acid strength measurement (TPD, pyridine IR acid base titration), Enthalpy and entropy of adsorption, interpretation of chemisorptions based on the structure and the nature of the solid – solid state theories – role of defects in catalysis, selection, preparation and evaluation of catalysts – test reaction, promoters, carriers and stabilizers, mechanism of selected reactions, hydrogenation and dehydrogenation reaction– dehydration of alcohols, olefin hydrogenation, decomposition of nitrous oxide, oxidation of CO- etonization of carboxylic acids, cracking of hydrocarbons.

**UNIT III: Fuel cell and Corrosion 15 hrs.**

Fuel cell: Introduction, types of fuel cell, Hydrogen – oxygen fuel cells, hydrocarbon - air fuel cell, alkaline fuel cells, phosphoric acid fuel cell (PAFC), proton exchange membrane fuel cells (PEMFC), solid oxide fuel cells, molten carbonate fuel cell (MCFC), solid polymer fuel cell (SPFC), applications of fuel cell.

Corrosion: Introduction, theories of corrosion, comparison between dry and wet corrosion, factors affecting corrosion, prevention of corrosion, corrosion inhibitors, types of corrosion, passivity.

**Unit IV: Nanomaterials** **15 hrs.**

Introduction, Preparations and applications of nanomaterials-Synthesis of nano materials via –gas phase and liquid phase methods, high energy ball milling metal-semiconductor-ceramics and composites- size dependent properties - uniqueness in these properties compared to bulk and microscopic solids– nanomaterials and nanostructures in nature, $TiO_2$, ZnO, $ZrO_2$, Composites and their applications.

## Reference Books:


1. G.W. Castellan - Physical Chemistry (Addision-Lesley Publishing Co.)
2. E. A. Moelwyn Hughes - Physical Chemistry (Pergamon Press)
3. L. C. Chapoy - Recent Advances in Liquid CrystallinePolymers
4. D. R. Crow - The Principles of Electrochemistry -(Chapman and Hall)
5. J.O.M.Bokris and A.K.N. Reddy - Modern Electrochemistry (Plenum Rosatta)
6. A. W. Adamson - Physical Chemistry of Surfaces
7. D. J. Shaw - Introduction to Colloid and Surface Chemistry
8. J. J. Bikermann - Surface Chemistry
9. Gurdeep Raj - Advanced Physical Chemistry (Goel Publishing House, Krishna Prakashan Media (P)Ltd., Meerut
10. Pahari S. - Physical Chemistry (New Central Book Agency (P) Ltd.) Kolkata
11. J.N. Gurtu and A. Gurtu – Advanced Physical Chemistry, $11^{th}$ Edition (Pragati Prakashan)
12. D. N.Bajpai - Advanced Physical Chemistry (S.Chand Publications)
13. Arun Bahl, B S Bahl, G D Tuli - Essentials of Physical Chemistry (S Chand Publication)
14. S H Maron and C F Prutton -Principles of Physical Chemistry
15. B. Viswanathan, S. Sivasanker and A. V. Ramaswamy - Catalysis: Principles and Applications.
16. Introduction to Nanoscience and Nanotechnology, Gabor.L et

## Paper IX, E- APCHT 303(C): Applied Analytical Chemistry– I

**Course Outcomes (COs):**

CO1 Learner will get knowledge of Thermal analysis techniques

CO2 Learner can understand basics and advance methods of chromatography in Analytical Chemistry.

CO3 Learner will gain knowledge of Forensics science in analytical chemistry

CO4 . Learner will understand the basic concept of Analytical Chemistry

**Unit I: Thermal Methods Of Analysis** **15 hrs**

Introduction to thermal methods: Principle, instrumentation, data analysis and applications of thermogravimetric analysis (TGA), differential thermal analysis (DTA), differential scanning calorimetry (DSC), dynamic mechanical analysis (DMA) and thermometric titrations. Thermal analysis of polymers.

**Unit II: Ion Exchange Chromatograph** **15 hrs**

Ion exchange equilibria, breakthrough capacity, inorganic ion exchangers, synthetic ion exchangers, chelating resins and their applications for separation of inorganic and organic compounds.

**Ion Chromatography**: Principle, instrumentation with special reference to separation and suppressor columns, applications.

**Exclusion Chromatography**: Theory, instrumentation and applications of gel permeation chromatography, retention behavior, inorganic molecular sieves, determination of molecular weight of polymers.

**Unit III: Super Critical Fluid Chromatography and Extraction**

Properties of supercritical fluid, Supercritical fluid chromatography: Instrumentation and operating variables, effect of pressure, stationary phases, mobile phases, detectors, comparison with other types of chromatography, Applications, supercritical fluid extraction: Advantages of SFE, instrumentation, of line and on line extraction, applications.

**Unit IV: Analytical Toxicology** **15 hrs**

Isolation, identification and determination of: Narcotics: Heroin, morphine and cocaine, Stimulants: Amphetamines and caffeine, Depressants: Benzodiazepines, Barbiturates and Mandrax, Hallucinogens: LSD and Cannabis, Metabolites of drugs in blood and urine of addicts, Viscera, stomach wash, vomit and postmortem blood for poisons like– cyanide, arsenic, mercury, insecticides and pesticides.

**References:**


1. M. C. Day and j. Selbin, "Theoretical Inorganic Chemistry", Affiliated East-West Press
2. F. A. Cotton and G. Wilkinson, "Advanced Inorganic Chemistry, John Wiley &Sons
3. J. E. Huheey, "Inorganic Chemistry – Principles of Structure and Reactivity", Harper Collins College Publishers.
4. A. I. Vogel, "A Text Book of Quantitative Inorganic Analysis" ,Longman
5. D. A. Skoog, D. M. West and F. J. Holler, "Fundamentals of Analytical chemistry", Saunders College Publishing.
6. W. W. Wendlandt, "Thermal Methods of Analysis", John Wiley &Sons
7. Injection Moulds & Moulding, J.B Dym, Van Ronstrandt-Reinhold, NewYork, 1980.
8. Thermal Methods of analysis, principles, applications and problems, P. J. Haines, SpringerScience Business Media B.V. 1st Ed.
9. . Principles of Thermal Analysis and Calorimetry, P. J. Haines, Royal Society of Chemistry
10. Principles and Applications of Thermal Analysis, Paul Gabbott, Blackwell Publishing Ltd. (2008).
11. Thermal Analysis in Practice, Fundamental Aspects, Matthias Wagner, Hanser Publications, 2018.
12. Forensic Chemistry, Suzanne Bell, Third Ed. Taylor and Francis
13. Clarke's Analytical Forensic Toxicology, Edited by Adam Negrusz, Gail AA Cooper, Pharmaceutical Press, UK, 2013

## Paper IX, E- APCHT 303 (D): Bioorganic Chemistry-I

**Course Outcomes (COs):**

| | |
|---|---|
| CO1 | Students will be able to describe the structures of key biomolecules like carbohydrates, proteins, and nucleic acids, and relate their structures to their functions and properties. |
| CO2 | Students will gain an understanding of metabolic pathways, such as those involved in glucose and amino acid metabolism. |
| CO3 | Students can explain fundamental chemical mechanisms of reactions relevant to biochemistry, including oxidation, reduction, and phosphorylation. |
| CO4 | Students will learn about the roles of metals and ligands in biological systems, including mechanisms of organometallic poisoning and the use of organometallic compounds in medicine. |

**UNIT I: Cell structure and metabolism** **15 hrs**

Prokaryotic and eukaryotic cells; Intracellular organelles and their functions; Comparison of plant and animal cells; Metabolic processes – catabolism and anabolism; ATP currency of biological energy; Energy-rich and energy-poor phosphates.

**Carbohydrates**

Structure and function of sugar derivatives (deoxy, amino, branched chain sugars); Polysaccharides of biological importance, dextran, sialic acid; Cell-cell recognition and blood group substances.

**UNIT II: Metabolic Reactions** **15 hrs**

Fatty acid metabolism: Biological importance of fatty acids and lipids, even chain and odd chain fatty acids, saturated and unsaturated fats, ketone bodies, fatty acid metabolism, calorific value of foods, biological membranes, properties and function of lipid bilayers and liposome. Protein- related transformations: Amino acid degradation (C3, C4, C5 family), urea cycle, uric acid and ammonia formation; Enzymatic hydrolysis of proteins to peptides; Amino acid sequencing; amino acid metabolism (biosynthesis and degradation).

**UNIT III Nucleic Acids** **15 hrs**

Chemical and enzymatic hydrolysis of nucleic acids; Structure and function of mRNA, tRNA, rRNA; Polymorphic nature of DNA, B- and Z-DNA, multi-stranded DNA; DNA sequence determination by chemical and enzymatic methods, Genetic code – origin, salient features, wobble hypothesis; Gene expression – transcription and translation; Gene mutation and carcinogenesis.

**UNIT IV Enzymes and Co-enzymes** **15 hrs**

**(a)** Co-enzyme Chemistry: Cofactors derived from vitamins, coenzymes, prosthetic groups, apo enzymes; Structure & biological function of coenzyme A, thiamine pyrophosphate, pyridoxal phosphate, NAD+, NADP+, FMN, FAD, lipoic acid and vitamin B12; Mechanisms of reactions catalyzed by above co-factors.

**(b)** Enzyme models: Host-guest chemistry, chiral recognition and catalysis, molecular recognition, diometric chemistry, crown ether, cryptates; Cyclodextrins, cyclodextrin-based enzyme models, calixarenes, ionophores, micelles, synthetic enzymes.

**References:**


1. Stryer, L. Biochemistry (4th edn.), W. H. Freeman & Co.(1995).
2. Zubay, S.. Biochemistry, Addison-Wesley (1983).
3. Sindell, R. P. DNA Structure and Function, Academic Press (1994).
4. Saenger, W. Principles of Nucleic Acid Structure, Springer-Verlag (1984).
5. Gringauz, A. Introduction to Medicinal Chemistry: How Drugs Act and John Wiley & Sons (1997).
6. Dugas, H. & Penny, C. Bioorganic Chemistry: A Chemical Approach to Enzyme Action, Springer Verlag(1998).
7. Palmer, T. Understanding Enzymes, Prentice Hall (1995).
8. Price, N. C. & Stevens, L. Fundamentals of Enzymology, Oxford University Press (1989)
9. Trevan, M. D. Immobilized Enzymes: An Introduction and Applications Biotechnology, John Wiley (1980).
10. Fersht, A. & Freeman, W. H. Enzyme Structure and Mechanism, W.H. Freeman, New York(1985).
11. Metzler, D. E. Biochemistry: The Chemical Reactions of Living Cells, Academic Press (2001).

**APCHP304: Practical-V ( 4 Credit, 120 Hrs )**

**(Applied Physical + Applied Inorganic + Applied Organic Chemistry Practical)**

**Course Outcomes (COs):**

| | |
|---|---|
| CO1 | Students will get: Ability in professional sampling and sample treatment before actual analysis |
| CO2 | Ability to treat and evaluate the results of organic compounds. |
| CO3 | Understanding and capability of performing basic chemical processes in a chemical laboratory |
| CO4 | Capability of performing measurements on basic analytical instruments ($p^H$meters, spectrometers, colorimeter, chromatographs, ion-selective electrodes etc.) |

## Applied Physical Chemistry

1. Statistical representation of given experimental data: Estimation of errors in measured and derived properties, reporting data with appropriate significant figures, graphical representation of data with x- and y-error bars.
2. Determination of indicator constant and isobestic point of an indicator.
3. Determination of stoichiometry and instability constant silver ammonia complex.
4. Determination of Thermodynamic Parameters for electrochemical reactions. (To determine ΔG0, ΔH0 and ΔS0 for the formation of 1 mole of cadmium in 1 wt. % amalgam at 25 °C).
5. Determination of equivalent conductance at infinite dilution and dissociation constant for weak acid using Kolharausch Law of independent ionic mobility.
6. pH-metric determination of dissociation constant of carbonic acid.

**(Any other relevant experiments may be added if required)**

## Applied Inorganic Chemistry

**A: Non-instrumentation Practical**

1. Ore Analysis - 2
2. Alloy Analysis - 2
3. Preparation of coordination complexes (four)
4. Ion exchange study of separation of mixtures & estimations
5. Solvent extraction
6. Soil analysis
7. Data analysis
8. Synthesis and Characterization of transition metal nanoparticles

**B: Instrumentation Practical**

1. Spectrophotometry
2. Nephelometry
3. Potentiometry
4. Conductometry
5. Thermal analysis
6. Magnetic properties of transition metal complexes
7. Spectro Fluorimetry
8. pH Metry
9. Polarography
10. Electrogravimetry
11. Nuclear and radiochemistry

(Any other experiments may be added when required

## Applied Organic Chemistry

**A. Qualitative analysis:**

1. Separation, purification and identification of compounds of ternary mixtures. using Semi- microanalysis.
2. Identification of organic mixture on TLC.
3. Extraction of organic compound by organic solvent from the given mixture.
4. Separation of binary mixture by column chromatography.
5. IR spectra to be used for functional group identification.

**B. Two step Preparation**

1. Preparation of m-nitroaniline
2. Preparation of Benzaanilide from benzophenone
3. Preparation of pthalimide
4. Preparation of N-bromosuccinimide.

C. Structure elucidation by using given spectral data.

D. Any other suitable experiment may be added.

**References**:

1. A.I.Vogel, "A Textbook of Quantitative Inorganic Anaysis", Longman
2. Gurudeep Raj, Advanced Practical Inorganic Chemistry, Krishna Prakashan.
3. W.G.Palmer, "Experimental Inorganic Chemistry", Cambridge University Press
4. Shikha Gulathi, J. L. Sharma and ShagunManocha, Practical Inorganic Chemistry, CBS publisher and Distributors.

5. J. B. Yadav, Advanced Practical Physical Chemistry, Krishna Publishers.
6. I.M.Kolthoff, V.J.Elving and Sandell, "Treatise on Analytical Chemistry", Interscience.
7. I.M.Kothoff and Strenger, "Volumetric Analysis", Interscience
8. Fruman and Welcher, "Standard Methods of Inorganic Analysis", Van Nostrand
9. G.Schwarzenback, "Complexomtric Titrations", Interscience
10. D.A.Skoog and D.M.West, "Analytical Chemistry – An Introduction", Reinholdt.
11. R.S.Drago, "Physical Methods in Inorganic Chemistry", Affiliated East-West Press
12. Instrumental Methods for Chemical Analysis-H. Kaur
13. Spectroscopy- B. K. Sharma
14. Instrumental Methods of Analysis-Willard, Merritt, Dean, Settle
15. Nanotechnology: Principles and Practices- Sulbha Kulkarni
16. Principles of Inorganic Chemistry-Puri, Sharma, Kalia
17. Concise Coordination Chemistry-R. Gopalan, V. Ramalingam
18. Elements of Magnetochemistry-Datta and Shymal
19. G.Zhong Cao. Nanostructures and Nanomaterials: Synthesis, Properties and Applications, Imperial College Press (2004).
20. T. Pradeep, Nano The Essentials: Understanding Nanoscience and Nanotechnology.

## APCHP305: Practical-VI (2 Credit, 60 Hrs )
## (Applied Physical + Applied Inorganic + Applied Organic Chemistry Practical)

**Course Outcomes (COs):**

| | |
|---|---|
| CO1 | Students will get: Ability in professional sampling and sample treatment before actual analysis |
| CO2 | Ability to treat and evaluate the results of organic compounds. |
| CO3 | Understanding and capability of performing basic chemical processes in a chemical laboratory |
| CO4 | Capability of performing measurements on basic analytical instruments ($p^H$ meters, spectrometers, colorimeter, chromatographs, ion-selective electrodes etc.) |

## Applied Physical Chemistry

1. Ion exchange study of separation of mixtures & estimations
2. Spectrophotometry
3. Nephelometry
4. Potentiometry
5. Conductometry

6. To determine the dissociation constant of orthophoshoric acid by pH metrically.
7. Determination of order of reaction for iodination of acetone catalyzed by acid with reference t acetone, iodine and acid catalyst.
8. Determination of apparent and partial molar volumes of 1:1 electrolytes in aqueous solutions using pyknometric method of density measurements.
9. To determine equilibrium constant of reaction $KI + I_2 \rightarrow KI_3$ spectrophotometrically
10. Determination of latent heat of fusion of a given solid.

**(Any other relevant experiments may be added if required)**

## Applied Inorganic Chemistry

1. Ore Analysis -3
2. Preparation of coordination compounds (Three) and preparations of mixed metal oxides(two)
3. Ion Exchange chromatography; separation of multicomponent mixtures
4. Solvent extraction
5. Spectrophotometry
6. $P^H$ Metry
7. Conductometry
8. Polarography
9. Electrogravimetry
10. Nuclear and radiochemistry
11. Analysis of vitamin A in food products
12. Estimation of Aspirin
13. Kjeldahl's method of protein estimation in foods and feeds
14. Analysis of Lindane in BHC powder.
15. Determination of pK value of an indicator.
16. Polarographic estimation of traces of Cu, Cd, Ni, Zn and Fe in sample solution.

## Applied Organic Chemistry

1) Preparation of 4-methyl-7-acetoxy coumarin
2) Preparation of 1,2,3,4-Tetrahydro carbazole
3) Preparation of p-ethoxy acetanilide
4). Colorimetry & PH metry experiments
5). Experiment on Hammet equation
6). Structure elucidation by using given spectral data.
7). Any other suitable experiment may be added.

**References:**


1. A. I. Vogel, "A Textbook of Quantitative Inorganic Analysis", Longman
2. Gurudeep Raj, Advanced Practical Inorganic Chemistry, Krishna Prakashan.
3. W. G. Palmer, "Experimental Inorganic Chemistry", Cambridge University Press
4. J. B. Yadav, Advanced Practical Physical Chemistry, Krishna Publishers.

5. I. M. Kolthoff, V. J. Elving and Sandell, “Treatise on Analytical Chemistry”, Interscience.
6. Instrumental Methods for Chemical Analysis-H. Kaur
7. Spectroscopy- B. K. Sharma

## RP-306: Research Project ( 4 Cr, 120 Hrs)

**Course Outcomes (COs):**

| | |
|---|---|
| CO1 | Students will gain a thorough understanding of the research problem, relevant theories, and the chosen research methodology. |
| CO2 | Design and develop appropriate research studies, including appropriate methodologies, sampling techniques, and data collection plans. |
| CO3 | Clearly, comprehensively, and persuasively communicate research results through effective written reports and oral presentations |
| CO4 | Develop skills to effectively manage project timelines and adapt to changing circumstances during research. |

**See Annexure-I for details**.

## M.Sc. Part-II (Sem- IV) Applied Chemistry

### Paper X, APCHT401: Applied Inorganic Chemistry-II

**Course Outcomes (COs):**

CO1 To understand the concept of Infrared and Raman Spectroscopy and its problems

CO2 This course will promote understanding about the microwave spectroscopy.

CO3 Make Students aware of the fine structure of ESR absorption, Hyperfine structure, g values and factors affecting on g values, instrumentation and applications of ESR spectroscopy.

CO4 Understand the principles and applications of Mossbauer spectroscopy.

**Unit I: a) Infrared and Raman Spectroscopy** **15 hrs.**

Molecular vibrations, force constants, diatomic model, simple harmonic oscillator, anharmonic oscillator, Raman spectroscopy, classical and quantum mechanical theory of Raman effect, use of symmetry considerations to determine the number of lines in IR and Raman Spectra: mutual exclusion rule, selection rule in inorganic structure determinations: hydrogen bonding and infrared spectra, metal ligand and related vibrations, applications of Raman and Infrared spectroscopy.

**b) Microwave spectroscopy**

Basic concept, rotation spectra of simple inorganic compounds, classification of molecules, rigid rotor model, effect of isotopic substitution on transition frequencies& intensities non rigid rotor, stark effect nuclear and electron spin interaction and effect of external field. Applications of micro wave spectroscopy.

**Unit II: Electron Spin Resonance Spectroscopy** **15 hrs.**

Principle, fine, hyperfine, super-hyperfine and zero field splitting, ESR of $d^1$ and $d^9$ transition metal ions; g values and factors affecting on g values, instrumentation and applications.

**Mossbaur Spectroscopy:** Introduction, Principles, Mossbaur nuclei, Mossbaur effect, Instrumentation, isomer shift, Quadrapole splitting and hyperfine interactions, applications.

**Unit III: Spectroscopic & Microscopic Characterization techniques of Inorganic Materials** **15 hrs.**

**Spectrometric techniques:** UV-VIS-NIR spectroscopy, Energy dispersive X-ray spectroscopy (EDS), X-ray photoelectron spectroscopy (XPS)

**Microscopic techniques:** Transmission Electron Microscopy [TEM]; High resolution Transmission Microscopy [HRTEM]; Scanning Electron Microscopy [SEM];Scanning Tunneling Microscopy [STM]; Atomic Force Microscopy [AFM]

**Unit IV: Instrumentation for Characterization of Inorganic Materials** **15 hrs.**

a) X-ray Diffraction (XRD)

b) Superconducting Quantum Interface (SQUID) Maganetometry

c) Brunauer-Emmett-Teller Gas Absorption Surface Area Measurement and Pore Structure Analysis (BET Method)

d) Dynamic light scattering (DLS)

## Reference Books:


1. Instrumental Methods for Chemical Analysis-H. Kaur
2. Spectroscopy (Atomic and molecular)- Gurudeep R. Chatwal and Sham K. Anand
3. R. S. Drago, Physical Methods in Chemistry, Saunders College Publishers (1977).
4. Spectroscopy- B. K. Sharma
5. Instrumental Methods of Analysis-Willard, Merritt, Dean, Settle
6. Nanotechnology: Principles and Practices- Sulbha Kulkarni
7. K J Klabunde, Nanoscale materials in Chemistry, Wiley Interscience 2001
8. A R West, Basic Inorganic Chemistry, II Ed, Jhon Wiley & Sons (1999)
9. C. N. Benwell and E. M. Mc Cash, Fundamentals of Molecular Spectroscopy, Tata Mcgraw Hill, New Delhi (2006)

**Paper XI, APCHT402 Advanced Organic Chemistry – II**

## Course Outcomes (COs):

| | |
|---|---|
| CO1 | To develop interest among students in advanced organic chemistry. |
| CO2 | To impart essential theoretical knowledge about aromaticity and some reactions. |
| CO3 | To aware about the idea and knowledge about Kinetic and thermodynamic control of reactions. |
| CO4 | To details study about some oxidation reaction with Cr and Mn compounds and some other types. |

**Unit I: Aromaticity in Non-benzenoid aromatic compounds.** **15 hrs.**

**Non benzenoid aromatic compounds**: Aromaticity in Non- benzenoids compounds Annulenes and heteroannulenes, fullerenes, tropone, tropolone, azulene, fulvene, tropylium salts, ferrocene, three and five membered systems. Crown ether complexes, cyclodextrins, cryptands, catenanes and rotaxanes, bonding in fullerenes.

**Unit II: Applications of following reagents in organic chemistry** **15 hrs**

Oxidation with Cr and Mn Compounds: oxidation of alcohol, aldehyde, C=C, C-H bonds in organic molecules, Pyridiniumchloro chromate (PCC), Oxidation with peracids and other peroxides Prevost and Woodward hydroxylation, cis and trans-hydroxylation, glycol cleavage reagent. $HIO_4$, $Pb(OAc)_4$, mercuric acetate, $SeO_2$, DDQ.

**Unit III: Chemistry of Natural Products** **15 hrs.**

**A) Terpenoids:** Introduction to Natural products, Isolation methods, Hofmann, Emde and Von-Braun degradation. Classification of terpenoids, Structure and synthesis of Abietic acid and Camphor

**B) Alkaloids:** Structure elucidation and synthesis of Papaverine and Quinine.

**C) Prostaglandings:** Nomenclature, structure (not elucidation) and EJ Corey's synthesis of Prostaglandins $PGE_2$, and $PGF2\alpha$.

**Unit IV: Selected Organic Reactions and Reagents** **15 hrs.**

Lithium dimethyl cuprate, Trimethylsilyl iodide, Phase-transfer catalysts. 1,3-dipolar cyclo-addition and chelotropic reactions, sigmatropic rearrangement, supra and antarafacial shifts of H, Sigmatropic shifts involving carbon moieties, (3,3) and (5,5) sigmatropic rearrangement and Claisen and Cope and Aza Cope rearrangement, Ene reaction.

**Reference Books**:


1. L. M. Hardwood, Polar rearrangements, Oxford University
2. J. March, Advanced Organic Chemistry, Wiley
3. S. N. Issacs, Physical Organic Chemistry, Longman
4. P. Y. Bruice, Organic Chemistry, Prentice Hall
5. H. Arora, Organic photochemistry and Pericyclic reactions
6. C. H. Dupuoy, and O. L. Chapman, Molecular reactions and Photochemistry, Prentice Hall
7. J. M. Cozon and B. Holton, Organic Photochemistry, Cambridge University Press
8. S. H. Pine, Organic Chemistry by McGraw-Hill
9. I. L. Finar, Organic Chemistry Vol W, Longman

## Elective papers (Choose any One)

**M.Sc. II, SEM-IV**

**Paper XII, E-APCHT403 (A): Applied Organic Chemistry – II**

**Course Outcomes (COs):**

CO1 Students will understand the concept building blocks of biomacromolecules.

CO2 Students will have an idea regarding Classification, Structure and functions of different bioorganic molecules.

CO3 The students will understand some fundamental aspects of applied organic chemistry.

CO4 Student also will learn mechanism of some organic reactions, classification of pericyclic reactions.

**Unit I: Chemistry of Biopolymers** **15 hrs.**

Amino acids: Introduction and classification, protection and deprotection of N-terminus and C-terminus of amino acids, Peptides and their synthesis. Solid phase peptide synthesis (SPPS) Proteins: Structure and classification, Chemistry of nucleic acid bases A.G.C.T and U and their synthesis, structure of DNA. Structure of starch, cellulose Glycogen and Chitin.

**Unit II: Pericyclic Reactions** **15 hrs.**

Molecular orbital symmetry, Frontier orbitals of ethylene 1, 3butadiene, 1, 3, 5, hexatriene and allyl system, classification of pericyclic reactions, Woodward-Hoffmann correlation diagrams. FMO and PMO approach. Electrocyclic reactions – conrotatory and disrotatory motion, 4n, 4n+2 and allyl systems. Cycloadditions – antarafacial and suprafacialaddition, 4n and 4n+2 systems, 2+2 addition of ketens, 3, 3, dipolar cycloadditions. Sigmatropic rearrangements – Suprafacial and antarafacial shifts of H, sigmatropic shifts involving carbon moieties, 3, 3, and 5, 5 sigmatropic rearrangements. Ene reaction.

**Unit III: Chemistry of Drugs & Pharmaceuticals** **15 hrs.**

**Drugs:** Classification of drugs. Chemotherapeutic and pharmacodynamic agents. Synthesis of any two common drugs from each class of chemotherapeutic agents and pharmacodynamic agents. Scientific aspects in manufacturing process of drugs like Aspirin, Paracetmol, Ibuprofen, Procaine, Isoniazid, Ethambutol, and Meperidine.

**Unit IV: Heterocycles** **15 hrs.**

**Six membered Heterocycles with one heteroatom**: Synthesis and reactions of pyrillium salts and pyrones and their comparison pyridinium and thiopyrylium salts and pyridines. Synthesis and reactions of coumarins, chromones.

**Six membered heterocycles with two and more heterocycles**: Synthesis and reactions of diazines and triazines. Seven membered heterocycles: Synthesis and reactions of azepines, oxepines and thiepines.

**Reference books:**


1. Text book of polymer science, F. W. BillmeyersJr Wiley
2. Polymer science, V. R. Gowarikar, N. V. Vishwanathan and J Shreedhar, Wiley
3. Functional monomers and polymers, K. Takemote, Y. Inkiand R. M. Ottanbrite.
4. Contemporary polymer chemistry, H. R. Alcoek and F. W. Lambe, Practice Hall.
5. H. Arora, Organic Photochemistry and Pericyclic Reactions
6. Lendieer and Mitscher: The organic chemistry of drug synthesis (I. W.)
7. Burger Medicinal Chemistry.
8. A. Kar: Medicinal Chemistry.
9. W. O. Foye: Principles of Medicinal Chemistry.
10. R. M. Acheson : An introduction to chemistry of heterocyclic compounds (Interscience)
11. Joule and Smith: Heterocyclic Chemistry (Van Nostrand).
12. R. K. Bansal: Heterocyclic Chemistry (Wiley E).
13. L. A. Paquitte: Principles of Modern Heterocyclic Chemistry.
14. M. H. Palamer: The structure and reactions of heterocyclic compounds.
15. A. R. Katritzky: Advances in heterocyclic chemistry
16. Finar: Organic Chemistry (Vol. 1 & 2)
17. Cohn and Stumpt: Outline of Biochemistry.
18. Williams: Introduction to the chemistry of enzyme action.
19. The organic chemistry of drug design and drug action, R. B. Silverman Academic press.
20. Strategies for organic drug synthesis and design, D. Lednicer, J. Willey.

**Paper XII, E-APCHT403 (B): Inorganic Chemical Industries**

## Course Outcomes (COs):

| | |
|---|---|
| CO1 | To learn the important aspects in inorganic chemical Industries such as special materials for electronic industry, fertilizer industry |
| CO2 | To understand the concept of glass, ceramics and manufacturing of inorganic heavy chemicals. |
| CO3 | To know the various industrial applications of glass and ceramics and its applications |
| CO4 | To understand the concepts of fertilizers and heavy inorganic chemicals and its industrial applications |

**UNIT I: Special materials for electronic Industry** **15 hrs.**

High purity Silicon, Germanium, Gallium Arsenide (GaAs) Indium phosphide (InP) etc. preparation using Zone refining, Crystal growth and there use in electronic industry. High temperature materials, High alumina, alumina, SiC, Chromite, Zirconia, Magnesite etc. Ionic & Superionic conductors, β-alumina oxide ion conductors, halide conductors superionic, Fastion conductors-RbAg4I5, Arrhenious equation.

**UNIT II: Fertilizer Industries** **15 hrs.**

**General Principles of plant Nutrition**: Essential plant nutrients, functions of the essential elements, classification of commercial nitrogenous fertilizers. Manufacturing of ammonium sulphate, Urea, Ammonia nitrate Commercial phosphatic fertilizers. Manufacturing process and properties of phosphatic fertilizers, single super phosphate and triple superphosphate.

**Commercial potassic fertilizers:**

Chemicals of potassium compounds, classification, manufacturing process and properties of potasium fertilizer, muriate of potassium, potassium sulphate, mixed fertilizer.

**Micronutrients:** Role and deficiency symptom of micronutrients.

**Biofertilizers:** Classification, demands and production, Present status of fertilizer Industries in India

**UNIT III: Glass & Ceramics** **15 hrs.**

Physical and chemical properties of glasses, Raw materials, manufacturing of special glasses. Ceramics and their properties, raw materials, manufacturing of ceramics, Applications of colors to pottery, use of ceramics.

**Industrial Gases**: Manufacturing and industrial uses of $H_2$ $O_2$, $N_2$, $CO_2$, $Cl_2$ & acetylene gases. Liquification of gases, production of low temperature.

**Chemicals of Utility**: Inorganic fine chemicals, magnesia, alumina, $AlCl_3$, $CaCO_3$, $Na_2SiO_3$, $MnO_2$, $FeSO_4$, $PbO_2$ and NaOH.

**UNIT IV: Manufacturing of Inorganic Heavy Chemicals** **15 hrs.**

Introduction to chemical industry: Flow sheet preparation. Principles of process selection and operation selection. Basic raw materials and routes to major inorganic products. Flow sheets and engineering aspects of the manufacture of sulphuric acid, sodium hydroxide, chlorine, ammonia, phosphoric acid, nitric acid and Portland cement.

## References:


1. H. V. Keer, Principles of Solid state.
2. A. R. West, Solid State Chemistry and its applications, John Wiley & Sons, 2003.
3. B. K. Sharma, Engineering chemistry, Krishna Prakashan Media.
4. Lowenheim F A (1978) Electroplating MC Graw-Hill Book Company.
5. Gable, D: Principal of metal Treatment and protection. Pergaman, Press Oxford(1978)
6. G.A. Keneth: Electroplating for Engineering's A Hand Book
   IIIrdEdn Van NastradReinbold Co London
7. F A Lowinbein: Modern Electroplating, Electroplating Publication New Jersey
8. Burke, Progess in ceramic science Vol. IV
9. R. R. Iash: afromulary of paints and other coating Vol. I
10. Industrial chemistry, B. K. Sharma.
11. Engineering chemistry, B. K. Sharma.
12. S. D. Shukla & G N Pandey: A text book of chemical technology Vol. 1
13. F A. Henglein: Chemical Technology (Pergamon)
14. D. Patranabis, Sensors and Transdusers, 2nd Edn, Prentice, Hall of India (2003).
15. RajankumarBasak, Fertilizers, A text Book
16. R. Balsubramaniam, Materials Science and Engineering

**Paper XII E-APCHT403 (C): Pollution Monitoring and Control**

## Course Outcome (COs):

| | |
|---|---|
| CO1 | To learn identify monitoring criteria for various pollutants which would help in planning a monitoring programme |
| CO2 | To learn Process, analyze, and interpret environmental data, including using statistical methods for time series and spatial analysis. |
| CO3 | Understand and use various instruments for monitoring air, water, radiation, and noise pollution |
| CO4 | Formulate plan for monitoring of various environmental pollutants |

**Unit I: Pollution and its Control** **15 hrs**

Air pollution: Composition of air. Classification of pollutants. Sources of air pollutants. Industrial pollution: Power plants. Fertilizers. Petrochemicals. Automobile pollution. Water pollution: Water quality criteria for domestic and industrial uses. Analysis of water and waste water. Principles of water and waste water treatments. Removal of organics and harmful inorganic from water and waste water. Biological treatment of wastewater: Theory and practice. Sludge treatment and disposal.

**Unit II: a] Removal of Heavy Toxic Metals** **15 hrs**

Chromium, Mercury, Lead, Cadmium, Arsenic analytical methods of determination of small amounts of the metal pollutants, copper recovery,

Treatment of waste to remove heavy metals, Recovery techniques.

**b] Removal of Particulate Matter:** Particulate matter and dynamics of particles separations, Particulate matter in gas stream, filtering, gravity separation, liquid scrubbing cyclone separations, electrostatic precipitations safety of workers analysis of particulate matter.

**Unit III: Removal of Nuclear Hazardous Materials** **15 hrs**

Sources of Phenolic residues, Analytical methods, treatment by using stream gas stripping, ion – exchange, solvent extraction, oxidation methods, Microbiological treatment. Role of Vapor pressure, role of solubility, effect of pH on solubility, extractive methods of recovery and recycle, Chemical methods of conversion to less soluble nontoxic or biodegradable and products carcinogens.Origin of $SO_2$ and its hazard, Analysis of $SO_2$, $SO_2$ control methods, desulphurization of fuels, Indian cola and Indian Crude oil. Economics of $SO_2$control measures NOx, dissolved NOx, nitrites, ammonia, Urea and other nitrogen containing compounds in the effluents fertilizer explosive, industrial effluents, effluents from nitro aromatic industries.

**Unit IV: a] Biotechnology in Chemical Industry 15 hrs**

Essential elements in biological system Mettallo proteins and mettallo–enzymes. Metal ions as a charge carriers Health effects due to deficiency and excess of metals of non-metals Biotechnology for the production of chiral compounds. Role of biotechnology in Industry.

**b] Polymer Recycling:**

Environmental and polymer Industries. Recycling of polymers waste.

## References:


1. S.P. Mahajan: Pollution control in processes Industries(J.W)
2. P. N. Chennsioff and R. A Young: Air Pollution control and design Hand Book and recovery(J.W)
3. J.R. Holmes: Refuse recycling and recovering(J.W)
4. M. Sitting: Resources recovery and recycling Hand Book and Industrial Wastes (NDS)
5. J.O. Niagh: Sulphur in the Environment Vol. I & II(J.W)
6. P. S. Minor: The Industry/EPA controntation (MGH)
7. R. B. Pojaselc: Toxic and Hazardous waste disposal Vol. I &II(AAS)
8. S. M. Khopkar: environmental pollution analysis
9. A. K. Dey: Environmental Chemistry
10. W.Handley: Industrial safety Handbook

**Paper XII E-APCHT403 (D): Chemical Engineering in Applied Chemistry**

## Course Outcome (COs):

CO1 To learn Analyze and solve complex problems within process and allied industries.

CO2 To understand Manage hazards associated with chemical processes.

CO3 Use modern engineering tools and techniques for chemical engineering practice.

CO4 To learn advances methods of Manufacturing of Inorganic Heavy Chemicals and organic chemicals.

**Unit I: Principle of Chemical Engineering** **15 hrs**

Introduction to chemical engineering. Comparison of academic and industrial Chemistry. Material and energy balances. Units and dimensions, Fluid mechanics. Fluid statistics, Benoulli equation, Flow measurements, pipe fittings and valves. Heat transfer: Steady state heat conduction, unsteady state heat conduction, Heat flow by convection, Heat exchange and evaporators. Distillation: vapor-liquid equilibrium, fractionating column, Comparison of plate columns and packed columns, mass transfer operations, Principles of extraction, leaching and absorption. Chemical reactions: Batch and continuous reactors. Concept of residence time, space time and space velocity.

**Unit II: Polymers** **15 hrs**

Introduction, classification, characteristics and properties of polymers, co-polymerization, and addition polymerization: Free radical and ionic polymerization, Plastics: Thermoplastics, Thermosetting plastics, Elastomers or Rubber, Zeigler-Natta catalysts, condensation polymerization, conducting polymers and its application, importance of bio-polymers.

**Unit III: Manufacturing of Organic Chemicals** **15 hrs**

Raw materials and routes to major organic products. Flow sheets and engineering aspects of the manufacture of important products such as nitrobenzene, linear alkyl enzyme sulphonate, chlorobenzene vinyl chloride, DMT, ethyl acetate, cummene, alkyl benzenes, cyclohexanone, Phallic acid, soaps, detergents and hydogenation of oils. Pharmaceuticals: Manufacturing processes of aspirin, vitamin-A and paracetamol. Pesticides: Manufacture of BHC, DDT, Carbaryl Malathion and Manufacture of dyes.

**Unit IV: Manufacturing of Inorganic Heavy Chemicals 15 hrs**

Introduction to chemical industry: Flow sheet preparation. Principles of process selection and operation selection. Basic raw materials and routes to major inorganic products. Flow sheets and engineering aspects of the manufacture of sulphuric acid, sodium hydroxide, chlorine, ammonia, phosphoric acid, nitric acid, ammonium nitrate, urea, glass, ceramics, refractories and Portland cement.

## References:


1. E. K. Rideal, “Concepts in catalysis”, Academic Press
2. A. Clark, “The Theory of Adsorption and Catalysis”, Academic Press
3. R. Pearce and W. R. Patterson (Eds.), “Catalysis and Chemical Processes.”,Backie and sons
4. J. M. Betty, “Applied Industrial Catalysis”, Academic Press
5. Coulson and Richardson, “Chemical Engineering”, Vol. 1,2, &3
6. McCabe, “Unit Operation of Chemical Engineering”
7. A. Pahari and B. Chauhan, Engineering Chemistry
8. Peter Wiseman, “Industrial Organic Chemistry”
9. N. R. Nerris Shreve, “Chemical Process Industries”
10. Dridens, “Outline of Chemical Technology”
11. B. K. Sharma, “Industrial Chemistry, Goel Publishing House

**APCHP404 (4 Cr): Practical-VII**

## Course Outcomes (COs):

| | |
|---|---|
| CO1 | Learn the principles and operation of instruments such as pH meters, colorimeters, conductometers, and spectrophotometers. |
| CO2 | Students learn to synthesize various inorganic compounds, such as metal complexes and functional materials, with specific properties. |
| CO3 | The practical course helps students identify organic compounds and functional groups through various experimental tests. |
| CO4 | Students will learn to operate modern analytical instruments and interpret the resulting spectra and data. |

**Applied Physical Chemistry Practical**

1. Determination of stability constant of ferric thiocyanate complex.
2. To determine stoichiometry and stability constant of ferric-salicylate complex by Job's Method and mole ratio method spectrophotometrically.
3. Determination of the critical micelle concentrate on of a given surfactant in aqueous and aqueous salt solutions.
4. Determination of isoeletric points and dissociation constants for neutral, acidic and basic amino acids using pH-metric technique.
5. Study of the effect of ionic strength on the reaction between persulphate and iodide by visual method.
6. Indexing X-ray diffractometer pattern of NaCl.
7. To determine pK value of methyl red indicator at room temperature spectrophotometrically.
8. To determine half wave potential of a given ion using half height method, differential method and wave equation method.
9. Characterization of the complexes by electronic and IR spectral data.
10. Determination of unknown concentration of $Cd^{+2}/Zn^{+2}$ ions in the given solution by standard addition method.
11. Estimation of quinine as quinine sulfate from medicinal tablets by fluorimetrically.

**Applied Inorganic Chemistry Practicals**

**A: Non-instrumentation Practicals**

1. Ore Analysis - 2
2. Alloy Analysis - 2
3. Preparation of coordination complexes (four) and preparations of mixed metal oxides (two)
4. Ion exchange study of separation of mixtures & estimations
5. Solvent extraction
6. Soil analysis
7. Data analysis
8. Synthesis and Characterization of transition metal nanoparticles

**B: Instrumentation Practicals**

1. Spectrophotometry
2. Nephelometry
3. Potentiometry
4. Conductometry
5. Thermal analysis
6. Magnetic properties of transition metal complexes
7. Spectro Fluorimetry
8. pH Metry
9. Polarography
10. Electrogravimetry
11. Nuclear and radiochemistry

**C: Interpretation exercises**

1. X-ray powder diffraction analysis of cubic compound
   a. Determination of lattice constants and geometry
   b. Partical Size
   c. Density
2. Interpretation of Mossbaur spectrum with reference to determination of
   a. Isomer shift
   b. Quadruple splitting
   c. Internal magnetic field
   d. general comment
3. Interpretation of IR spectrum with reference to stretching vibration C=N, C=O,

N-, M-O

4. Interpretation of absorption spectra for

a. Verification of position of ligands in spectrochemical series.

b. Determination of gemetry (Octahedral, square planer, tetrahedral) of a given compound.

c. Calculation of spectral splitting parameters.

5. Calculation of band gap of semiconductors with the help of plots of log & vs. 10 3/4.

**Applied Organic Chemistry Practical**

A. Estimation of Sulphur & Nitrogen from organic compound.
B. Two or Three stage preparations starting with 5g or less & TLC.
   1. Preparation of anthranilic acid
   2. Preparatin of p- Amino benzoic acid
   3. Preparation of p- chloro nitrobenzene by Sandmeyer reaction
   4. Preparation of p- Idonitrobenzene by Sandmeyer reaction

**References:**


1. Findlay's Practical Chemistry – Revised by J.A. Kitchner ($V^{th}$ Edition).
2. Text Book of Quantitative inorganic analysis : A.I. Vogel.
3. Practical Physical Chemistry : B. Viswanathan and P.S. Raghavan, 2nd edition, (2012).
4. Systematic Experimental Physical Chemistry :S.W. Rajbhoj and T.K. Chondhekar.
5. Experiments in Physical Chemistry, J.M. Wilson, K.J. Newcombe, A.R. Denko. R.M.W. Richett ( Pergamon Press).
6. Experimental Physical Chemistry by D. P. Shoemaker, Mc. Growhill, 7th Edition, 2003.
7. Experiments in Physical Chemistry by Carl Garland, Joseph Nibler , David Shoemaker 8th Edition, Kindle Edition.
8. Laboratory manual of physical chemistry by H.D. Crockford, J.W. Nowell John Wiley & Sons, INC.


**RP-405: Research Project: See Annexture II**

**NOTE: Study tour is compulsory for M.Sc. Part- II Students in Sem-IV to visit Chemical Industries in India**.

# Annexture-I

## Research Project Paper Guidelines for all specializations

(Inorganic, Organic, Physical, Analytical, Applied and Industrial Chemistry)

### Semester III

**RP-306 Credits= 04, 120 Hours, 100 Marks**

- The students should write a synopsis of proposed research work.
- The students should perform a detailed literature survey related to the research problem.
- The students should design the problem and start experimental work. The students should complete at least 25% of their experimental work during semester III, and the same work should be continued in semester IV.
- **The student should submit a spiral-bound copy of research work (Project) carried out during semester III. It Should include the Title page, certificate, index, synopsis, Literature survey write-up, experimental work and certified progress report. (Single Spiral Bound Copy containing all above-mentioned documents)**
- The Research Project will be examined by internal and external examiners separately during the practical examination at the end of the semester.
- The students should present their work during the evaluation in the form of power point presentation (PPT).
- **Marking Scheme:**

| **Sr. No.** | **Description** | **Marks** | |
|---|---|---|---|
| | | **Internal Evaluation** | **External Evaluation** |
| 1 | Synopsis of proposed research work | 10 | 10 |
| 2 | Literature Survey Write-up | 10 | 10 |
| 4 | Daily Lab notebook record | 10 | -- |
| 5 | Progress of Experimental Work | 10 | 20 |
| 6 | Quality and effectiveness of presentation | -- | 20 |
| | **Total** | **40** | **60** |

**Broad guidelines for preparation of synopsis of proposed research work**

A. The proposed synopsis for research should be self-contained and should cover the rationale for carrying out research.

B. There should not be repetition of the work or topic or theme.

C. The synopsis of the proposed research shall contain the following points:

1. Title of the Research Proposal
2. Motivation with reasoning and significance of the proposed research
3. Statement of the problem
4. Review of the relevant literature
5. Objectives of the study
6. The methodology comprising

a. Methods of research

b. Sampling design and assumptions

c. Conceptual framework if any

d. Research design (explanation of how research is being conducted and the tools used for the same)

e. Methods of data collection

f. Methods of data analysis (use of parametric and non-parametric tools and techniques as the case may be)

7. Expected outcome
8. Bibliography.

**Marking Scheme (University Examination):**

Internal Evaluation = 40 Marks (At College/Department level)

External Evaluation= 60 Marks (by External Examiners- At the time of Practical Examination)

# Annexture II

## Research Project Paper Guidelines for all specializations

(Inorganic, Organic, Physical, Analytical, Applied and Industrial Chemistry)

**Semester IV**

**RP-405, Credits= 06, 180 Hours, 150 Marks**

- The student should submit the **final hardbound dissertation** copy of research work carried out during semesters III and IV.
- **It Should include a title page, certificate, declaration, acknowledgement, abbreviations, index, Synopsis of proposed research work, Literature Survey write-up, abstract, introduction, experimental section, results and discussion, conclusions, references, participation in conferences/seminars and publications if any and certified progress report. (Single hardbound Copy containing all the above mentioned documents)**
- The final project should not be less than **25 pages** and contain a minimum of **3000-4000 words.**
- The students should present their work during the evaluation in the form of power point presentation (PPT).

- **Marking Scheme:**

| **Sr. No.** | **Description** | **Marks (150)** | |
|---|---|---|---|
| | | **Internal Evaluation (60)** | **External Evaluation (90)** |
| 1 | Dissertation **hardbound** copy | 10 | 10 |
| 2 | Daily Lab notebook record | 10 | -- |
| 3 | Quality of Experimental work, Overall progress (originality, methodology and depth of analysis, presentation of data and writing style, conclusions and implications) | 30 | 30 |
| 3 | Presentation of work at conference/workshop/poster competitions/Avishkar/National Science Day in offline mode only (Oral/Poster)-2 activities | 10 | 10 |
| 4 | Final Dissertation/thesis defence (technical content, communication skill, ability to explain the work, subject knowledge and answering questions, presentation quality, effective use of visual aids) | -- | 40 |
| | **Total** | **60** | **90** |

**Note:**

The project can be completed individually or by a group of three students (Maximum).

**(Not more than three students are allowed)**

**Marking Scheme (University Examination):**

Internal Evaluation = 60 Marks (At College/Department level)

External Evaluation= 90 Marks (by External Examiners- At the time of Practical Examination)