

University of Mumbai



DEPARTMENT OF CHEMISTRY

(AUTONOMOUS)

INFORMATION BROCHURE

FOR M. Sc. AND Ph. D. DEGREE PROGRAMMES
IN CHEMISTRY

DEPARTMENT OF CHEMISTRY

UNIVERSITY OF MUMBAI

VIDYANAGARI

SANTACRUZ (E)

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2023-2024

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DEPARTMENT OF CHEMISTRY (AUTONOMOUS)

1. A PROFILE

The University Department of Chemistry, University of Mumbai, established in the year 1967, conducts Choice Based Credit System (CBCS) 4-SEMESTER- courses in Physical, Inorganic, Organic and Analytical Chemistry, leading to the award of M. Sc. degree of the Department of Chemistry, University of Mumbai. In addition, it also conducts program leading to Ph. D. degree. The Department is a recipient of DST-FIST and UGC-SAP grants. The Department has been conferred autonomous status from the academic year 2009-10.

Since inception of the department, over 2000 students have taken their Master's degree by papers; more than 250 students have been awarded doctorates, and more than 150 students have taken their M. Sc. Degree by research. Under the M. Phil. programme, 50 teachers from affiliated colleges have received their degrees. After autonomy of the department, over 381 students have taken their Master's degree by papers; more than 93 students have been awarded doctorates, and more than 16 students have taken their M. Sc. Degree by research. It is indeed a pleasure to report that alumni of the department are holding key positions in the industry and academic institutions.

The Department is actively engaged in organizing Refresher Courses for college teachers sponsored by U.G.C. and the State Government. It also conducts workshops for teachers for effective, smooth teaching and uniformity in the implementation of the revised syllabi from time to time. The Department has organized several National and International conferences. In addition, the Department along with other reputed institutes and registered societies jointly organizes lectures, workshops and research scholars' meet, science day etc. for the benefit of teachers and students. The Department also offers consultancy services to the industry, whenever solicited.

A Post-graduate institution is judged not only by maintenance of high teaching standards, but also by its focus on research activity. Though plagued by problems of infrastructure in terms of senior academic positions, the Department has consistently endeavored to raise its standards. The Department runs projects received from the various national funding agencies such as UGC, DST, CSIR, DAE etc. and also from the Industries. It is heartening to point out that members of the faculty have been receiving appreciative comments on their research articles/reviews in standard journals.

2. LOCATION

The Department is housed in Lokmanya Tilak Bhavan and the ground floor of Sant Dnyaneshwar Bhavan in the Vidyanagari campus of the University of Mumbai. The Vidyanagari Campus is accessible from both the Central Railway (Kurla) and Western Railway (Santacruz) by the BEST Bus routes. The bus route Nos. 313 and 318 plying between Santacruz (East) and Kurla (West) pass via Vidyanagari. Additionally route Nos. 37 (between Kurla & J. M. Mehta Marg), 181 (between Seepz-Wadala), 213 (between Santacruz - Pr. Thakre Udyan), 306 (between Santacruz - Mulund), 312 (between Seepz & Pratiksha Nagar),

374 (between Goregaon-East & Anushakti Nagar), 449 (between Dharavi Depot & Kandivali Bus St.-East) pass via Vidyanagari.

3. LABORATORY FACILITIES FOR PAPER AND RESEARCH STUDENTS

There are four M. Sc. Paper Laboratories well equipped with the necessary instruments/infrastructure to perform experiments in Analytical, Inorganic, Organic, and Physical Chemistry.

All the research students are comfortably accommodated in the various research laboratories.

There is a computer laboratory equipped with twelve computers with an internet connection.

The Department is well equipped with the necessary infrastructure and sophisticated instruments. A 300 MHz NMR and CHN analyzer have been procured through the DST-FIST program. GC-MS instrument has been procured through UGC-SAP program. In addition, the department has FTIR, UV-Visible spectrophotometers, Spectrofluorimeter, HPLC, GC, Digital Polarimeter, Ion meters, Electro-chemical workstations, CVD, Catalytic Hydrogenator, Microwave Oven, Auto-titrator, Ultrasonic reactors, TG/DTA, AAS, GPC, and XRD. The department has also acquired new technological devices such as an Audio-Visual system, LCD Projector, E-Beam System, Media Imager, and Visual Presenter. Internet access is provided to the staff and research as well as paper students.

The Department has a seminar room with a seating capacity of 60.

4. LIBRARY

The Department has its own library on the ground floor of Sant Dnyaneshwar Bhavan. In addition, Jawaharlal Nehru Library, which is a central library at the Vidyanagari campus, is well equipped with books, journals, periodicals and Encyclopedias of Chemistry. There is a separate facility for carrying out literature survey. The students enrolled in the Department can avail of reading as well as lending facilities.

5. HOSTEL ACCOMODATION FOR STUDENTS

Six rooms in Boy's hostel and Eight in Girl's hostel are reserved for the Department students. These hostel rooms are allotted as per the University rules.

6. FINANCIAL ASSISTANCE

A) M. Sc. By Papers : As per the rules of University of Mumbai and Government on merit basis (if applicable)

B) Ph. D. : Nil

7. FACULTY OF THE DEPARTMENT

[1] Name: Dr. Shivram S. Garje



● **Designation:** Professor and Head

PAPERS PUBLISHED:	66	Ph. D STUDENTS UNDER GUIDANCE:	03
M.Sc (BY RESEARCH) STUDENTS GUIDED:	05	RESEARCH PROJECTS:	03
Ph. D STUDENTS GUIDED:	10	Patents	Granted-02 Published-01
POSTDOC.	02	BOOK CHAPTER	01

● **Key Awards/Honors:**

- “**BOYSCAST Fellowship**”, Department of Science and Technology, Government of India (2004)
- “**Performance Based Incentive Award**”, University of Mumbai (2008)

● **Research interests:**

- Synthesis of novel molecular precursors for the preparation of nanomaterials, nanocomposites and thin films.
- Applications of nanomaterials for environmental remediation and as nanocatalysts, photocatalysts and electrode materials for energy storage devices.

Key Publications

1. One pot solvothermal synthesis of bimetallic copper iron sulfide (CuFeS₂) and its use as electrode material in supercapacitor applications
A. Ansari, R. A. Badhe, D. G. Babar and S. S. Garje, Appl. Surf. Sci. Adv., 9 (2022) 100231.

2. Study of optical properties of TiO₂ nanoparticles and CdS@TiO₂ nanocomposites and their use for photocatalytic degradation of Rhodamine B under natural light irradiation.
R. A. Badhe, A. Ansari, S. S Garje, Bull. Mater. Sci, 44 (2021) 11.
3. One pot synthesis of bimetallic transition metal sulfide NiFeS₂ nanocomposite and its use as a high performance supercapacitor material.
A. Ansari, R. A. Badhe, S. S. Garje, Mater. Lett., 281 (2020) 128636.
4. Nitrogen and phosphorus co-doped carbon dots for selective detection of nitro explosives.
D. G. Babar, S. S. Garje, ACS omega, 5 (6), (2020) 2710-2717.
5. Photocatalytic performance of ZnO carbon composites for the degradation of methyl orange dye.
P. A. Borade, J. S. Suroshe, K. Bogale, S. S. Garje, S. M. Jejurikar, Mater. Res. Express, 7 (1) (2020) 015512.
6. Synthesis of bare and surface modified TiO₂ nanoparticles via single source precursor and insights into their interactions with Serum Albumin.
A. Ansari, S. Sachar and S. S. Garje, New J. Chem., 42 (2018) 13358-13366.
7. Lead (II) halide cinnamaldehyde thiosemicarbazone complexes as single source precursors for oleylamine-capped lead sulfide nanoparticles.
S. Masikhane, C. Gervas, S. Mlowe, A. S. Pawar, S. S. Garje; N. Revaprasadu, J. Mater. Sc.: Mat. Electronics, 29 (2) (2018) 1479-1488.
8. Capacitive behaviour of functionalized carbon nanotube/ZnO composites coated on glassy carbon electrode.
J. S. Suroshe and S. S. Garje, J. Mater. Chem. A, 3 (2015) 15650–15660.
9. Synthesis and X-ray single crystal structure of a cadmium(II) acetophenone thiosemicarbazone complex and its use as a single-source precursor for the preparation of CdS nanocrystallites and thin films.
A. M. Palve, P. V. Joshi, V. Puranik and S. S. Garje, Polyhedron, 61 (2013) 195-201.
10. Preparation of ternary metal chalcogenide (M_{1-x}Fe_xS, M = Cd and Zn) nanocrystallites using single source precursors.
S. D. Disale and S. S. Garje, J. Organomet. Chem., 696 (2011) 3328-3336.

[2] NAME: Dr. (Smt.) M. Karve



● DESIGNATION: Professor

PAPERS PUBLISHED:	35	Ph. D STUDENTS GUIDED:	03
M.Sc (BY RESEARCH)	03	RESEARCH PROJECTS	01

STUDENTS GUIDED:		COMPLETED:	
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- **RESEARCH INTERESTS:** Solvent Extraction, Solid phase Extraction, Environmental Analysis.

KEY PUBLICATIONS:

1. Cyanex272 impregnated on Amberlite XAD-2 for separation and preconcentration of U(VI) from uranmicrolite (leachates) ore tailings, M. Karve and K. Pandey, *J. Radioanal. Nucl. Chem.* 285(2010)627-633.
2. Octadecyl bonded silica membrane disk modified with Cyanex302 for preconcentration and determination of traces of cobalt in urine by flame atomic absorption spectrometry, M. Karve and R. V. Rajgor, *Anal. Lett.* 42 (2009) 2520-2532.
3. Octadecyl bonded silica membrane disk modified with Cyanex302 for separation and flame atomic absorption spectrometric determination of nickel from tap water and CONSULTANCY effluent, M. Karve and R. V. Rajgor, *J. Hazard. Mater.* 166 (2009) 576-580.
4. Selective separation of Scandium(III) and Yttrium(III) from other Rare Earth Elements using Cyanex302 as an extractant, M. Karve and B. Vaidya, *Sep. Sci. Technol.* 43 (2008) 1111-1123.
5. Amberlite XAD-2 impregnated Organophosphinic acid Extractant for separation of Uranium(VI) from rare earth elements, M. Karve and R. V. Rajgor, *Desalination* 232 (2008) 191-197.
6. Amberlite XAD-2 impregnated with Cyanex302 for separation of traces of thorium(IV), M. Karve and R. V. Rajgor, *Sep. Sci. Technol.* 42 (2007) 2255-2273.
7. Solid phase extraction of lead on octadecyl bonded silica membrane disk modified with Cyanex302 and determination by flame atomic absorption spectrometry, M. Karve and R. V. Rajgor, *J. Hazard. Mater.* 141 (2007) 607-613.
8. Extraction of U(VI) with Cyanex 302, M. Karve and C. Gaur, *J. Radioanal. Nucl. Chem.*, 273 (2007) 405-409.
9. Solvent extraction separation of scandium(III) with Cyanex272 as an extractant M. Karve and B. Vaidya, *Indian J. Chem.* 45A (2006) 2658-2660.
10. Hydrochemistry of Mithi River and associated sediments, Mumbai, T. Gurav, M. Karve, and D. Chandrasekharam, *Journal of Indian School of Mines*, 1 (2006) 33-41.

[3] NAME: Dr. N. G. Shimpi



- **DESIGNAT:** Professor

PAPERS PUBLISHED	85	Ph. D STUDENTS UNDER GUIDANCE:	06
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PATENTS	04	RESEARCH PROJECTS:	07 (Completed) 02 (in progress)
Ph. D STUDENTS GUIDED	12	CONSULTANCY PROJECTS COMPLETED	01 (in progress)

● **KEY AWARDS/HONORS:**

- AICTE Career Award for Young Teachers (CAYT).
- Young Scientist Award by APA, IIT, New Delhi (International)

- **RESEARCH INTERESTS:** Synthesis of nanomaterials, Conducting polymers, Biodegradable polymer nanocomposites, Gas sensing materials, Organic transformation reactions, Dye degradation and Shape memory polymers

KEY PUBLICATIONS:

1. Development of Ni doped ZnO/Polyaniline nanocomposites as high response room temperature NO₂ sensor, Shilpa Jain, Narayan Karamkar, Navinchandra Shimpi, Material Science and Engineering: Part B, 2019 (Published online).
2. Studies on effect of ethyl 4-amino cinnamate functionalized multiwall carbon nanotubes (f-MWCNTs) on properties of millable polyurethane rubber (MPU) nanocomposites, M. S Tamore, D. Ratna, N.G. Shimpi, Polymer-Plastics Technology and Materials 58 (11), 1141-1156, 2019.
3. High performance visible light photocatalysis of electrospun PAN/ZnO hybrid nanofibers, A.P. Shah, S. Jain, V.J. Mokale, N.G. Shimpi, Journal of Industrial and Engineering Chemistry, 77, 154-177, 2019.
4. Ultrasound-Mediated Synthesis of Novel α -Aminophosphonates Using Graphene Nanosheets-Silver Nanoparticles (GNS-AgNPs) as a Recyclable Heterogeneous Catalyst, S.A Rasal, M.S. Tamore, N.G. Shimpi, ChemistrySelect 4 (8), 2293-2300, 2019.
5. Effect of functionalized multi-walled carbon nanotubes on physicochemical properties of silicone rubber nanocomposites, M.S. Tamore, D. Ratna, S. Mishra, N.G. Shimpi, Journal of Composite Materials, 0021998319827080, 2019.
6. Novel sonochemical green approach for synthesis of highly crystalline and thermally stable barium sulphate nanoparticles using Azadirachta indica leaf extract, M. Jha, S. Ansari, N.G. Shimpi, Bulletin of Materials Science 42 (1), 22, 2019.
7. Effect of functionalized multi-walled carbon nanotubes on physicochemical properties of silicone rubber nanocomposites, M.S. Tamore, D. Ratna, S. Mishra, N.G. Shimpi, Journal of Composite Materials, 0021998319827080, 2019.
8. Spherical nanosilver: Bio-inspired green synthesis, characterizations, and catalytic applications, M. Jha, N.G. Shimpi, Nano-Structures & Nano-Objects 16, 234-249, 2018.
9. Reusable zinc oxide nanoflowers for the synthesis of α -aminophosphonates under solvent-free ultrasonication, S. Rasal, S. Jain, N.G. Shimpi, Synthetic Communications 48 (18), 2420-2434, 2018.
10. High-performance polyimide film based hybrid nanostructures: Synthesis,

characterization, and properties investigation, N. G. Shimpi, D.P Hansora, S. Mishra, Polymer Composites 39 (8), 2650-2661,2018.

[4] NAME: Dr. Rajesh M. Kamble



● **DESIGNATION:** Professor

PAPERS PUBLISHED:	42	Ph. D STUDENTS UNDER GUIDANCE:	06
M.Sc (BY RESEARCH) STUDENTS GUIDED:	01	RESEARCH PROJECTS:	03
Ph. D STUDENTS GUIDED:	04	CONSULTANCY PROJECTS (IN PROGRESS)	Nil

● **RESEARCH INTERESTS:** Design, Synthesis and characterization of novel AIE and TADF functional organic materials for applications in Organic Light Emitting Devices (OLEDs), Solar cells, as Chemosensors and for Bio-imaging purpose. And the development of composite materials for efficient supercapacitors and electrochemical investigation of materials for supercapacitors. Also to develop sensors in the form of chemically modified electrodes based on the synthesized nanocomposites.

KEY PUBLICATIONS:

1. Dicyanopyrazino phenanthrene based charge transfer derivatives: Role of amine donor in tuning of photophysical, aggregation-induced emission, electrochemical and theoretical properties. Pooja S. Singh, Sajeew Chacko and **Rajesh M. Kamble**, Journal of Molecular Structure, 1271 (2023) 134052 (<https://doi.org/10.1016/j.molstruc.2022.134052>) (Impact Factor: 3.841)
2. 2,2',3,3'-Tetrakis(4-bromophenyl)-6,6'-biquinoxaline based novel Donor–Acceptor–Acceptor–Donor (DAAD) Blue–Orange emitting molecules: Opto-electrochemical, AIE and theoretical investigation. Suraj S. Mahadik, Dinesh R. Garud, Mohammed K. Ghadiyali, Sajeew Chacko and **Rajesh M. Kamble**, Journal of Luminescence, 252 (2022) 119350, (<https://doi.org/10.1016/j.jlumin.2022.119350>) (Impact Factor: 4.171)
3. Blue-red emitting materials based on a pyrido[2,3-*b*]pyrazine backbone: design

and tuning of the photophysical, aggregation-induced emission, electrochemical and theoretical properties. Deepak M. Kapse, Pooja S. Singh, Mohammed Ghadiyali, Sajeev Chacko and Rajesh M. Kamble, RSC Advances, 2022, 12, 6888–6905 (DOI: 10.1039/d2ra00128d) (Impact Factor: 4.036)

4. D–A–D based pyrido-pyrazino[2,3-*b*]indole amines as blue-red fluorescent dyes: Photophysical, aggregation-induced emission, electrochemical and theoretical studies. Pooja S. Singh, Mohammed Ghadiyali, Sajeev Chacko and Rajesh M. Kamble, Journal of Luminescence, 2022, 242, 118568 (<https://doi.org/10.1016/j.jlumin.2021.118568>) (Impact Factor: 4.171)
5. Blue-orange emitting carbazole based donor-acceptor derivatives: Synthesis and studies of modulating acceptor unit on opto-electrochemical and theoretical properties. Pooja S. Singh, Purav M. Badani and Rajesh M. Kamble, J. Photochem. Photobiol. A: Chem, 2021, 419, 113457 (<https://doi.org/10.1016/j.jphotochem.2021.113457>) (Impact Factor: 5.141)
6. Acridone-amine D-A-D thermally activated delayed fluorescence emitters with narrow resolved electroluminescence and their electrochromic properties. Marharyta Vasylieva, Piotr Pander, Bharat K. Sharma, Azam M. Shaikh, Rajesh M. Kamble, Fernando B. Dias, Malgorzata Czichy and Przemyslaw Data, Electrochimica Acta, 2021, 384, 138347 (<https://doi.org/10.1016/j.electacta.2021.138347>) (Impact Factor: 7.336)
7. Design, Synthesis and Opto-electrochemical Properties of Novel Donor–Acceptor Based 2,3-di(hetero-2-yl)pyrido[2,3-*b*]pyrazine amine derivatives as Blue-Orange Fluorescent Materials. Suraj Mahadik, Dinesh R. Garud, Anuja P. Ware, Subhash S. Pingale and Rajesh M. Kamble, Dyes & Pigments, 2021, 184, 108742 (<https://doi.org/10.1016/j.dyepig.2020.108742>) (Impact Factor: 5.122)
8. Synthesis and investigation of the photophysical, electrochemical and theoretical properties of phenazine–amine based cyan blue-red fluorescent materials for organic electronics. Deepali N. Kanekar, Sajeev Chacko and Rajesh M. Kamble, New J. Chem., 2020, 44, 3278–3293 (DOI: 10.1039/c9nj06109f) (Impact Factor: 3.925)
9. Quinoxaline based amines as Blue-orange emitters: Effect of modulating donor system on Optoelectrochemical and theoretical properties. Deepali N. Kanekar, Sajeev Chacko and Rajesh M. Kamble, Dyes & Pigments, 2019, 167, 36–50 (<https://doi.org/10.1016/j.dyepig.2019.04.005>) (Impact Factor: 5.122)
10. Electrochemically synthesised xanthone-cored conjugated polymers as materials for electrochromic windows. H. F. Higginbotham, M. Czichy, B. K. Sharma, A. M. Shaikh, R. M. Kamble, P. Data, Electrochimica Acta, 2018, 273, 264–272 (doi.org/10.1016/j.electacta.2018.04.070) (Impact Factor: 7.336)

[5] NAME: Dr. Vishwanath R. Patil



● **DESIGNATION:** Professor

PAPERS PUBLISHED:	68	Ph. D STUDENTS GUIDED:	16
PATENTS:	33	Ph. D STUDENTS UNDER GUIDANCE:	07
M.Sc (BY RESEARCH) STUDENTS GUIDED:	04	RESEARCH PROJECTS COMPLETED:	04

● **KEY AWARDS/HONORS:**

- Prof. B. C. Haldar Memorial Research Award – 2002.
- Best Researcher & Academician Award (Bionano Frontier & University of Mauritius)- 2017.
- *Dr. Arvind Kumar Memorial* Award for Best Young Scientist in Chemistry, by Indian Council of Chemists, India-2018.
- Best Teacher Award, University of Mumbai-2019.
- Fellow of Maharashtra Science Academy-2021.

- **RESEARCH INTERESTS:** Light emitting polymers, Water soluble polymers, biosynthesis of nanoparticles, Polymer-nano campsites, Self-healing polymers, Invisible barcodes, click chemistry, Antiviral nanocoatings,

● **KEY PUBLICATIONS:**

1. Enhancement of recovered graphite's electrochemical performance during LIB recycling to promote circular sustainable development, Roshan P. Rane, Bhavesh M. Patil, Satyavan P. Varande, Paresh M. Patil, Vasant M. Patil, Kanchan A. Barve, Kamini J. Donde, Quinn Qiao, Sunil N. Peshane, Vishwanath R. Patil, Sustainable Materials and Technologies 36 (2023) e00613, <https://doi.org/10.1016/j.susmat.2023.e00613> (**Impact factor: 10.68**).
2. Gold Separation Recovery Cycle Economic Route from Bio-sensing AuNPs: Nanowaste and Covid-19 Testing Kits, Amol V. Pansare, Shubham V. Pansare, Priyanka V. Pansare, Bhausaheb P. More, Kamini J. Donde, Amit A. Nagarkar Michel Barbezat, Vishwanath R. Patil and Giovanni P. Terrasi, *Dalton Trans.*, 2022, **51**, 14686-14699, <https://doi.org/10.1039/D2DT01405J> ISSN 1477-9234 (Online) (**Impact factor: 4.569**).
3. Blue light-emitting fluorene–dendron hybridized polymers: optophysical features, Rupashri K Kadu, Pramod B Thakur, Santosh W Zote, Kamini J Donde, Michel Barbezat, Giovanni P Terrasi, Vishwanath R Patil, Amol V Pansare, Polymer Bulletin, 2022, <https://doi.org/10.1007/s00289-022-04571-x>, (**Impact factor-2.014**).
4. Click Gold Quantum Dots Biosynthesis with Conjugation of Quercetin for Adenocarcinoma Exertion, Amol V. Pansare, Priyanka V. Pansare, Amol A. Shedje, Shubham V. Pansare, Vishwanath R. Patil, Giovanni P. Terrasi and Kamini J. Donde, RSC Advances, 2022, 12, 18425, DOI: 10.1039/d2ra02529a, ISSN: 2046-2069, (**Impact Factor: 3.36**).

5. Deciphering the sensing of a-amylin acetate with hs-DNA: a multipronged biological probe, Amol V. Pansare, Amol A. Shedge, Maryappa C. Sonawale, Shubham V. Pansare, Akshay D. Mahakal, Shyam R. Khairkar, Shraddha Y. Chhatre, Dnyaneshwar K. Kulal and Vishwanath R. Patil, RSC Advances, 2022, 12, 1238–1243, DOI: 10.1039/d1ra07195e, ISSN: 2046-2069, **(Impact Factor: 3.36)**.
6. Highly efficient potentiometric sensing device for gadolinium based on Tetraazacyclododecane-1, 4, 7, 10 -tetraacetic acid crown ether and multiwalled carbon nanotube composite, Nayan S Gadhari, Suyog S Patil, Jayram V Gholave, Vishwanath R Patil, Sharad S Upadhyay, Microchemical Journal, Vol.175 (107130) 2022), <https://doi.org/10.1016/j.microc.2021.107130>, **(Impact factor-4.821)**.
7. Biological macromolecule chitosan grafted co-polymeric composite: bio-adsorption probe on cationic dyes, Shyam R. Khairkar, Shubham V. Pansare, Amol A. Shedge, Shraddha Chhatre, Dnyaneshwar K. Kulal, Vishwanath R. Patil, Amol V. Pansare, Polymer Bulletin, 2021 <https://doi.org/10.1007/s00289-021-03954-w>, **(Impact factor-2.014)**.
8. High performance HPLC-UV Method development and validation for sulfadoxine from its potential interfering impurities, Nayan S Gadhari, Jayram V Gholave; Suyog S Patil, Ajay R. Patil, Kiran Shelke, Vishwanath R Patil, Sharad S Upadhyay, Current Chromatography, 2021, (DOI : [10.2174/2213240608666210813105715](https://doi.org/10.2174/2213240608666210813105715)) ISSN (Print): 2213-2406 ISSN (Online): 2213-2414.
9. Sono-Maceration- A Rapid and Inexpensive Method for the Isolation of Ursolic Acid from Neolamarckia cadamba Leaves, Jennifer George, Gangadhar A. Meshram, Vishwanath R. Patil, Natural Product Research. 2021, (<https://doi.org/10.1080/14786419.2021.1971978>). ISSN: 1478-6419 (print) 1478-6427 (web) **(Impact factor 2.158)**.
10. Enantioselective high performance new solid contact ion-selective electrode potentiometric sensor based on sulphated γ -cyclodextrin-carbon nanofiber composite for determination of multichiral drug moxifloxacin, Nayan S Gadhari, Jayram V Gholave; Suyog S Patil, Vishwanath R Patil, Sharad S Upadhyay, Journal of Electroanalytical Chemistry, 882, 114981, 2021, <https://doi.org/10.1016/j.jelechem.2021.114981>, ISSN: 1572-6657 **(Impact factor 3.218)**.

[6] NAME: Dr. Suresh Damodar Pawar



● **DESIGNATION: Associate Professor**

PAPERS	33	Ph. D STUDENTS UNDER	06
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PUBLISHED:		GUIDANCE:	
M.Sc (BY RESEARCH) STUDENTS GUIDED:	01	RESEARCH PROJECTS:	03 (Minor)
Ph. D. STUDENTS GUIDED:	02	CONSULTANCY PROJECTS (IN PROGRESS)	-

RESEARCH INTERESTS: Solvent Extraction, Coordination Chemistry, Nanomaterials, Metal Organic Framework.

Key Publications

1. Synthesis of Fluorescent Cu-MOF and Ni-MOF Sensors for Selective and Sensitive Detection of Arginine and Hydrogen Sulfide, Chaturvedi S. Gujja and Suresh D. Pawar, **Journal of Inorganic and Organometallic Polymers and Materials**, Published online on 20/05/2023.
2. Selective and sensitive detection of hydrogen sulphide using hydrolytically stable Cu-MOF, Chaturvedi S. Gujja, Divyesh S. Shelar, Ekta P. Asiwal, Sudesh T. Manjare, Suresh D. Pawar, **Journal of Molecular Structure**, 1273, 2023, 134277.
3. A Ni-MOF based luminescent sensor for selective and rapid sensing of Fe(II) and Fe(III) ions, Ekta P. Asiwal, Divyesh S. Shelar, Chaturvedi S. Gujja, Sudesh T. Manjare and Suresh D. Pawar, **New Journal of Chemistry**, 2022, 46, 12679.
4. Novel Schiff base scaffolds derived from 4-aminoantipyrine and 2-hydroxy-3-methoxy-5-(phenyldiazenyl)benzaldehyde: Synthesis, antibacterial, antioxidant and anti-inflammatory, Mangesh S. Kasare, Pratik P. Dhavan, Aksh Hina I. Shaikh, Bhaskar L. Jadhav, Suresh D. Pawar, **Journal of Molecular Recognition**, 35(9), 2022, e2976.
5. Design, synthesis and biological evaluation of furan based α -aminophosphonate derivatives as anti-Alzheimer agent, Jasmin J. Uparkar, Pratik P. Dhavan, Bhaskar L. Jadhav, Suresh D. Pawar*, **Journal of the Iranian Chemical Society**. Published online on 25/02/2022.
6. In-vitro antibacterial activity of Ni(II), Cu(II), and Zn(II) complexes incorporating new azo-azomethine ligand possessing excellent antioxidant, anti-inflammatory activity and protective effect of free radicals against plasmid DNA, Mangesh S. Kasare, Pratik P. Dhavan, Bhaskar L. Jadhav, Suresh D. Pawar, **Synthetic Communications**, 49(23), 2019, 3311-3323.
7. Synthesis of Azo Schiff Base Ligands and Their Ni(II), Cu(II) and Zn(II) Metal Complexes as Highly-Active Antibacterial Agents, Mangesh S. Kasare, Pratik P. Dhavan, Bhaskar L. Jadhav, Suresh D. Pawar*, **Chemistry Select**, 4, 2019, 10792-10797.

8. Extraction of Yttrium (III) from Sodium Acetate and Sodium Succinate Mediums using Cyanex-923, A.H.I. Shaikh and S.D. Pawar*, **Journal of Applicable Chemistry**, 8 (3), 2019, 1231-1240.
9. Liquid-liquid extraction of Cd(II) metal ion using trialkyl Phosphine oxide extractant, A. H. I. Shaikh and S. D. Pawar*, **Journal of Applicable Chemistry**, 7 (4), 2018, 964-972.
10. Extraction studies of Fe(III) metal ion from hydrobromic acid medium using Cyanex-923 extractant, A. R. Bhoir and S. D. Pawar* **Journal Indian Chemical Society**, Vol. 93, December 2016, 1-4.

[7] NAME: Dr. S. Sachar



● **DESIGNATION:** Assistant Professor

PAPERS PUBLISHED:	27	Ph. D STUDENTS UNDER GUIDANCE:	4
M.Sc (BY RESEARCH) STUDENTS GUIDED:	-	RESEARCH PROJECTS:	1
Ph. D STUDENTS GUIDED:	2	CONSULTANCY PROJECTS (IN PROGRESS)	-

● **RESEARCH INTERESTS:**

- Solubility and stability properties of therapeutic drugs in the pre-formulation stage by complexing with different surface active agents
- Surface modifications of nanoparticles
- Colloidal Chemistry and its applications, e.g. in nanotechnology and bio-medical field.

● **KEY PUBLICATIONS:**

1. Surfactant influences the interaction of copper sulfide nanoparticles with biomolecules, Shagufta M. Khan, Shruti Bhatkalkar, Dinesh Kumar, Ahmad Ali, Shweta Sharma, Shilpee Sachar, *Journal of Molecular Liquids*, 369 (2023) 120881.
2. Incorporation of the poorly soluble drug cefixime inside the micellar core of conventional and gemini surfactants, Aparna Saraf, Shweta Sharma, Shilpee

Sachar, New Journal of Chemistry, 46, 8, (2022), 3697-3706.

3. Influence of surfactants on biomolecular conjugation of magnetic nanoparticles
Dinesh Kumar, Shruti G. Bhatkalkar, Shilpee Sachar, Ahmad Ali, Journal of Biomolecular Structure and Dynamics, (2021), 1-13.
4. Studies on the antiglycating potential of zinc oxide nanoparticle and its interaction with BSA, Dinesh Kumar, Shruti G. Bhatkalkar, Shilpee Sachar, Ahmad Ali, Journal of Biomolecular Structure and Dynamics, 39 (2020) 6918-6925.
5. Low-frequency ultrasound responsive release and enhanced antibacterial efficacy of Sulfamethoxazole decked Silver nanocomposite, Aparna Saraf, Omkar Padave, Shweta Sharma, Pamela Jha, Renitta Jobby, Ahmad Ali, Shilpee Sachar, Polyhedron, 195 (2020).
6. Evaluation of the antiglycating potential of thymoquinone and its interaction with BSA, Dinesh Kumar, Amisha Desa, Sana Chaugle Shruti G. Bhatkalkar, Shilpee Sachar, Dr. Selvaa Kumar C, Ahmad Ali, Journal of Biomolecular Structure and Dynamics, (2021) 1-9.
7. Studies on the antiglycating potential of zinc oxide nanoparticle and its interaction with BSA, Dinesh Kumar, Shruti G. Bhatkalkar, Shilpee Sachar, Ahmad Ali, Journal of Biomolecular Structure and Dynamics, 39 (2020) 6918-6925.
8. Low-frequency ultrasound responsive release and enhanced antibacterial efficacy of Sulfamethoxazole decked Silver nanocomposite, Aparna Saraf, Omkar Padave, Shweta Sharma, Pamela Jha, Renitta Jobby, Ahmad Ali, Shilpee Sachar, Polyhedron, 195 (2020).
9. Influence of surfactants on the interaction of copper oxide nanoparticles with vital proteins, Shruti G. Bhatkalkar, Dinesh Kumar, Ahmad Ali, Shilpee Sachar, Journal of Molecular Liquids, 304 (2020) 112791.
10. Evaluation of surfactants as solubilizing medium for Levofloxacin, Aparna Saraf, Shweta Sharma and Shilpee Sachar, Journal of Molecular Liquids, 319 (2020) 114060-114070.

[8] NAME: Dr. Purav Badani



● **DESIGNATION:** Assistant Professor

PAPERS PUBLISHED:	33	Ph. D STUDENTS UNDER GUIDANCE:	02
M.Sc (BY RESEARCH)	--	RESEARCH PROJECTS:	02

STUDENTS GUIDED:			
Ph. D STUDENTS GUIDED:	02	CONSULTANCY PROJECTS	01

● **KEY AWARDS/HONORS:**

Gold Medalist – University of Mumbai
 Young Scientist Awardee- SERB, Govt. of India
 Secretary – Indian Chemical Society (Mumbai Branch)

● **RESEARCH INTERESTS:** Computational Organic Chemistry, Theoretical Chemistry, Artificial intelligence and Machine Learning

● **KEY PUBLICATIONS:**

1. Effect of functional group on dissociation kinetics of ester and acid derivative of bromopropane. N Gulvi, P Maliekal, R Thorat and PM Badani Computational and Theoretical Chemistry 1207 (2022) 113509.
2. Role of non-covalent interactions in deciding the fate of product formation in bifunctional thiourea-assisted chiral organic reactions. P Maliekal, N Gulvi and PM Badani Theoretical Chemistry Accounts 141 (2022) 43.
3. Effect of substitution on dissociation kinetics of C_2H_5X ($X = F, Cl, Br$ and I): A theoretical study. N Gulvi, P Patel, P Maliekal and PM Badani Molecular Physics 119 (2021) e1807635.
4. Origin and turnaround of enantioselectivity in a chiral organocatalysed Diels-Alder reaction: A mechanistic study. P Maliekal, N Gulvi, AV Karnik and PM Badani Journal of Physical Organic Chemistry 33 (2020) e4072.
5. Exploring unimolecular dissociation kinetics of ethyl dibromide through electronic structure calculations. N. Gulvi, P. Patel, PM Badani Chemical Physics 505 (2018) 55-63.
6. Mechanistic and kinetic insights of reduction of indophenol by sodium borohydride: A theoretical study to explore the effect of solvent and counter ion. P. Patel, S. Lingayat, N. Gulvi and P. Badani Chemical Physics 504 (2018) 13-21.
7. Mass spectrometric and charge density studies of organometallic clusters photoionized by gigawatt laser pulses. PM Badani, S Das, P Sharma and RK Vatsa Mass Spectrometry Reviews 36 (2017) 188-212.
8. Rapid, chemoselective and mild oxidation protocol for alcohols and ethers with recyclable N-chloro-N-(phenylsulfonyl) benzenesulfonamide. A Palav, B Misal, P Ganwir, P Badani and G Chaturbhuj Tetrahedron Letters 73 (2021) 153094.
9. Benzyne-Mediated Nonconcerted Pathway toward Synthesis of Sterically Crowded [5]-and [7] Oxahelicenoids, Stereochemical and Theoretical Studies, and Optical Resolution of Helicenoids. P. Gawade, V. Khose, P. Badani, M. Hasan, S. Kaabel, S. Mobin Shaikh, V. Borovkov and AV Karnik The Journal of Organic Chemistry 84 (2018) 860-868.
10. Synthesis of Concave and Vaulted 2 H-Pyran-Fused BINOLs and

Corresponding [5] and [7]-Oxa-helicenoids: Regioselective Cascade-Concerted Route and DFT Studies. S. Kamble, P. Maliekal, P Dharpure, PM Badani and AV Karnik The Journal of Organic Chemistry 85 (2020) 7739-7747.

[9] NAME: Dr. R. G. Thorat



● **DESIGNATION:** Assistant Professor

PAPERS PUBLISHED:	7	Ph. D STUDENTS UNDER GUIDANCE:	Nil
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● **RESEARCH INTERESTS:** Chiral Chemistry, Synthetic Organic Chemistry, Heterocyclic Chemistry

● **KEY PUBLICATIONS:**

1. Synthesis of bis-1, 2, 3-triazole tweezer with BINOL backbone and amide subunits: An efficient sensor for iodide and magnesium ions. **Ramchandra Thorat***, Sushil khot, Manali Nikam & Anil V. Karnik. *Synthetic Communications*, **2022**, 52:22, 2138-2148.
2. Effect of functional group on dissociation kinetics of ester and acid derivative of bromopropane. N Gulvi,P Maliekal, **R Thorat** and PM Badani *Computational and Theoretical Chemistry* 1207 (**2022**) 113509.
3. Cysteine catalyzed water mediated eco-friendly approach for the synthesis of 5-substituted 1H-tetrazole and its derivatives. Vikas V. Borge, **Ramchandra G. Thorat**, Arun K. Kadu, Vikas M. Bangade, Parag S. Panse, Gangadhar A. Meshram, and Bhushan B. Popatkar*. *Heterocycles*, **2023**, 106, 7, 1175-1186.
4. Voltametric Quantification of the Antibiotic Roxarsone using a Surface modified Screen-printed Carbon Electrode. Mritinjay S.Tiwari, **Ramchandra G.Thorat**, Vikas Borge, Arun K. Kadu. *Chemistry select.* **2023**, 8:18.
5. Voltametric determination of doxycycline in feedstck using modified carbon screen-printed electrode. M.S.Tiwari, **R.G.Thorat**, V.V.Borge, B.B.Popatkar, A.K.Kadu. *Chemistry Select.* **2023**

[10] NAME: Dr. Bhushan B. Popatkar



● **DESIGNATION:** Assistant Professor

PAPERS PUBLISHED:	8	Ph. D STUDENTS UNDER GUIDANCE:	01
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● **RESEARCH INTERESTS:** Synthetic Organic Chemistry, Heterocyclic Chemistry, Green Chemistry, Water analysis.

KEY PUBLICATIONS:

1. HBTU-Catalyzed simple and mild protocol for the synthesis of quinoxaline derivatives. **Bhushan B. Popatkar*** and Gangadhar A. Meshram. *Heterocycles*, **2020**, 100, 7, 1009–1018.
2. Assessment of groundwater quality using GIS in Thane Municipal Corporation, Maharashtra, India. Sitaram Shinde, Pandurang P. Choudhari*, **Bhushan Popatkar** and Namit Choudhari. *Modeling Earth System and Environment*, **2021**, 7, 1739-1751.
3. Tomato fruit extract: an environmentally benign catalytic medium for the synthesis of isoxazoles derivatives. **Bhushan B Popatkar***, Ankita A Mane and Gangadhar A Meshram. *Indian Journal of Chemistry Sect-B*, 60B, **2021**, 1362-1367.
4. One Pot Catalyst-free Synthesis of Substituted Di-amino N-tosyl Benzoyl Thiazoles by Regioselective C–N Bond Cleavage and Its Anticancer Activity. Vikas M. Bangade*, Tulshiram L. Dadmal, **Bhushan B. Popatkar**, Prakash R. Mali, Harshadas M. Meshram. *Asian Journal of Organic Chemistry*, **2021** <https://doi.org/10.1002/ajoc.202100675>
5. Facile, One Pot Synthesis of Indoloquinoxaline and its Derivatives Using Aqueous Orange Peel Extract at Room Temperature. Nitin A. Sasane, Gangadhar A. Meshram, Kirti S. Bhise, **Bhushan B. Popatkar**. *International Journal of Advanced Research in Science Communication and Technology*, **2022**, 2, (3), 129-133.
6. [BMPTFB]-ionic liquid as an efficient catalyst for the rapid, and eco-friendly synthesis of benzimidazole, 2-substituted benzimidazole, and benzothiazole derivatives at room temperature. **Bhushan B. Popatkar***, Nitin A. Sasane and Gangadhar A. Meshram. *Synth. Commun.*, **2022**, 52 (23) 2249-2259.
7. [EMIM]AlCl₄-ionic liquid catalyzed mechanochemically assisted synthesis of 3,4-dihydropyrimidin-2-(1H)-one and thione derivatives. **Bhushan B. Popatkar***, Nitin A. Sasane and Gangadhar A. Meshram. *J. Heterocycl. Chem.*, **2023**, 60 (7) 1199-1209.
8. Cysteine catalyzed water mediated eco-friendly approach for the synthesis of 5-substituted 1H-tetrazole and its derivatives. Vikas V. Borge, Ramchandra G. Thorat, Arun K. Kadu, Vikas M. Bangade, Parag S. Panse, Gangadhar A. Meshram, and **Bhushan B. Popatkar***. *Heterocycles*, **2023**, 106, 7, 1175-1186.

[11] NAME: Dr. Sudesh T. Manjare



● **DESIGNATION:** Assistant Professor

PAPERS PUBLISHED:	33	RESEARCH PROJECTS:	03
Ph. D STUDENTS GUIDED:	05	Ph. D STUDENTS UNDER GUIDANCE:	02

● **KEY AWARDS/HONORS:**

- 1. Junior Research Fellowship, awarded by C.S.I.R., New Delhi, India - 2006.
- 2. Post-doctoral Research Fellow from **Institute for Basic Science in Korea Advanced Institute of Science and Technology (KAIST)**, Daejeon, South Korea.

● **RESEARCH INTERESTS:** Organometallics, Coordination Chemistry, chalcogen based Sensors. Synthesis of molecular probes based-on common fluorophore (such as BODIPY, HBT, fluorescein, rhodamine, 1,8-naphthalamide, etc) and chalcogen atoms. Designing and synthesis of new chelating pockets with common fluorophore. These probes can be used for the selective and sensitive detection of various analytes (such as ROS, bio-thiols, amino acids, metal ions and anions) through fluorescence turn ‘ON’ or ‘OFF’ response.

● **KEY PUBLICATIONS:**

1. Chapter 14: Chalcogen-based Probes, Gauri S. Malankar ; Beatriz S. Cugnasca ; Felipe Wodtke ; João L. Petrarca de Albuquerque ; Pratiksha P. Deshmukh ; Divyesh S. Shelar ; Alcindo A. Dos Santos ; **Sudesh T. Manjare (Chalcogen Chemistry: Fundamentals and Applications**, Edited by Vito Lippolis; Claudio Santi; Eder J. Lenardão; Antonio L. Braga) Published by **RSC, 2023** (15 Feb 2023), DOI: <https://doi.org/10.1039/9781839167386>, PDF ISBN: 978-1-83916-738-6.
2. Superoxide Targeted “Turn-On” Fluorescence Sensing Enabled by Diselenide Based Quinoline Probe and Its In-Vitro Anticancer Activity in Cancer Cells, Divyesh S. Shelar, Gauri S Malankar, Pinky Singh, Shashikant Prabhakar Vaidya, Rahul V. Pinjari and **Sudesh T Manjare, New J. Chem., 2023**, 47, 6653-6660 (Impact Factor 3.925).
3. Synthesis of Selenium-based BOPHY Sensor for Imaging of Cu(II) in Living HeLa Cells. Gauri S. Malankar, Divyesh S. Shelar, Manikandan M., Malay Patra, **Sudesh T. Manjare, J. Mol. Struct. 2022**, 1281, 135118 (Impact Factor 3.841).
4. Synthesis and Photophysical Study of Tetraphenyl Substituted BODIPY Based phenyl-Monoselenide Probe for Selective Detection of Superoxide.

- Shrikrishna T. Salunke, Divyesh S. Shelar, **Sudesh T. Manjare**, *J. Fluoresc.* **2022**, DOI: 10.1007/s10895-022-03096-w, (Impact Factor 2.525).
5. Selective and Sensitive Detection of Hydrogen Sulphide Using Hydrolytically Stable Cu-MOF. C. Gujja, Divyesh S. Shelar, E. Asawal, **Sudesh T. Manjare**, Suresh D. Pawar, *J. Mol. Struct.* **2022**, 134277, (Impact Factor 3.841).
 6. Selective Detection of Hypochlorous Acid in Living Cervical Cancer Cells with Organoselenium Based BOPPY Probe, Divyesh S. Shelar, Gauri S. Malankar, Manikandan M, Malay Patra, R. J. Butcher and **Sudesh T. Manjare** *New J. Chem.*, **2022**, 46, 17610 (Impact Factor 3.925).
 7. Synthesis and Single Crystal X-ray Study of Phenylselenenyl Embedded Coumarin-Based Sensors for Selective Detection of Superoxide, Gauri S. Malankar, Divyesh S. Shelar, R. J. Butcher and **Sudesh T. Manjare**, *Dalton Trans.*, **2022**, 51, 10518–10526 (Impact Factor 4.390).
 8. BOPHY based Fluorescent Probe for Hg²⁺ via an NTe₂ Chelation, Gauri S. Malankar, Divyesh S. Shelar, Manikandan M, Malay Patra, R. J. Butcher and **Sudesh T. Manjare** *Dalton Trans.*, **2022**, 51, 10069–10076 (Impact Factor 4.390).
 9. An efficient chemodosimeter for the detection of Hg(II) via diselenide oxidation, Pratiksha P. Deshmukh, a Gauri S. Malankar, Arunima Sakunthala, Ambuja Navalkar, Samir K. Maji, Dhiraj P. Murale, Raju Saravanan and **Sudesh T. Manjare**, *Dalton Trans.*, **2022**, 51, 2269–2277 (Impact Factor 4.390).
 10. Synthesis and study of organoselenium compound: DNA/Protein interactions, in vitro antibacterial, antioxidant, anti-inflammatory activities and anticancer activity against carcinoma cells, Divyesh S. Shelar, Pratik P. Dhavan, Pinky R. Singh, Bhaskar L. Jadhav, Shashikant P. Vaidya, **Sudesh T. Manjare**, *Journal of Molecular Structure*, **2021**, 1244, 130914 (Impact Factor 3.196).

[12] NAME: Dr. Arun K. Kadu



DESIGNATION: Assistant Professor

PAPERS PUBLISHED:	8	Ph. D STUDENTS UNDER GUIDANCE:	04
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RESEARCH INTERESTS:

Electrochemistry: Development of sensors, nano-composites for sensors and catalyst.

KEY PUBLICATIONS:

1. Voltammetric Quantification of the Antibiotic Roxarsone using a Surface Modified

- Screen-printed Carbon Electrode. Mritinjay S.Tiwari, Ramchandra G.Thorat, Vikas Borge, **Arun K. Kadu**. *Chemistry select*. **2023**.
2. Voltammetric determination of doxycycline in feedstock using modified carbon screen-printed electrode. M.S.Tiwari, R.G.Thorat, V.V.Borge, B.B.Popatkar, **A.K.Kadu**. *Analytical Sciences*. **2023**.
 3. Cysteine catalyzed water mediated eco-friendly approach for the synthesis of 5-substituted 1H-tetrazole and its derivatives. Vikas V. Borge, Ramchandra G. Thorat, **Arun K. Kadu**, Vikas M. Bangade, Parag S. Panse, Gangadhar A. Meshram, and Bhushan B. Popatkar. *Heterocycles*, **2020**, 106, 7, 1175-1186.
 4. Potentiometric Determination of Proton-Ligand Dissociation Constant of 1-[2-(2-Hydroxybenzilidene) Hydrazono]-1-Phenylpropan-2-One Oxime and Formation Constants of its Complexes with Cobalt, Nickel and Copper in Dioxane-Water System, **A. K. Kadu** and R. G. Deshmukh, *Journal of Chemistry and Chemical Sciences*, Vol.6(5), 433-442, May 2016.
 5. Synthesis and Characterization of Co(II), Ni(II), Cu(II) and Pd(II) Complexes of 1-[2-(5-bromo-2-hydroxybenzilidene)hydrazono]-1-phenylpropan-2-one oxime, **A. K. Kadu** and R. G. Deshmukh, *Journal of Chemical, Biological and Physical Sciences*, JCBPS; Section A; August 2016 – October 2016, Vol. 6, No. 4; 1196-1204
 6. Evaluation of Proton-Ligand Dissociation Constant of 1-(2-(1-(2-Hydroxyphenyl) Ethylidene)Hydrazono)-1-Phenylpropan-2-One and Formation Constants of its Complexes with Cobalt, Nickel and Copper in Dioxane-Water System by Potentiometry, **A. K. Kadu**, Sharad S. Sankhe, P. S. Kamble, *International Journal for Research in Applied Science & Engineering Technology*, Volume 5 Issue IX, September 2017.
 7. Synthesis and characterization of Co(II), Ni(II), Cu(II) and Pd(II) complexes of 1-[2-(2-hydroxybenzilidene)hydrazono]-1-phenylpropan-2-one oxime. **A. K. Kadu** and R. G. Deshmukh, *Journal of Emerging Technologies and Innovative Research*, August 2018, Volume 5, Issue 8.
 8. Equilibrium Studies and Effect of Ionic Strength on Binary Complexes of Bivalent Cobalt, Nickel and Copper with 1-[2-(5-bromo-2-hydroxybenzilidene)hydrazono]-1-phenylpropan-2-one, oxime **A. K. Kadu** and R. G. Deshmukh, *International Journal of Research and Analytical Reviews*, August 2018, Volume 5, Issue 3.

**9. COURSE STRUCTURE AND SYLLABIFOR M. Sc. CHOICE BASED CREDIT
SYSTEM (CBCS) FOUR-SEMESTER-COURSE IN CHEMISTRY AS PER NEP 2020**

Department of Chemistry
(Autonomous)

University of Mumbai

Credit Distribution Structure for Two Years

(M.Sc. in Physical Chemistry)

Year	Le vel	Sem	Major			RM	OJT/FP	RP	Cum. Cr.	Degree	
			Mandatory		Electives						
1	6	Sem I	3*4+ 2=14		4	4		-	22	PG Diploma (after 3 Years Degree)	
			Physical Chemistry-I (CHEM 501) / 112016150111	TH	4	Analytical Chemistry-I (CHEM 50511)/ 112016150511 (OR) Applied Industrial Chemistry-I (CHEM 50512)/ 112016150512					
			Inorganic Chemistry-I (CHEM 502)/ 112016150211	TH	4						
			Organic Chemistry-I (CHEM 503)/ 112016150311	TH	4						
			Chemistry Practical-I (CHEM 504)/ 112016150411	PR	2						
		Sem II	3*4+ 2=14		4		4	-	-		22
			Physical Chemistry-II (CHEM 507)/ 112016250711	TH	4	Analytical Chemistry-II (CHEM 51111)/ 112016251111 (OR) Applied Industrial Chemistry-II (CHEM 51112)/ 112016251112					
			Inorganic Chemistry-II (CHEM 508)/ 112016250811	TH	4						
			Organic Chemistry-II (CHEM 509)/ 112016250911	TH	4						
			Chemistry Practical-II (CHEM 510)/ 112016251011	PR	2						
Cum. Cr. For PG Diploma			28	8	4	4		44			
Exit Option: PG Diploma (44 credits) after Three Year UG Degree											

Department of Chemistry
(Autonomous)
University of Mumbai
Credit Distribution Structure for Two Years
(M.Sc. in Inorganic Chemistry)

Year	Level	Sem	Major			RM	OJT/FP	RP	Cum. Cr.	Degree	
			Mandatory		Electives						
1	6	Sem I	3*4+ 2=14		4	4		-	22	PG Diploma (after 3 Years Degree)	
			Physical Chemistry-I (CHEM 501) / 112016150111	TH	4	Analytical Chemistry-I (CHEM 50511) / 112016150511 (OR) Applied Industrial Chemistry-I (CHEM 50512) / 112016150512					Research Methodology (CHEM 506) / 112016150611
			Inorganic Chemistry-I (CHEM 502) / 112016150211	TH	4						
			Organic Chemistry-I (CHEM 503) / 112016150311	TH	4						
			Chemistry Practical-I (CHEM 504) / 112016150411	PR	2						
		Sem II	3*4+ 2=14		4	-	4 CHEM 512 / 112016251211	-	22		
			Physical Chemistry-II (CHEM 507) / 112016250711	TH	4						Analytical Chemistry-II (CHEM 51111) / 112016251111 (OR) Applied Industrial Chemistry-II (CHEM 51112) / 112016251112
			Inorganic Chemistry-II (CHEM 508) / 112016250811	TH	4						
			Organic Chemistry-II (CHEM 509) / 112016250911	TH	4						
			Chemistry Practical-II (CHEM 510) / 112016251011	PR	2						
Cum. Cr. For PG Diploma			28	8	4	4		44			
Exit Option: PG Diploma (44 credits) after Three Year UG Degree											

Department of Chemistry
(Autonomous)
University of Mumbai
Credit Distribution Structure for Two Years
(M.Sc. in Organic Chemistry)

Year	Level	Sem	Major				RM	OJT/FP	RP	Cum. Cr.	Degree
			Mandatory		Electives						
1	6	Sem I	3*4+ 2=14		4		4		-	22	PG Diploma (after 3 Years Degree)
			Physical Chemistry-I (CHEM 501) / 112016150111	TH	4	Analytical Chemistry-I (CHEM 50511)/ 112016150511 (OR) Applied Industrial Chemistry-I (CHEM 50512)/ 112016150512	Research Methodology (CHEM 506)/ 112016150611				
			Inorganic Chemistry-I (CHEM 502)/ 112016150211	TH	4						
			Organic Chemistry-I (CHEM 503)/ 112016150311	TH	4						
			Chemistry Practical-I (CHEM 504)/ 112016150411	PR	2						
		Sem II	3*4+ 2=14		4		-	4	-	22	
			Physical Chemistry-II (CHEM 507)/ 112016250711	TH	4	Analytical Chemistry-II (CHEM 51111)/ 112016251111 (OR) Applied Industrial Chemistry-II (CHEM 51112)/ 112016251112		CHEM 512/ 112016251211			
			Inorganic Chemistry-II (CHEM 508)/ 112016250811	TH	4						
			Organic Chemistry-II (CHEM 509)/ 112016250911	TH	4						
			Chemistry Practical-II (CHEM 510)/ 112016251011	PR	2						
Cum. Cr. For PG Diploma			28		8	4	4		44		
Exit Option: PG Diploma (44 credits) after Three Year UG Degree											

Department of Chemistry
(Autonomous)
University of Mumbai
Credit Distribution Structure for Two Years
(M.Sc. in Analytical Chemistry)

Year	Level	Sem	Major			RM	OJT/FP	RP	Cum. Cr.	Degree		
			Mandatory		Electives							
1	6	Sem I	3*4+ 2=14			4	4		-	22	PG Diploma (after 3 Years Degree)	
			Physical Chemistry-I (CHEM 501) / 112016150111	TH	4	Organic Chemistry-I (CHEM 50311)/ 112016150311 (OR) Applied Industrial Chemistry-I (CHEM 50512)/ 112016150512	Research Methodology (CHEM 506)/ 112016150611					
			Inorganic Chemistry-I (CHEM 502)/ 112016150211	TH	4							
			Analytical Chemistry-I (CHEM 505)/ 112016150511	TH	4							
			Chemistry Practical-I (CHEM 504)/ 112016150411	PR	2							
		Sem II	3*4+ 2=14			4		4	-	-		22
			Physical Chemistry-II (CHEM 507)/ 112016250711	TH	4	Organic Chemistry-II (CHEM 50911)/ 112016250911 (OR) Applied Industrial Chemistry-II (CHEM 51112)/ 112016251112	CHEM 512/ 112016251211					
			Inorganic Chemistry-II (CHEM 508)/ 112016250811	TH	4							
			Analytical Chemistry-II (CHEM 511)/ 112016251111	TH	4							
			Chemistry Practical-II (CHEM 510)/ 112016251011	PR	2							
Cum. Cr. For PG Diploma			28		8	4	4		44			
Exit Option: PG Diploma (44 credits) after Three Year UG Degree												

Department of Chemistry
(Autonomous)
UNIVERSITY OF MUMBAI

Syllabus For M.Sc. Physical Chemistry
Semester I and II
Choice Based Credit System
Under New Education Policy (NEP) 2020
(To be implemented from the academic year, 2023-2024)

PROGRAM OUTLINE 2023-2024

YEAR		COURSE CODE	COURSE TITLE	CREDITS
M.Sc. Sem-I	Mandatory Course-I	CHEM 501/ 112016150111	Physical Chemistry-I	04
	Mandatory Course-II	CHEM 502/ 112016150211	Inorganic Chemistry-I	04
	Mandatory Course-III	CHEM 503/ 112016150311	Organic Chemistry-I	04
	Mandatory Course Practical	CHEM 504/ 112016150411	Chemistry Practical-I	02
	Elective 1	CHEM 50511/ 112016150511	Analytical Chemistry-I	04
	Elective 2	CHEM 50512/ 112016150512	Applied Industrial Chemistry-I	04
	RM	CHEM 506/ 112016150611	Research Methodology	04
M.Sc. Sem-II	Mandatory Course-I	CHEM 507/ 112016250711	Physical Chemistry-II	04
	Mandatory Course-II	CHEM 508/ 112016250811	Inorganic Chemistry-II	04
	Mandatory Course-III	CHEM 509/ 112016250911	Organic Chemistry-II	04

	Mandatory Course Practical	CHEM 510/ 112016251011	Chemistry Practical-II	02
	Elective 1	CHEM 51111/ 112016251111	Analytical Chemistry-II	04
	Elective 2	CHEM 51112/ 112016251112	Applied Industrial Chemistry-II	04
	OJT/FP	CHEM 512/ 112016251211	Industrial Training/Field Project	04

Department of Chemistry
(Autonomous)
UNIVERSITY OF MUMBAI

Syllabus For M.Sc. Inorganic Chemistry
Semester I and II
Choice Based Credit System
Under New Education Policy (NEP) 2020
(To be implemented from the academic year, 2023-2024)

PROGRAM OUTLINE 2023-2024

YEAR		COURSE CODE	COURSE TITLE	CREDITS
M.Sc. Sem-I	Mandatory Course-I	CHEM 501/ 112016150111	Physical Chemistry-I	04
	Mandatory Course-II	CHEM 502/ 112016150211	Inorganic Chemistry-I	04
	Mandatory Course-III	CHEM 503/ 112016150311	Organic Chemistry-I	04
	Mandatory Course Practical	CHEM 504/ 112016150411	Chemistry Practical-I	02
	Elective 1	CHEM 50511/ 112016150511	Analytical Chemistry-I	04
	Elective 2	CHEM 50512/ 112016150512	Applied Industrial Chemistry-I	04
	RM	CHEM 506/ 112016150611	Research Methodology	04
M.Sc. Sem-II	Mandatory Course-I	CHEM 507/ 112016250711	Physical Chemistry-II	04
	Mandatory Course-II	CHEM 508/ 112016250811	Inorganic Chemistry-II	04
	Mandatory Course-III	CHEM 509/ 112016250911	Organic Chemistry-II	04
	Mandatory Course Practical	CHEM 510/ 112016251011	Chemistry Practical-II	02

	Elective 1	CHEM 51111/ 112016251111	Analytical Chemistry-II	04
	Elective 2	CHEM 51112/ 112016251112	Applied Industrial Chemistry-II	04
	OJT/FP	CHEM 512/ 112016251211	Industrial Training/Field Project	04

Department of Chemistry
(Autonomous)
UNIVERSITY OF MUMBAI

Syllabus For M.Sc. Organic Chemistry
Semester I and II
Choice Based Credit System
Under New Education Policy (NEP) 2020
(To be implemented from the academic year, 2023-2024)

PROGRAM OUTLINE 2023-2024

YEAR		COURSE CODE	COURSE TITLE	CREDITS
M.Sc. Sem-I	Mandatory Course-I	CHEM 501/ 112016150111	Physical Chemistry-I	04
	Mandatory Course-II	CHEM 502/ 112016150211	Inorganic Chemistry-I	04
	Mandatory Course-III	CHEM 503/ 112016150311	Organic Chemistry-I	04
	Mandatory Course Practical	CHEM 504/ 112016150411	Chemistry Practical-I	02
	Elective 1	CHEM 50511/ 112016150511	Analytical Chemistry-I	04
	Elective 2	CHEM 50512/ 112016150512	Applied Industrial Chemistry-I	04
	RM	CHEM 506/ 112016150611	Research Methodology	04
M.Sc. Sem-II	Mandatory Course-I	CHEM 507/ 112016250711	Physical Chemistry-II	04
	Mandatory Course-II	CHEM 508/ 112016250811	Inorganic Chemistry-II	04
	Mandatory Course-III	CHEM 509/ 112016250911	Organic Chemistry-II	04
	Mandatory Course Practical	CHEM 510/ 112016251011	Chemistry Practical-II	02

	Elective 1	CHEM 51111/ 112016251111	Analytical Chemistry-II	04
	Elective 2	CHEM 51112/ 112016251112	Applied Industrial Chemistry-II	04
	OJT/FP	CHEM 512/ 112016251211	Industrial Training/Field Project	04

Department of Chemistry
(Autonomous)
UNIVERSITY OF MUMBAI

Syllabus For M.Sc. Analytical Chemistry
Semester I and II
Choice-Based Credit System
Under New Education Policy (NEP) 2020
(To be implemented from the academic year, 2023-2024)

PROGRAM OUTLINE 2023-2024

YEAR		COURSE CODE	COURSE TITLE	CREDITS
M.Sc. Sem-I	Mandatory Course-I	CHEM 501/ 112016150111	Physical Chemistry-I	04
	Mandatory Course-II	CHEM 502/ 112016150211	Inorganic Chemistry-I	04
	Mandatory Course-III	CHEM 505/ 112016150511	Analytical Chemistry-I	04
	Mandatory Course Practical	CHEM 504/ 112016150411	Chemistry Practical-I	02
	Elective 1	CHEM 50311/ 112016150311	Organic Chemistry-I	04
	Elective 2	CHEM 50512/ 112016150512	Applied Industrial Chemistry-I	04
	RM	CHEM 506/ 112016150611	Research Methodology	04
M.Sc. Sem-II	Mandatory Course-I	CHEM 507/ 112016250711	Physical Chemistry-II	04
	Mandatory Course-II	CHEM 508/ 112016250811	Inorganic Chemistry-II	04
	Mandatory Course-III	CHEM 511/ 112016251111	Analytical Chemistry-II	04
	Mandatory Course Practical	CHEM 510/ 112016251011	Chemistry Practical-II	02

	Elective 1	CHEM 50911/ 112016250911	Organic Chemistry-II	04
	Elective 2	CHEM 51112/ 112016251112	Applied Industrial Chemistry-II	04
	OJT/FP	CHEM 512/ 112016251211	Industrial Training/Field Project	04

PROGRAMME SPECIFIC OUTCOME (PSOs)

1. Gain knowledge of the advanced concepts in the branch of chemistry, identify and accomplish a solution to problems encountered in the field of research and analysis.
2. Apply the basic knowledge of chemistry to perform various tasks assigned to them at the workplace in industry and academia to meet the global standards.
3. Deduce qualitative and quantitative information of chemical compounds using advanced spectroscopic methods which can further be analysed using practical skills inculcated in them during the course.
4. Imbibe the attitude as well as aptitude of a scientific approach along with analytical reasoning with respect to the novel techniques actually implemented in the Industry.
5. Use the subject knowledge, communication and ICT skills to become an effective team leader/team member in the interdisciplinary fields.
6. Understand, Manage and contribute to solve basic societal issues and environmental concerns ethically based on principles of scientific knowledge gained.
7. Exhibit professional work ethics and norms of scientific development.

PROGRAM(s): M.Sc.-I		SEMESTER: I		
Course: Paper-I		Course Code: (CHEM501 / 112016150111) Course Title:- Physical Chemistry-I		
Teaching Scheme				Evaluation Scheme
Lectures (Hours per week)	Tutorial (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 50)	Semester End Examination (Marks- 50)
04	–	04	50	50
Learning Objectives: 1.To enable learners to have comprehensive knowledge and understanding of the advanced concepts in reaction kinetics, molecular dynamics and chemical thermodynamics. 2. To apply the basic knowledge of Physical chemistry to perform various tasks assigned to them at the workplace in industry and academia to meet the job requirements as per global standards. 3. Accomplish a solution to problems encountered in the field of research.				
Course Outcomes: 1. The learners will apply the advanced thermodynamics, Maxwell equation and its applications to ideal gasses. 2. The learners evaluate the different theories of chemical kinetics and effect of temperature on reaction rates. 3. The learners will implement the applications of chemical thermodynamics to real gases, solutions, surfaces and their energetics. 4. The learners will understand the applications of operators and Schrodinger equation in the field of quantum Chemistry. 5. The learners will evaluate the resting membrane potential by using the concept of bio electrochemistry. 6. The learners will try to accomplish a solution to problems encountered in the field of research.				

Semester – I
Paper -I
Course Code: CHEM 501 / 112016150111
PHYSICAL CHEMISTRY-I

Unit-I THERMODYNAMICS-I [15L]

State function, exact and inexact differentials, Internal energy, Enthalpy, Heat capacity, Relation between C_p and C_v , Limitations of first law of thermodynamics, Joule-Thomson experiment, Joule-Thomson coefficient, Joule-Thomson coefficient for real and an ideal gas, Inversion temperature

Absolute temperature, Spontaneous or irreversible process, Entropy, Thermodynamic equation of state, Maxwell relation, Helmholtz and Gibbs free energy, Third law of thermodynamics, Nernst heat theorem, Determination of absolute entropies, entropy changes in chemical reaction, residual entropy.

Unit-II FUNDAMENTAL ASPECTS OF QUANTUM CHEMISTRY (15L)

Introduction: Historical background, Old Vs New Quantum Theory, Heisenberg's Uncertainty Principle, The wave nature of matter

Fundamental Background: Postulates of Quantum Chemistry, Commutators of operators, Properties of Linear and Hermitian operators, Operators for the dynamic variables of a system such as position, linear momentum, angular momentum and total energy, Expectation Value,

Progressive and standing waves, Conditions on the wave function and its interpretation, Normalization and orthogonality, Separation of variables, Obtaining Schrödinger's time independent wave equation from Schrödinger's time dependent wave equation.

Application of Quantum Chemistry in Translation motion: Particle in one dimension box: Differential equation and its solution, Graphical representation of wavefunctions and probability densities, Normalization and orthogonality of wave functions. Even and Odd Functions.

Particle in a two- and three-dimensional box: Differential equation and its solution, Degeneracy, Energy level Diagram.

Unit-III PHASE RULE AND ITS APPLICATIONS [15L]

Recapitulation: - Phase rule, Phase diagrams and their classification, Lambda transition.

Two component Liquid systems:

Completely Miscible Liquid Systems: - Vapor pressure – composition diagrams, Temperature-Composition Diagram, fractional distillation of Zeotropic and Azeotropic mixtures.

Partially Miscible Liquid Systems: - Temperature Composition diagram, Critical solution temperature, influence of foreign substances (impurities) on CST.

Three component Liquid systems:

Type I-Formation of one pair of partially miscible liquids: Graphical representations, binodal curves, plait point, influence of temperature-System showing real critical solution temperature, System showing no real critical solution temperature.

Type II-Formation of two pairs of partially miscible liquids.

Type III-Formation of three pairs of partially miscible liquids

Influence of impurities on ternary system, Ternary Azeotropic mixtures, Preparation of absolute alcohol by azeotropic elimination of water.

Unit-IV CHEMICAL KINETICS [15L]

Accounting for the rate laws: simple reactions, temperature dependence of reaction rates, consecutive reactions, (rate determining step approximation and steady-state approximation), unimolecular reactions – Lindemann-Hinshelwood mechanism.

Kinetics of complex reactions - Chain reactions, polymerization reactions, explosions, photochemical reactions.

Fast reactions: Study of kinetics by flow methods, relaxation methods, flash photolysis, magnetic resonance method, shock tube method.

***Derivation not expected**

Note: Numerical and theoretical problems from each Unit- are expected.

References books:

1. Peter Atkins and Julio de Paula, *Atkin's Physical Chemistry*, 7th ed., Oxford University Press, 2002.
2. K. J. Laidler and J. H. Meiser, *Physical Chemistry*, 2nd ed., CBS Publishers and Distributors, New Delhi, 1999.
3. Robert J. Silby and Robert A. Alberty, *Physical Chemistry*, 3rd ed., John Wiley and Sons (Asia) Pte. Ltd., 2002.
4. Ira R. Levine, *Physical Chemistry*, 5th ed., Tata McGraw-Hill, New Delhi, 2002.
5. G. W. Castellan, *Physical Chemistry*, 3rd ed., Narosa Publishing House, New Delhi, 1983.
6. D. A. McQuarrie and J. D. Simon, *Physical Chemistry - a molecular approach*, Viva Books Private Limited, New Delhi, 1998.
7. S. Glasstone, *Text Book of Physical Chemistry*, 2nd ed., McMillan and Co. Ltd., London, 1962.
8. D. A. McQuarrie, *Quantum Chemistry*, Viva Books Private Limited, New Delhi, first Indian ed., 2003.
9. B. K. Sen, *Quantum Chemistry including spectroscopy*, Kalyani Publishers, 2003.
10. A. K. Chandra, *Introductory Quantum Chemistry*, Tata Mc Graw-Hill, 1994.
11. R. K. Prasad, *Quantum Chemistry*, 2nd ed., New Age International Publishers, 2000.
12. D. O. Hayward, *Quantum Mechanics for Chemists*, Royal Society for Chemists, 2002.
13. Sydney T. Bowden, *The phase rule and the phase reaction*, McMillan and Co. Ltd., London, 1938.
14. A. N. Cambell, Alexander Findlay, *The Phase Rule and its Applications*, Dover publications.
15. G. L. Agarwal, *Basics Chemical kinetics*, Tata Mcgraw Hill, New Delhi.
16. K. J. Laidler, *Chemical Kinetics*, 3rd ed., Pearson Education.
17. R. P. Rastogi, R. R. Mishra, *An Introduction to Chemical Thermodynamics*, Vikas Publishing House Pvt. Ltd.

List of Books for further reading:

1. S. Glasstone, *Thermodynamics for Chemists*, Affiliated East-West Press, New Delhi, 1964.
2. W. G. Davis, *Introduction to Chemical Thermodynamics – A Non-Calculus Approach*, Saunders, Philadelphia, 1972.
3. I. M. Klotz and R. M. Rosenberg, *Chemical Thermodynamics*, 5th ed., John Wiley and Sons, Inc., 1994.

4. Peter A. Rock, *Chemical Thermodynamics*, University Science Books, Oxford University Press, 1983.
5. Ira N. Levine, *Quantum Chemistry*, 5th ed., Pearson Education (Singapore) Pte. Ltd., Indian Branch, New Delhi, 2000.
6. J. P. Lowe, *Quantum Chemistry*, 2nd ed., Academic Press, New York, 1993.
7. R. Anantharaman, *Fundamentals of Quantum Chemistry*, McMillan India Limited, 2001.
8. Mahendra R. Awode, *Quantum Chemistry*, S. Chand and Co. Ltd., New Delhi, 2002.

PROGRAM(s): M.Sc.-I		SEMESTER: I		
Course: Paper-II		Course Code: (CHEM502, 112016150211) Course Title:- Inorganic Chemistry-I		
Teaching Scheme				Evaluation Scheme
Lectures (Hours per week)	Tutorial (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 50)	Semester End Examination (Marks- 50)
04	–	04	50	50
Learning Objectives: 1. To develop the ability to predict the feasibility and pathways of different chemical reactions. 2. To learn about the existence of various weak chemical forces and their effects on the physical properties of molecules.				
Course outcomes: 1. The learner will gain an understanding of various mechanisms involved in inorganic chemical reaction. 2. The learner will acquire knowledge about the various aspects of organometallic compounds. 3. The learner will gain understanding of various weak intermolecular forces and wavefunction representation of different hybridization. 4. The learner will know the important fundamental concept of chemical reactivity of different entities.				

Paper II
Course Code: CHEM 502/ 112016150211
INORGANIC CHEMISTRY-I

UNIT I: INORGANIC REACTION MECHANISMS [15 L]

- (i) Rate of reactions, factors affecting the rate of reactions; techniques for the determination of rate of reactions. (Direct chemical analysis, spectrophotometric methods, polarimetric method, electrochemical and flow methods).
- (ii) Mechanisms and factors affecting the ligand substitution reactions of (a) octahedral complexes with and without breaking of metal-ligand bond, stereochemistry of substitution reactions of octahedral complexes. (b) square planar complexes – trans-effect, its theories and applications and (c) tetrahedral complexes;
- (iii) Redox reactions: inner and outer sphere mechanisms. Complimentary and non-complimentary reactions.
- (iv) Isomerization and racemization reactions.

UNIT II : ORGANOMETALLIC CHEMISTRY [15 L]

- (i) Recapitulation of classification of organometallic compounds, electron counting and eighteen electron rule.
- (ii) Sixteen electron square planar complexes.
- (iii) Synthesis, structure and bonding of the following organometallic compounds: (a) Alkyl and Aryl derivatives, (b) Carbenes and Carbynes, (c) Alkene complexes, (d) Alkyne complexes, (e) Allyl complexes, (f) Cyclopentadiene complexes and (g) Arene complexes (sandwich and half sandwich complexes).

UNIT III : CHEMICAL BONDING [15L]

- (i) Hybridization: Derivation of wave functions for the following orbital hybridisation types: sp (BeH_2); sp^2 (BF_3); sp^3 (CH_4) considering only sigma bonding.
- (ii) Molecular Orbital Theory (LCAO-MO approach) for Electron deficient and Electron rich species.
- (iii) Weak intermolecular forces: Hydrogen bonding: concept, types, properties, and importance. Van der Waal's forces: ion-dipole, dipole-dipole, London forces.
- (iv) Bent's Rule: Reactivity of molecules: e.g. chlorofluorides of phosphorous, fluoromethanes, etc.

UNIT IV: CHEMICAL REACTIVITY [15 L]

- (i) Recapitulation of acidity of cations and basicity of anions. Hard soft acids and bases (HSAB) principle, Acid-base strength and softness and hardness.
- (ii) Oxoanions, oxocations, Classification of oxoacids based on Pauling's rules, structural anomalies.
- (iii) Classification of Lewis acids and bases based on Frontier Molecular orbital topology, Reactivity matrix of Lewis acids and bases; Group 13-17 Lewis acids, superacids and bases. Heterogeneous acid base reactions.
- (iv) Redox properties of the elements: Latimer diagram: Construction of the diagram, non-adjacent species and disproportionation. Frost Diagram: Construction and interpretation. Pourbaix diagram of Iron in natural water.

Reference books

Unit I

1. F. Shriver and P. W. Atkins, *Inorganic chemistry*, 3rd edition, Oxford University Press, 1999.
2. E. Housecroft and A. G. Sharpe, *Inorganic Chemistry*, Pearson Education Ltd. 2nd Edition, 2005.
3. Basalo and R. G. Pearson, *Mechanism of Inorganic Reactions*, 2nd Ed., Wiley, 1967.
4. L. Tobe and J. Burgess, *Inorganic Reaction Mechanism*, Longman, 1999.
5. G. Wilkins, *Kinetics and Mechanism of Reactions of Transition Metal Complexes*, VCH, 2nd edition, 1991.

Unit II

1. C. Mehrotra and A. Singh, *Organometallic Chemistry-A Unified Approach*, 2nd Ed., New Age International Pvt. Ltd., 2000.
2. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, *Inorganic Chemistry*, 6th Ed., Oxford University Press, 2016.
3. Ghosh and M.S. Balakrishna, *Introduction to Organometallic Chemistry*, Publisher National Programme on Technology Enhanced Learning (NPTEL)
4. Huheey, F. A. Keiter and R. I. Keiter, *Inorganic Chemistry – Principles of Structure and Reactivity*, 4th Ed., Harper Collins, 1993.

Unit III

1. Huheey, F. A. Keiter and R. I. Keiter, *Inorganic Chemistry – Principles of Structure and Reactivity*, 4th Ed., Harper Collins, 1993.
2. L. Kapoor, *A textbook of Physical Chemistry*, Volume 4, Mc Millan, 2001.
3. Miessler and D. Tarr, *Inorganic Chemistry*, 3rd Ed., Pearson Education, 2004.
4. W. Pfennig, *Principles of Inorganic Chemistry*, Wiley, 2015.

Unit IV

1. Wulfsberg, *Inorganic Chemistry*, Viva Books Pvt. Ltd., 2002.
2. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, *Inorganic Chemistry*, 5th Ed., Oxford University Press, 2010.
3. W. Pfennig, *Principles of Inorganic Chemistry*, Wiley, 2015.
4. Huheey, F. A. Keiter and R. I. Keiter, *Inorganic Chemistry – Principles of Structure and Reactivity*, 4th Ed., Harper Collins, 1993.
5. [tp://www.meta-synthesis.com/webbook.html](http://www.meta-synthesis.com/webbook.html)

PROGRAM(s): M.Sc.-I			SEMESTER: I
			Course Code: (CHEM 503/CHEM 50311/ 112016150311) Course Title:-Organic Chemistry-I
Teaching Scheme			Evaluation Scheme
Lectures (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 50)	Semester End Examination (Marks- 50)
04	04	50	50
Course Objectives: 1. To enable learners to have conceptual knowledge of organic chemistry to understand detail aspects of physical organic Chemistry. 2. To apply the basic knowledge of chiral chemistry to understand various Stereochemical aspects of Chemistry in detail. 3. To enable learners to understand mechanisms of name reactions and its applications in various pathways of reaction mechanisms. 4. To understand spectroscopic knowledge which provides solutions to problems encountered in structural elucidation of organic compounds.			
Course Learning Outcomes. After completing the course students will be able to: 1. Predict the reactivity of organic compound from its structure. 2. Understand different methods used for determination of Organic Reaction Mechanism. Understand the fundamental concept in stereochemistry by applying various symmetry elements of organic molecule. 3. Acquire the knowledge of chirality by taking examples of symmetrical and unsymmetrical molecule 4. Develop interest in stereochemistry by studying stereochemical features of different classes of organic compounds. 5. Understand Organic spectroscopy by problem solving approach for different class of organic compound.			

Paper III

Course Code: CHEM 503 / CHEM 50311 / 112016150311:

ORGANIC CHEMISTRY-I

Unit-I-PHYSICAL ORGANIC CHEMISTRY [15L]

1.1 Acidity-Basicity:

Different concepts and examples; factors affecting acidity and basicity. Electrophilicity and nucleophilicity. Ambident Electrophiles and Nucleophiles. Difference between nucleophilicity and basicity, electrophilicity and acidity.

1.2 Linear Free Energy Relationships:

Effect of structural factors on reactivity. Hammett equation, substituent and reaction constants. Through conjugative effects of substituents. Linear free energy relationships in the determination of reaction mechanism.

1.3 Arrhenius equation and its application to estimate Eact;

Hammond's postulate, principle of microscopic reversibility; Kinetic vs. thermodynamic control.

1.4 Influence of solvent polarity on reaction rates;

Solvent scales (Y-scale), solvatochromism (Z and ET scales); Ionic strengths and salt effect; Acid-base catalysis Bronsted catalysis equation.

Unit-II STEREOCHEMISTRY [15L]

2.1 Molecules with central chirality. Interconversion of projection formulae:

Molecules with central chirality. Tetrahedral geometry for molecules with asymmetric atom. Examples of chiral molecules with carbon, nitrogen, phosphorous, sulphur and silicon atoms in tetra-coordinated / tri-coordinated states and their relative configurational stabilities. Racemization of nitrogen compounds through pyramidal inversion. Merits and demerits of different projection formulae and interconversion of the same.

2.2 Molecules with two or more chiral centres: Nomenclature for relative configuration for constitutionally unsymmetrical molecules; Erythro-threo and syn-anti. Stereochemistry of constitutionally symmetric molecules with odd and even number of chiral centres; the dissymmetric forms and meso forms. Concept of stereogenic, non-stereogenic, chirotopic, achirotopic and pseudoasymmetric centres. The examples of achirotopic but stereogenic centres and chirotopic but non-stereogenic centres. A lack of direct connection between chirotopicity and stereogenicity.

2.3 Axial and Planar chirality: Principles, stereochemical features, configurational descriptors of axial, planar chirality. Helicity as a sub-class of molecules with chiral axis. Stereochemical features and configurational descriptors of allenes, alkylidene cycloalkanes, spiranes, biaryls (including binaphthyls), ansa compounds, cyclophanes and helicenenes.

2.4 Concept of prochirality, homotopic, enantiotopic and diastereotopic ligands and faces. Criteria based on symmetry and substitution/addition. Notations of prochirality for

all classes of molecules. Notation for molecules with pro-pseudosymmetric centres. Notations for molecules with presence of a chiral and a pro-chiral centres. Top-right mnemonic. Discrimination / recognition of stereo-heterotopic ligands and faces by chemical reagents/catalysts and NMR.

Unit-III METHODS OF C-C BOND FORMATION USING THE CARBONYL FUNCTION [15L]

3.1 Reactivity of carbonyl group, Enols and enolates- Regioselective kinetic and thermodynamic enolate formation using LDA. Different types of aldol condensations under acid and base catalysis

3.2 Generation of dianion derived from active methylene compounds and regioselective C-C bond formation on unstabilized site

3.3 Mechanism, stereochemistry and applications of the following reactions: Claisen, Darzen, Dieckman, Beckman, Knoevenagel, Mannich, Michael, Robinson Annulation and Stobbe.

3.4 Enamines as enolate equivalents. Metalloenamines, Synthesis of enamines and selected C-C bond formation.

Unit- IV SPECTROSCOPY [15L]

4.1 UV-Visible Spectroscopy: Recapitulation of basic concepts and sample handling. Woodward-Fieser rules for calculation of λ_{Max} of conjugated dienes, polyenes, enones and aromatic carbonyl compounds.

Problems based on Woodward-Fieser rules.

4.2 IR Spectroscopy: Recapitulation of basic concepts and sample handling. Group frequencies and their use in detection and identification of functional groups.

4.3 PMR Spectroscopy: Recapitulation of basic concepts and sample handling. Prediction of structure of organic compounds based on the use of chemical shift and J values.

4.4 Mass Spectrometry: Recapitulation of basic concepts and sample handling. Fragmentation Pattern of major classes of organic compounds, Retro-Diels Alder reaction, McLafferty rearrangement and ortho effect.

4.5 Structure determination of organic compounds involving individual or combined use of the above spectral techniques.

References Books:

1. Organic Chemistry, J. Claydens, N. Greeves, S. Warren and P. Wothers, Oxford University Press.
2. Advanced Organic Chemistry, F.A. Carey and R.J. Sundberg, Part A and B, Plenum Press.
3. Stereochemistry: Conformation and mechanism, P.S. Kalsi, New Age International, New Delhi.
4. Stereochemistry of carbon compounds, E.L. Eliel, S.H. Wilen and L.N. Manden, Wiley.
5. Stereochemistry of Organic Compounds- Principles and Applications, D. Nasipuri. New International Publishers Ltd.
6. March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure, Michael B. Smith, Jerry March, Wiley.
7. Advanced Organic Chemistry: Reactions and mechanism, B. Miller and R. Prasad, Pearson Education.
8. Advanced Organic Chemistry: Reaction mechanisms, R. Bruckner, Academic Press.

PROGRAM(s): M.Sc.-I			SEMESTER: I
			Course Code: (CHEM 505/ CHEM 50511 / 112016150511 Course Title:-Analytical Chemistry-I
Teaching Scheme			Evaluation Scheme
Lectures (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 50)	Semester End Examination (Marks- 50)
04	04	50	50
Course Objectives: 1. To enable learners to have comprehensive knowledge, understanding of the various types of instruments. 2. To create, select and apply appropriate techniques, resources and modern technology in multidisciplinary environment. 3. A research oriented learning that develops analytical and integrative problem-solving approaches. 4. To get hands on various advance techniques with laboratory skills on preparation of various solutions, design of some reactions with its work up and isolation. 5. To enable learners to perform various tasks assigned to them at the workplace in industry and academia to meet the job requirements as per global standards.			
Course Learning Outcomes. After completion of this Course, the learner will be able to: 1. Understand various terms used in analytical chemistry. 2. Students will be able to classify the analytical methods; select a method for analysis based on performance. 3. Learn the details of atomic absorption spectrometry and its applications to biological and environmental samples. 4. To learn the applications of UV-Visible spectroscopy for the quantitative determination of trace metals in food, blood and urine samples. 5. In AES, construction and working of plasma sources and their applications in geological, metallurgical, food, agricultural, environmental and biological samples. 6. In IR, the concept of Fourier Transform spectroscopy, various instrumentation like dispersive, non-dispersive and FT-types of instruments and their uses in the detection of CO and CO₂ in the atmosphere. 7. Also the practical and theory needs to know to the students about the principle and working of Gas Chromatography and High Performance Liquid Chromatography techniques including discussion on carrier gas/liquid supply, sample introduction on-column and injection techniques; analytical columns; detectors, mode of separation and applications in various fields with examples.			

Course Code: CHEM 505 / CHEM 50511 / 112016150511

ANALYTICAL CHEMISTRY- I

Unit I: Fundamentals in Analytical Chemistry [15L]

- 1.1 Terms: Precision and Accuracy recapitulations and applications Criteria for the selection of methods. Regression analysis with respect to applications in research, Chemometrics. [6L]
- 1.2 Concepts of optical methods: LASER as a source in optical methods, wavelength selectors and their functioning, and effective bandwidth. [4L]
- 1.3 Concepts of Spectroscopy: Concept of Fourier Transform Spectroscopy, IR spectroscopy: Sample handling, instrumentation, advantages of FT-IR. [5L]

Unit II: Atomic and Molecular Spectroscopy: Instrumentation and Applications [15L]

- 2.1 Atomic Absorption Spectrometry: Recapitulation, Hydride generation technique for trace metal analysis, Cold Vapor technique for the determination of mercury, Importance of electro thermal analyzer in biological samples. [4L]
- 2.2 Atomic Emission Spectroscopy based on plasma sources, advantages of plasma sources. Applications including sample handling in geo-analysis, metallurgy, agriculture, food samples and environmental analysis. [5L]
- 2.3 Infrared Spectroscopy (Applications): Non-dispersive IR for detection of environmental gases. [2L]
- 2.4 UV-Visible Spectroscopy: Derivative and dual wavelength spectroscopy, molecular transitions, application to trace analysis (d-d transition and charge transfer), biological samples and simultaneous determination. [4L]

UNIT III: Separation methods [15L]

- 3.1 Solvent Extraction and Solid Phase Extraction: Recapitulation of basic concepts of solvent extraction and solid phase extraction. Liquid anion and cation exchangers. Mechanism of extraction. Crown ethers as extractants. Extraction equilibria of metal chelates. Factors favoring solvent extraction of metal chelates. Sorbents. [7L]
- 3.2 Chromatography: General classification of chromatographic methods. Efficiency, resolution, selectivity and separation capability. Broadening of chromatographic peak and van Deemter equation. Optimization of chromatographic conditions. Qualitative and Quantitative Analysis [8L]

UNIT IV: Column chromatography techniques [15L]

4.1 Gas Chromatography:

Recapitulation of concepts Principle of GLC and GSC; Instrumentation: carrier gas supply, sample introduction systems, packed & capillary columns; choice of detectors and comparative account of Recapitulation of TCD, FID, ECD & thermionic detector. Use of Temperature programming in separations [4L]

- 4.2 Applications of GC in environmental, pharmaceuticals, agrochemical, food, chemical analysis and forensic sciences. [3L]
- 4.3 High Performance Liquid Chromatography (HPLC): Principles of HPLC Types of

liquid chromatography, Recapitulation of HPLC, Instrument for LC: mobile phase reservoir and solvent treatment systems, pumping systems, sample introduction systems, columns, Detectors: UV, RI, EC and diode array. [5L]

4.4 Applications of HPLC in environmental, pharmaceuticals, agrochemical, food, chemical analysis and forensic sciences. [3L]

References:

1. *Analysis*, 5th ed., Philadelphia: Saunders College Publishing, 1998.
2. D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch, *Fundamentals of Analytical Chemistry*, 8th ed., Philadelphia: Saunders College Publishing, 2004.
3. G. D. Christian, *Analytical Chemistry*, 6th ed., John Wiley and Sons, New York, 2003.
4. G. H. Jeffery, J. Bassett, J. Mendham and R. C. Denney, *Vogel's Textbook of Quantitative Chemical Analysis*, 6th ed., ELBS, Longman Scientific & Technical, England, 2002.
5. H. H. Willard, L. L. Meritt, jr., J. A. Dean and F. A. Settle, Jr., *Instrumental Methods of Analysis*, 6th ed., CBS 1986.
6. R. D. Braun, *Introduction to Instrumental Analysis*, McGraw Hill, 1987.
7. G. H. Morrison and H. Freiser, *Solvent Extraction in Analytical Chemistry*, John Wiley & Sons, New York, 1966.
8. S. M. Khopkar, *Basic concept of Analytical Chemistry*, 3rd ed., Age International Publisher 2008.
9. T. Sekine and Y. Hasegawa, *Solvent Extraction chemistry*, Marcel Dekker, 1977.
10. P. G. Swell and B. Clarke, *Chromatographic Separations, Analytical Chemistry by open learning*, John Wiley & Sons, New York, 1987.
11. S. Sindsay, *High Performance Liquid Chromatography, Analytical Chemistry by open learning*, John Wiley & Sons, New York, 1987.
12. A. J. Bard and L. R. Faulkner, *Electrochemical Methods*, Wiley, New York, 1980
13. A. M. Bond, *Modern Polarographic Methods in Analytical Chemistry*, Marcel Dekker, New York, 1980.
14. L. C. Thomas and G. J. Chamberline, *Colorimetric Analytical Methods*, 9th ed., The Fintometer Ltd., Salisbury, England, 1980.
15. T. C. Morrili, R. m. Silverstein and G. C. Bassler, *Spectrometric Identification of Organic Compounds*, Wiley, 1981.
16. Vogel's Text Book of Quantitative Organic Analysis, 2th ed. ELBS.
17. R. A. Day, Jr. and A. L. Underwood, *Quantitative Analysis*, 6th ed., Prentice Hall of India Pvt. Ltd., New Delhi, 1993.
18. Jared L. Anderson, Alain Berthod, Veronica Pino, and Apryll M. Stalcup (ed), *Analytical Separation Science (Volume 1-5)*. WILEY-VCH 2015.
19. Jack Cazes (ed) *Ewing's Analytical Instrumentation Handbook*, 3rd edition, Marcel Dekker 2009.
20. R. Kellner, J.M. Mermet, M. Oto, M. Valcarcel, H. M. Widmer (ed), *Analytical Chemistry: A modern Approach to Analytical Science* 2nd

edition. WILEY-VCH 2004.

21. Solid phase Extraction- Principles, Techniques and Applications, N. J. K. Simpson, Marcel Dekker, New York, (2000).

Elective II

PROGRAM(s): M.Sc.-I			SEMESTER: I
			Course Code: (CHEM 50512/112016150512) Course Title:-Applied Industrial Chemistry-I
Teaching Scheme			Evaluation Scheme
Lectures (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 50)	Semester End Examination (Marks- 50)
04	04	50	50
Course Objectives: 1. To enable learners to have comprehensive knowledge, understanding of the types of instruments with operations and automated methods of analysis. 2. To apply the basic knowledge of quality systems, quality audit and quality managements,. 3. To enable learners to perform various tasks assigned to them at the workplace in industry and academia to meet the job requirements as per global standards. 4. To provide solutions to problems encountered in the field of analysis and research.			
Course Learning Outcomes. After completing the course students will be able to: 1) predict the reactivity of organic compound from its structure. 2) understand different methods used for determination of Organic Reaction Mechanism 3) understand the fundamental concept in stereochemistry by applying various symmetry elements of organic molecule. 4) acquire the knowledge of chirality by taking examples of symmetrical and unsymmetrical molecule. 5) develop interest in stereochemistry by studying stereochemical features of different classes of organic compounds 6) identify the nomenclature of various stereochemical phenomena			

Course Code: CHEM 50512/ 112016150512

Applied Industrial Chemistry-I

Unit-I [15 L]

Perfumery Chemicals:

Essential oils and their application in cosmetic industries, synthetic preparation of eugenol, geraniol, phenyl ethanol, civetone, Yara-Yara, β -ionone, synthetic musk, musk ketone, ambrette, and xylene, phenylacetic acid and its esters derivatives, benzyl acetate, Extraction process of naturally occurring perfumery like sandalwood oil, rose oil, and jasmine.

Unit-II [15 L]

Petrochemicals and Biofuels:

Petroleum refining, chemicals derived from ethylene, xylene, and naphthalene.

Types of biofuels (bioethanol, biodiesel), synthesis, properties, standard specification and uses of biofuels, Influence of biofuels on the environment and economy, modification of vegetable oils as biodiesel.

Unit-III [15L]

Paper, pulp, and Leather industry:

Introduction, types of pulping, types, and quality of paper, lignin and lignans, recycling. Introduction, constituents of animal skin, manufacture process, tanning: leather, vegetable, chrome; tanning effluents, pollution control.

Unit-IV [15 L]

Semiconductors in Electronic Industries

Introductions, applications of phosphorus, gallium, indium, germanium and arsenic and their composites in electronic industries, ferrite and magnetic materials, synthesis and characterizations of organic semiconductors, band gap engineering and its applications,.

Recommended Books

1. G. T. Austin, Shrieves Chemical Process Industries, Tata McGraw Hill publication, 2011.
2. M. G. Rao and M. Marshall, Dryden's Outline of Chemical Technology, East west press, 1997.
3. Shah and Pandey, Chemical Technology , Sangam Books Limited, 2000
4. K. R. Smith, Biofuels: Air Pollution and Health, East-West Center, Honolulu, USA, 1987.
5. G. M. Gübitz, M. Mittelbach, M. Trabi, biofuels and Industrial Products from Jatropha Curcas, 1997.
6. B. Billot and F. V. Wells, Perfumery Technology, 1981.
7. P. G .More, Comprehensive Industrial Chemistry, Pragati Prakashan 2018.
8. A. D. Covington, Tanning Chemistry: The Science of Leather, 2015.
9. P. Y. Yu and M. Cardona Fundamentals of Semiconductors: Physics and Materials Properties, 4th Edition, 2010, Springer
10. L. Alcacer, Electronic Structure of Organic Semiconductors: Polymers and Small Molecules, IOP Science and Morgan and Claypool Publishers, UK 2018.

PROGRAM(s): M.Sc.-I		SEMESTER: I		
Course: Practical		Course Code: CHEM504 / 112016150411 Course Title:- Chemistry Practical-I		
Teaching Scheme				Evaluation Scheme
Practical (Hours per week)	Tutorial (Hours per week)	Credit	Continuous Assessment (CA) (Marks-25)	Semester End Examination (Marks- 25)
16	NA	02	25	25
Learning Objectives: 1. To Gain knowledge of the advanced concepts in pH metry, quantum mechanics, potentiometry and conductometry experiments. 2. To understand advance concept of thermodynamics and chemical kinetics in the chemical reactions. 3. To develop scientific temper and research based skills accomplish to encountered in the field of research. 4. The learners will characterize different coordination compounds with the help of conductivity measurements, electronic and magnetic measurements and spectroscopic measurements. 5. The learners will learn to open up different types of Alloys/Ores and carry out a Quantitative Analysis of the elements present in them. Inorganic: 1.To gain ability to perform inorganic synthetic reactions. 2.To characterize synthesized compounds using different analytical methods.				
Course Outcomes: 1. To usage of subject fundamentals-principles with practical knowledge to design experiments, analyze and interpret data so as to reach to proper conclusions. 2. Learner will train the handling of equipments like potentiometer, conductivity meter, colorimeter and spectrophotometer. 3. Learner will develop scientific temper and research-based skills accomplish to encountered in the field of research. 4. Apply the knowledge of quantitative analysis for the determination of metals from ores/alloys. 5. Able to understand the analysis of various commercial inorganic compounds. Inorganic Chemistry 1.The learner will learn to synthesize different coordination compounds. 2. The learner will gain knowledge and hands on experience of different analytical methods to characterize the synthesized coordination compounds.				

Chemistry Practical-I

Physical Chemistry Practical-I

Instrumental Experiments*:

Conductometry and Potentiometry

1. Titration of a mixture of trichloroacetic acid, monochloroacetic acid and acetic acid with sodium hydroxide conductometrically.
2. Verification of Ostwald's dilution law and determination of the dissociation constant of a weak monobasic acid conductometrically.
3. Study of the effect of substituent on dissociation constant of acetic acid conductometrically.
4. Determination of concentrations and amounts of iodide, bromide and chloride in the mixture by potentiometric titration with silver nitrate.
5. Determination of solubility product of silver chloride potentiometrically using a concentration cell.
6. Determination of the formula of the silver-ammonia complex by potentiometric method.
7. Determination of pK values of phosphoric acid by potentiometric titration with sodium hydroxide using a glass electrode.
8. Determination of acidic and basic dissociation constants of an amino acid and hence the iso-electric point of the acid.

(* Any four Physical Chemistry experiments to be performed from the above list)

Inorganic Chemistry Practical-I

Synthesis, Purification and Analysis of the following Inorganic Preparations:

1. Hexamminenickel(II) sulphate
2. Potassium dioxalatocuprate(II) dihydrate
3. Potassium trioxalato chromate (III) trihydrate
4. Potassium trioxalatoaluminate(III) trihydrate

Organic Chemistry Practical-I

Separation of Binary mixture by microanalytical technique

Separation of the binary mixtures using physical and chemical methods. Identification of one of the compounds and checking its purity by TLC. Preparation of the derivative of one of the compounds. The following types are expected: Solid-Solid mixtures. Compounds from the same or different chemical classes. The candidate is expected to carry out the separation of 4 mixtures.

Reference Books:

1. Elementary Practical Organic Chemistry Part-I small-scale preparations, A.L. Vogel (Longman)
2. Laboratory Manual of Organic Chemistry, B.B. Dey and M.V. Sitaram revised by T.R Govindachari (Allied Publishers Ltd.)

Analytical Chemistry Practical-I

Non-Instrumental Experiments*:

1. Calibration of a 10 mL pipette by weighing at room temperature and reporting the result with statistical data.
2. Determination of Manganese from pyrolusite by potassium permanganate method.
3. Estimation of vitamin C by titration with potassium bromate.
4. Determination of number of nitro group in organic compound by titanium method.
5. Separation and determination of Fe (III) and Mg (II) /Zn (II) using ethyl acetate /ether as a solvent.
6. Determination of exchange capacity of cation ion-exchange resin.

(* Any four Analytical Chemistry experiments to be performed from the above list)

Research Methodology

PROGRAM(s): M.Sc.-I			SEMESTER: I
			Course Code: (CHEM 506 / 112016150611) Course Title:- Research Methodology
Teaching Scheme			Evaluation Scheme
Lectures (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 50)	Semester End Examination (Marks- 50)
04	04	50	50
Course Outcomes: At the end of the Course, 1. To enable the student to be able to extract information from journals and digital resources. 2. Understanding tools to analyse the data, writing and presenting scientific papers. 3. Safe working procedure And ethical handling of chemicals. 4. Describe research, identification of research problems, and preparation of proposals. 5. Practice ethics in all the domains of research. 6. Analyze the results using mathematical and statistical tools.			
Course Learning Outcomes. 1. To create awareness and understanding the terms like intellectual property, patents, copyright, industrial designs, trademarks, geographical indications etc. 2. To know trade secrets, IP infringement issues, economic value of intellectual property and study of various related international agreements. 3. To explore cheminformatics to facilitate molecular modeling and structure elucidations. 4. To apply the knowledge gained about various chemistry principles, techniques and tools in drug designing, target identification and validation, lead finding and optimization..			

Course Code: CHEM 506 / 112016150611
Research Methodology

Unit-I LITERATURE SURVEY

[15L]

Print:

[5L]

Primary, Secondary, Tertiary sources,

Journals:

Journal abbreviations, abstracts, current titles, reviews, monographs, dictionaries, text-books, current contents, Introduction to Chemical Abstracts and Beilstein, Subject Index, Substance Index, Author Index, Formula Index, and other Indices with examples.

Digital:

[5L]

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

Information Technology and Library Resources:

[5L]

The Internet and World Wide Web, Internet resources for chemistry, Finding and citing published information.

Unit-II DATA ANALYSIS

[15L]

The Investigative Approach:

Making and recording Measurements, SI Unit-s and their use, Scientific methods and design of experiments.

Analysis and Presentation of data:

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

Unit-III METHODS OF SCIENTIFIC RESEARCH & WRITING SCIENTIFIC PAPERS

[15L]

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

Writing scientific papers:

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

Unit IV: CHEMICAL SAFETY & ETHICAL HANDLING OF CHEMICALS

[15L]

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

waste, disposal of chemicals in the sanitary sewer system, incineration and transportation of hazardous chemicals.

Reference books:

1. Dean, J. R., Jones, A. M., Holmes, D., Reed, R., Weyers, J., & Jones, A., (2011), *Practical skills in chemistry*, 2nd Ed., Prentice Hall, Harlow.
2. Hibbert, D. B., & Gooding, J. J., (2006), *Data analysis for chemistry*, Oxford University Press.
3. Topping, J., (1984), *Errors of observation and their treatment*, 4th Ed. Chapman Hill, London.
4. Harris, D. C., (2007), *Quantitative chemical analysis*, 6th Ed., Freeman Chapters 3-5
5. Levie, R. de., (2001), *How to use Excel in analytical chemistry and in general scientific data analysis*, Cambridge Univ Press 487 pages.
6. Chemical safety matters-IUPAC-IPCS, Cambridge University Press, 1992.
7. OSU safet manual 1.01

SEMESTER: II

PROGRAM(s): M.Sc.-I		SEMESTER: II		
Course: Paper-I		Course Code: CHEM507 / 112016250711 Course Title:- Physical Chemistry-II		
Teaching Scheme				Evaluation Scheme
Lectures (Hours per week)	Tutorial (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 50)	Semester End Examination (Marks- 50)
04	–	04	50	50
Learning Objectives: 1. To gain knowledge of the advanced concepts in quantum mechanics, applications of HMO theory, chemical kinetics and molecular dynamics. 2. To understand the advanced concepts in chemical thermodynamics and photochemistry. 3. To develop the skill to solve the problems encountered in the field of quantum and electrochemistry. Course outcomes:- 1. To learn the concept of quantum chemistry and able to solve problems related to 1D box, 2D box, 3D box and to explain the role of operators in quantum chemistry. 2. To understand the use of Schrodinger wave equation in one and two electron systems along with applications of HMO. 3. To develop the skill to solve the problems based on chemical thermodynamics, molecular dynamics and quantum Chemistry. 4. To apply the concept of Jabolonski mechanism in photochemical reactions. 5. Learners will get knowledge of advanced chemical kinetics and molecular dynamics.				

Semester II
Course code: CHEM 507 / 112016250711
PHYSICAL CHEMISTRY-II

Unit-I THERMODYNAMICS-II

[15 L]

Partial molar quantities, chemical potential for ideal gas, gas mixtures, Gibbs free energy of mixing, entropy and volume of mixing, Gibbs Duhem equation, Variation of chemical potential with pressure and temperature.

Excess functions (Chemical potential, Gibbs free energy and enthalpy function), Equilibrium constant and its dependence on temperature and pressure.

Unit-II APPLIED ASPECTS OF QUANTUM CHEMISTRY

[15]

Application of Quantum Chemistry in Vibrational motion:

The one-dimensional harmonic oscillator: Classical and Quantum mechanical treatment, Hermite polynomials, Wavefunctions, probability densities, and energy levels

Application of Quantum Chemistry in Rotational motion:

Spherical polar coordinates, Separation of variables, The rigid rotor: Legendre functions, energy levels and wave functions*.

Application of Quantum Chemistry in Atomic system:

The hydrogen atom and hydrogen-like ions, Reduction of the two-particle problem to two one-particle problems, Solutions to $R(r)$, $\Theta(\theta)$ and $\Phi(\phi)$ equations*, Hydrogen-like orbitals, sketches of wave functions (ψ) and probability densities ($|\psi|^2$), polar plots of angular parts, orbital and spin angular momentum, spin orbitals.

Unit-III APPLICATIONS OF THERMODYNAMICS AND ELECTROCHEMISTRY
[15L]

Experimental techniques for determination of thermodynamic quantities: Bomb Calorimeter, Coffee Cup Calorimeter, Differential Scanning Calorimeter.

Exergonic and endergonic reactions, Thermodynamics of ATP,

Debye-Hückel theory of strong electrolyte, ionic atmosphere, activity coefficients of electrolyte solutions- Debye-Hückel limiting law, extension to higher concentrations.

Electrolytic conductance and ion-ion interactions, Debye-Hückel-Onsager equation, validity of equation, Debye-Falkenhagen effect, Wien effect, weak electrolyte and Debye-Huckel theory.

Determination of thermodynamic functions of cell reaction.

Electrochemistry in water and effluent treatment.

Unit-IV MOLECULAR REACTION DYNAMICS **[15L]**

Collision theory, steric factor, activated complex theory, reaction coordinate and transition state, thermodynamic aspects, reaction between ions, salt effects, and dynamics of molecular collisions.

Homogeneous catalysis – enzyme catalysis, Michaelis-Menten mechanism, acid base catalysis.

Heterogeneous catalysis – Examples: hydrogenation, oxidation, cracking and forming.

****Derivation not expected***

Note: Numerical and theoretical problems from each Unit- are expected.

Reference books:

1. Peter Atkins and Julio de Paula, *Atkin's Physical Chemistry*, 7th ed., Oxford University Press, 2002.
2. K. J. Laidler and J. H. Meiser, *Physical Chemistry*, 2nd ed., CBS Publishers and Distributors, New Delhi, 1999.
3. Robert J. Silby and Robert A. Alberty, *Physical Chemistry*, 3rd ed., John Wiley and Sons (Asia) Pte. Ltd., 2002.
4. Ira R. Levine, *Physical Chemistry*, 5th ed., Tata McGraw-Hill, New Delhi, 2002.
5. G. W. Castellan, *Physical Chemistry*, 3rd ed., Narosa Publishing House, New Delhi, 1983.
6. D. A. McQuarrie and J. D. Simon, *Physical Chemistry - a molecular approach*, Viva Books Private Limited, New Delhi, 1998.
7. S. Glasstone, *Text Book of Physical Chemistry*, 2nd ed., McMillan and Co. Ltd., London, 1962.
8. Derek Pletcher, *Industrial Electrochemistry*, London New York.
9. S. Glasstone, *Thermodynamics for Chemists*, Affiliated East-West Press, New Delhi, 1964.
10. Ira N. Levine, *Quantum Chemistry*, 5th ed., Pearson Education (Singapore) Pte. Ltd., Indian Branch, New Delhi, 2000.
11. J. P. Lowe, *Quantum Chemistry*, 2nd ed., Academic Press, New York, 1993.
12. R. Anantharaman, *Fundamentals of Quantum Chemistry*, McMillan India Limited, 2001.
13. Mahendra R. Awode, *Quantum Chemistry*, S. Chand and Co. Ltd., New Delhi, 2002.
14. R. K. Prasad, *Quantum Chemistry*, 2nd ed., New Age International Publishers, 2000.
15. D. O. Hayward, *Quantum Mechanics for Chemists*, Royal Society for Chemists, 2002.
16. Samuel Glasstone, *An introduction to electrochemistry*, East West edition, New Delhi.
17. G. L. Agarwal, *Basics Chemical kinetics*, Tata McGraw Hill, New Delhi.
18. D. R. Crow, *Principles and Applications of Electrochemistry*, 4th edition, Blackie, London, 1994.
19. J.O'm. Bockris and A. K. N. Reddy, *Modern Electrochemistry*-Vol. 1 and 2, Plenum press, New York.
20. R. A. Robinson and R.H. Stokes, *Electrolyte Solutions*, 2nd Edition, Butterworths, London 1959.
21. R. P. Rastogi, R. R. Mishra, *An Introduction to Chemical Thermodynamics*, Vikas Publishing House Pvt. Ltd.
22. K. J. Laidler, *Chemical Kinetics*, 3rd ed., Pearson Education.

List of Books for further reading:

1. W. G. Davis, *Introduction to Chemical Thermodynamics – A Non-Calculus Approach*, Saunders, Philadelphia, 1972.
2. I. M. Klotz and R. M. Rosenberg, *Chemical Thermodynamics*, 5th ed., John Wiley and Sons, Inc., 1994.
3. Peter A. Rock, *Chemical Thermodynamics*, University Science Books, Oxford University Press, 1983.

PROGRAM(s): M.Sc.-I		SEMESTER: II		
Mandatory Course -II		Course Code: CHEM 508/ 112016250811 Course title : Inorganic Chemistry-II		
Teaching Scheme				Evaluation Scheme
Lectures (Hours per week)	Tutorial (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 50)	Semester End Examination (Marks- 50)
04	–	04	50	50
Learning Objectives: 1. The course aims at generating awareness about the positive as well as negative aspects of inorganic chemicals on biophysical processes and our environment. 2. The course aims at developing theoretical approach to analyze symmetry, structure and physical properties of molecules. 3. The course aims to impart knowledge of basic concepts and recent advances in nano-sciences.				
Course Outcomes: 1. The learner will gain understanding regarding the different crystal structures. They will also gain knowledge about the various aspects of nanoscience and nanotechnology. 2. The learner will be able to correlate the structure, symmetry and properties interrelationship of different molecules. 3. The learners will get awareness about the effect of toxic chemicals and radiations on our environment. 4. The learners will understand the role of different metallic compounds in various biological processes and applications.				

Paper II

Course Code: CHEM-508 / 112016250811

INORGANIC CHEMISTRY-II

(Total lectures: 60, Credits: 4)

Unit I Solid State Chemistry and Nanomaterials 15 L

(A) Solid State Chemistry

- (i) Recapitulation of basic solid state chemistry.
- (ii) Structures of compounds of the type: AB [zinc sulfide (ZnS), nickel arsenide (NiAs)], AB₂ [fluorite (CaF₂), antifluorite (Na₂O), rutile (TiO₂) and layer structures viz., cadmium chloride (CdCl₂) and cadmium iodide, (CdI₂)].

(B) Nanomaterials

- (i) Introduction to nanomaterials.
- (ii) Preparative methods: Ball milling, Solvothermal, Sol-gel, Biological methods
- (iii) Basic characterization techniques for nanomaterials.
- (iv) Applications of nanomaterials.

Unit II Molecular Symmetry and Group theory 15 L

- (i) Symmetry elements and symmetry operations, product of symmetry operations, Cartesian coordinate system and symmetry elements.
- (ii) Symmetry classification of molecules: point groups, mathematical requirement for a point group, systematic assignment of point groups to molecules.
- (iii) Identification of molecular point groups of molecules having low symmetry, high symmetry and special symmetry.
- (iv) Descent in symmetry of molecules with substitution.
- (v) Group multiplication tables, classes of symmetry operations. Matrix representation of symmetry elements and point groups.
- (vi) Construction of C_{2v} character table.
- (vii) Symmetry criteria for optical activity, Symmetry restrictions on dipole moment.

Unit III Environmental Chemistry 15 L

- (i) Chemical Toxicology: MSDS, LD50, toxic chemicals in the environment, biochemical effects and speciation of toxic elements like arsenic, lead, mercury and cadmium; antidotes for the toxic elements. Biochemical effects of fluoride and pesticides.
- (ii) Radiation pollution: Sources and biological implication of radioactive pollutants.
- (iii) Non-conventional energy sources: Solar power, Wind power, Geothermal energy, Ocean thermal energy conversion (OTEC), Tidal power.

Unit IV Bioinorganic Chemistry 15 L

- (i) Biological oxygen carriers: myoglobin, hemoglobin, Hill equation, Bohr effect and their implications, hemerythrin and hemocyanine.
- (ii) Reactions of dioxygen in biological system with examples of peroxidase, monooxygenase, superoxide dismutase and oxidase reactions. Biochemical effect of cyanide.
- (iii) Nitrogen fixation: Nitrogenase, Hydrogenases.
- (iv) Metal ion transport and storage: transferrin and Ferritin.

- (v) Metal ions in medicines: Introduction to metallodrugs, cis-platin and related compounds.

Reference books

Unit I

1. R. West, Solid State Chemistry and Its Applications, John Wiley & Sons, 1987.
2. N. R. Rao and G. Gopalkrishnan, New Directions in solid state chemistry, 2nd Ed., Cambridge University Press, 1997.
3. sley E. Smart and Elaine A. Moore, Solid State Chemistry – An introduction, 3rd Ed., Taylor and Francis, 2005.
4. R. Puri, L. R. Sharma and K. C. Kalia, Principles of Inorganic Chemistry, Milestone, 2014.
5. K. Kulkarni, Nanotechnology-Principles and Practices, Capital Publishing Co., 2007.
6. Cao, Nanostructures and Nanomaterials- Synthesis, Properties and Applications, Imperial college Press, 2004.
7. N. R. Rao, A. Muller and A. K. Cheetham, The Chemistry of Nanomaterials-Synthesis, Properties and Applications, Volume-I, Wiley VCH, 2004.

Unit II

1. V.Reddy, Symmetry and Spectroscopy of Molecules, 2nd Ed., New Age International Publishers2009.
2. L. Carter, Molecular Symmetry and Group Theory, John Wiley & Sons, 1998.
3. S. Kunju and G. Krishnan, Group Theory and its Applications in Chemistry, PHI-Learning, 2010.
4. A. Cotton, Chemical Applications of Group Theory, 2nd Ed., Wiley Eastern Ltd., 1989.

Unit III

1. K. De, Environmental Chemistry, 7th Ed., New Age International Publishers, 2007.
2. E. Girard, Principles of Environmental Chemistry, 2nd Ed., Jones and Bartlett publishers, 2011.
3. Kaur, Environmental Chemistry, Pragati Prakashan, 8th Ed., 2014.

Unit IV

1. Bertini, H.B.Gray, S. J. Lippard and J.S. Valentine, Bioinorganic Chemistry, 1st Indian Ed., Viva Books, 1998.
2. Banerjea, Coordination Chemistry, Tata Mc Graw Hill, 1993.
3. N. Mukherjee and A. Das, Elements of Bioinorganic Chemistry, Dhuri&Sons, 1988.

General Inorganic Chemistry Reference books

1. D. Banerjea, Coordination Chemistry, Tata McGraw Hill, 1993.
2. P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, Inorganic Chemistry, 5th Ed., Oxford University Press, 2010.
3. R. Gopalan and V. Ramlingam, Concise Coordination chemistry, Vikas Publishing house Pvt Ltd., 2001
4. R. H. Crabtree, The Organometallic Chemistry of the Transition Metals, 5th Ed.,

Wiley Interscience, 2009.

5. G. O. Spessard and G. L. Miessler, Organometallic Chemistry, Prentice-Hall, 1977.
6. K. F. Purcell and J. C. Klotz, Inorganic Chemistry, Saunders, 1977.
7. B. Douglas, D. H. McDaniel and J. J. Alexander, Concepts and Models of Inorganic Chemistry, 2nd Ed., John Wiley & Sons, 1983.
8. G. Miessler and D. Tarr, Inorganic Chemistry, 3rd Ed., Pearson Education, 2004.
9. R. L. Madan and G. D. Tuli, Inorganic Chemistry, 5th Ed., S. Chand, 2012.
10. J. D. Lee, Concise Inorganic Chemistry, 5th Ed., Wiley, 2012.
11. B. R. Puri, L. R. Sharma and K. C. Kalia, Principles of Inorganic Chemistry, Milestone, 2014.
12. G. Raj, A. Bhagi and V. Jain, Group Theory and Symmetry in Chemistry, 3rd Ed., Krishna Prakashan, 2010.
13. P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, Inorganic Chemistry, 5th Ed., Oxford University Press, 2010.
14. R. S. Drago, Physical Methods in Inorganic Chemistry, Affiliated East-West Press Pvt. Ltd., 2014.
15. G. S. Sodhi, Fundamental Concepts of Environmental Chemistry, 3rd Ed., Narosa Publishing House, 2013.
16. S. S. Dara and D. D. Mishra, A Textbook of Environmental Chemistry and Pollution Control, S. Chand & Company Ltd., 2012.
17. S. K. Banerji, Environmental Chemistry, 2nd Ed., Prentice-Hall of India, 2005.
18. R. A. Bailey, H. M. Clark, J. P. Ferris, S. Krause and R. L. Strong, Chemistry of Environment, 2nd Ed., Academic Press, 2005.
19. R. W. Hay, Bioinorganic Chemistry, Ellis Harwood, 1984.
20. J. A. Cowan, Inorganic Biochemistry-An introduction, VCH Publication, 1993.
21. S. J. Lippard and J. M. Berg, Principles of Bioinorganic Chemistry, University Science Publications, Mill Valley, California, 1994.
22. P. J. Durrant and B. Durrant, Introduction to Advanced Inorganic Chemistry, Oxford University Press, 1967.
23. R. L. Dekock and H.B. Gray, Chemical Structure and Bonding, The Benjamin Cummings Publishing Company, 1989.
24. R. Sarkar, General and Inorganic Chemistry, Books & Allied (P) Ltd., 2001.
25. C. M. Day and J. Selbin, Theoretical Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., 1985.
26. J. N. Murrell, S. F. A. Kettle and J. M. Tedder, The Chemical Bond, Wiley, 1978.
27. G. A. Jeffrey, An Introduction to Hydrogen Bonding, Oxford University Press, Inc., 1997.
28. W. W. Porterfield, Inorganic Chemistry-A Unified Approach, 2nd Ed., Academic Press, 1993.
29. L. V. Azaroff, Introduction to solids, Tata McGraw Hill Book Co, 1977.
30. H. V. Keer, Principles of Solid State, Wiley Eastern Ltd., 1993.

PROGRAM(s): M.Sc.-I			SEMESTER: II
			Course Code: (CHEM 509 / CHEM50911/ 112016250911) Course Title:-Organic Chemistry-II
Teaching Scheme			Evaluation Scheme
Lectures (Hours per week)	Credit	Continuous Assessment (CA) (Marks-50)	Semester End Examination (Marks- 50)
04	04	50	50
Course Objectives: 1. To gain knowledge of aromaticity and understand Nomenclature system and various other concepts related to aromaticity 2. To understand various rules of reaction mechanism and various new concepts of elimination and substitution reactions. 3. To introduce new aspects of reaction mechanism and stereo chemical behaviors of reaction mechanism. 4. To study various organic reagents and its applications in synthetic organic Chemistry.			
Course outcomes: - After completing the course students will be able to: 1) Recognize the type of mechanism & intermediates involved in the given organic reaction and to prove mechanism for the reaction. 2) Identify the ways to modify aliphatic and aromatic compounds via Nucleophilic and Electrophilic substitution reactions. 3) Predict the mechanism and stereochemistry of important organic reactions. 4) Understand and write the mechanism of rearrangement reactions with stereochemistry and its applications. 5) Understand the HOMO-LUMO concept and its significance in organic chemistry. 6) To understand and recognize use of reagents in various functional group modifications.			

Semester II

Course Code: CHEM-509 / CHEM 50911/ 112016250911

ORGANIC CHEMISTRY-II

UNIT- I: PHYSICAL ORGANIC CHEMISTRY AND AROMATICITY [15L]

- 1.1 Idea about molecular orbitals, application to Hydrogen molecule, ethylene molecule and carbonyl group, **a qualitative approach**. Empirical idea about magnitude of coefficients in molecular orbitals. Discussion on unequal sizes of coefficients in 1,3-butadiene. Relative energies of FMOs of hard/soft electrophiles and nucleophiles. Identification of hard / soft electrophilic centres in allylcation and hard / soft nucleophilic centres in allyl anion. Ambident nucleophiles and ambident electrophiles.
- 1.2 Structural, thermodynamic and magnetic criteria for aromaticity. Shielding deshielding effects in NMR due to ring current, DRE, REPE, London diamagnetism, diamagnetic exaltation.
- 1.3 Huckel's $(4n+2)$ pi electron rule and idea about closed shell configuration. Frost-Musulin diagram.
- 1.4 Concept about Aromatic, antiaromatic and Homoaromatic compounds. Aromaticity of benzenoid systems, annulenes, five-membered and six-membered heterocyclic compounds with one hetero atom, metallocenes, azulenes, tropyliumcation and conjugated monocyclic molecules with exocyclic double bond.

Unit-II: ELIMINATION AND NUCLEOPHILIC SUBSTITUTION REACTIONS [15L]

- 2.1 Types of elimination reactions, E_1 and E_2 mechanisms
- 2.2 Orientation of elimination reactions: Saytzeff and Hoffmann rules. E_2 - reactions of vinyl halide, E_{1cB} mechanism. Nomenclature for relative configuration for constitutionally unsymmetrical molecules; Erythro-threo and syn-anti. Stereochemistry of constitutionally symmetric molecules with odd and even number of chiral centres; the dissymmetric forms and meso forms. Concept of stereogenic, non-stereogenic, chirotopic, achirotopic and pseudoasymmetric centres. The examples of achirotopic but stereogenic centres and chirotopic but non-stereogenic centres. A lack of direct connection between chirotopicity and stereogenicity.
- 2.3 Pyrolytic elimination: Chugaev reaction, Cope reaction, Hoffmann's and Pyrolysis of acetates.
- 2.4 Aliphatic nucleophilic substitution at sp^3 carbon: S_N1 , S_N2 , S_Ni , S_NCA reactions. Ion pair in S_N1 reactions, Stereochemistry of all the above reactions, Factors affecting these reactions: substrate nucleophilicity, solvent, steric effect, hard-soft interaction, leaving group.
- 2.5 Nucleophilic substitution reactions at sp^2 (vinylic) carbon.
- 2.6 Aromatic nucleophilic substitution reaction: S_NAr , S_N1 , Benzyne mechanism, ipso, cine and tele substitutions, vicarious substitution.

Unit-III: REACTIONS AND REARRANGEMENTS [15L]

3.1 Mechanism, stereochemistry (if applicable) and applications of the following:

Arndt-Eistert reaction, Baylis-Hilman reaction, McMurry Coupling, Mitsunobu reaction and Mukiyama esterification, Woodward Prevost Hydroxylation.

3.2 Mechanism, stereochemistry (if applicable) and applications of the following:

Cope rearrangement, Claisen rearrangement, Dienone-Phenol rearrangement, Favroskii rearrangement, Fries rearrangement and Tiffeneau-Demjanov rearrangement.

3.3 Ester hydrolysis (all 8 mechanisms of acid and base catalyzed hydrolysis)

Unit-IV: OXIDATION-REDUCTION [15L]

4.1 Preparation of reagents (wherever applicable), mechanism and applications of the following:

Epoxidation: Baeyer-Villiger Oxidation and Oppenauer Oxidation. Oxidations using Osmium Tetroxide, Lead Tetraacetate, Periodic acid, Selenium dioxide, PCC and PDC.

4.2 Dehydrogenation with DDQ and TCQ, and Ozonolysis

4.3 Preparation of reagents (wherever applicable), mechanism and applications of the following: Wolf-Kishner reduction, Clemmensen reduction, Meerwein-Pondorff-Verley reduction, Birch reduction, Reductions with NaBH_4 , LiAlH_4 and DIBAL.

4.4 Homogeneous reductions: Wilkinson's catalysts and related systems.

References Books:

1. Organic Chemistry, J. Claydens, N. Greeves, S. Warren and P. Wothers, Oxford University Press.
2. Advanced Organic Chemistry, F.A. Carey and R.J. Sundberg, Part A and B, Plenum Press.
3. Stereochemistry: Conformation and mechanism, P.S. Kalsi, New Age International, New Delhi.
4. Stereochemistry of carbon compounds, E.L. Eliel, S.H. Wilen and L.N. Manden, Wiley.
5. Stereochemistry of Organic Compounds- Principles and Applications, D. Nasipuri. New International Publishers Ltd.
6. March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure, Michael B. Smith, Jerry March, Wiley.
7. Advanced Organic Chemistry: Reactions and mechanism, B. Miller and R. Prasad, Pearson Education.
8. Advanced Organic Chemistry: Reaction mechanisms, R. Bruckner, Academic Press.
9. Understanding Organic Reaction Mechanisms, Adams Jacobs, Cambridge University Press.
10. Writing Reaction Mechanism in organic chemistry, A. Miller, P.H. Solomons, Academic Press.

11. Principles of Organic Synthesis, R.O.C. Norman and J.M Coxon, Nelson Thornes.
12. Advanced Organic Chemistry: Reactions and mechanism, L.G. Wade, Jr., Maya Shankar Singh, Pearson Education.
13. Introduction to Spectroscopy, Donald L. Pavia, Gary M. Lampman, George S. Kriz, Thomson Brooks.
14. Spectrometric Identification of Organic Compounds, R. Silverstein, G.C Bassler and T.C. Morrill, John Wiley and Sons.
15. Organic Spectroscopy, William Kemp, W.H. Freeman & Company.
16. Organic Spectroscopy-Principles and Applications-Jagmohan, Narosa Publication.
17. Organic Spectroscopy, V.R. Dani, Tata McGraw Hill Publishing Co.
18. Spectroscopy of Organic Compounds, P.S. Kalsi, New Age International Ltd.
19. Mechanism in Organic Chemistry, Peter sykes, 6th edition onwards.
20. Physical Organic Chemistry, Neil Isaacs
21. Modern Physical Organic Chemistry, Eric V. Anslyn and Dennis A. Dougherty
22. Stereochemistry: A Three-Dimensional Insight by Anil V. Karnik and Mohammed Hasan.

PROGRAM(s): M.Sc.-I	SEMESTER: II		
Course:	Course Code: CHEM 510 / 112016251011 Course Title:- Chemistry Practical-II		
Teaching Scheme			Evaluation Scheme

Practical (Hours per week)	Tutorial (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 25)	Semester End Examination (Marks- 25)
16	–	02	25	25

Learning Objectives:
Physical Chemistry

1. To gain knowledge of the advanced concepts in pH metry, quantum mechanics, potentiometry and conductometry experiments.
2. To develop scientific temper and research based skills accomplish to encountered in the field of research.
3. To gain ability to analyze different samples of ores and alloys.
4. To learn different analytical methods for composition analysis.

Course Outcomes:-
Physical Chemistry

1. To use the concept of quantum chemistry to interpret the shape and information about the orbitals like 1s, 2pz and 3dz².
2. To apply the subject fundamentals-principles with practical knowledge to design experiments, analyze and interpret data so as to reach to proper conclusions
3. Learner will train to handle the sophisticated instrument like digital potentiometer, conductivity meter, spectrophotometer.

Inorganic Chemistry

1. The learner will learn to analyze the composition of different ores and alloys.
2. The learner will gain knowledge and hands on experience of different analytical methods used in the estimation of metals.

Course Code: CHEM 510 / 112016251011
CHEMISTRY PRACTICAL-II

Physical Chemistry Practicals-II

Non-Instrumental Experiments*:

Thermodynamics, Phase Rule and Reaction Kinetics:

1. Determination of heat of solution of benzoic acid by solubility measurements.
2. Determination of heat of solution of salicylic acid by solubility measurements.
3. Study of three-component system: Water-Acetic acid-Chloroform.
4. Study of three-component system: Water-Toluene-Acetic acid.
5. Study of variation of solubility of calcium sulphate with ionic strength and hence determine the thermodynamic solubility product. (Complexometric titration with EDTA)
6. Determination of equilibrium constant of the reaction $KI + I_2 \rightleftharpoons KI_3$ by distribution method.

7. Investigation of the reaction between acetone and iodine.

(* Any four Physical Chemistry experiments to be performed from the above list)

Inorganic Chemistry Practical-II

Analysis of Complex Materials:

1. Lime Stone Ore: Loss on ignition; Ca by EDTA method.
2. Solder Alloy: Sn gravimetrically by oxide method; Pb by EDTA method.
3. Cu-Ni Alloy: Cu by iodometric method; Ni gravimetrically by DMG method.
4. Devarda's Alloy: Cu by EDTA method, Al gravimetrically by oxine method.

Reference books for practicals

1. I. Vogel, Vogel's Text Book of Quantitative Inorganic Analysis, 6th Ed., Pearson Education, 2000.
2. J. D. Woolins, Inorganic Experiments, Wiley-VCH Verlag GmbH and Co., 2003.
3. W. G. Palmer, Experiments in Inorganic Chemistry, Cambridge University Press, 1954.
4. G. Raj, Advanced Practical Inorganic Chemistry,
5. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 and 2, Academic Press, 1967.
6. Marr and B. W. Rockette, Practical Inorganic Chemistry, Van Nostrnad Reinhond, 1972.
7. Pass and H. Sutcliffe, Practical Inorganic Chemistry, 2nd Ed., Chapman and Hall, 1985.

Organic Chemistry Practical-II

Separation of Binary mixture by microanalytical technique

Separation of the binary mixtures using physical and chemical methods. Identification of one of the compounds and checking its purity by TLC. Preparation of the derivative of one of the compounds. The following types are expected: (i) Non-volatile liquidNon-volatile liquid (ii) Water-soluble/insoluble solid-Non-volatile liquid with compounds from the same or different chemical classes. The candidate is expected to carry out the separation of 4 mixtures.

Reference Books:

1. Systematic Qualitative organic analysis, H. Middleton (Orient Longman)
2. A Handbook of Organic Analysis, H.T. Clark (Orient Longman)
3. Systematic Identification of organic compounds, R.L. Shriner (John Wiley, New York)

Analytical Chemistry Practical-II

Instrumental Experiments*:

1. Non aqueous titration: Determination of sodium benzoate / glycine by using perchloric acid in glacial acetic acid by potentiometry using glass-calomel system.
2. Determination of glucose by Folin-Wu method.
3. Determination of nitrite in a water sample by colorimetric method.
4. Determination of chromium and manganese by simultaneous spectrophotometry (to be replaced).
5. Determination of silica by Molybdenum Blue method.
6. Flame Photometric determination of Li /Na/K by standard addition method.

(* Any four Analytical Chemistry experiments to be performed from the above list)

PROGRAM(s): M.Sc.-I			SEMESTER: II
			Course Code: (CHEM 511/ CHEM 51111 / 112016251111) Course Title:-Analytical Chemistry-II
Teaching Scheme			Evaluation Scheme
Lectures (Hours per week)	Credit	Continuous Assessment (CA) (Marks-50)	Semester End Examination (Marks- 50)
04	04	50	50
Course Objectives: 1. To gain knowledge about electroanalytical techniques and applications of sensing electrodes. 2. To understand basic instrumentation of NMR and Mass techniques. 3. To principle, construction, working and applications of XRF, XRA and XRD techniques. 4. To apply the surface analytical techniques for system. 5. To learn about the automations in chemical analysis and process analytical techniques with some hyphenated techniques.			
Course outcomes: - After completion of this Course, the learner will be 1. able to learn the tool for quantitative analysis of analytes using solid state, precipitate and liquid-liquid membrane, enzyme and gas sensing electrodes with applications. 2. able to know the basic concepts of modern voltammetric techniques with electrochemical properties of compounds and systems and also the theory of thermodynamics and kinetics of electrochemistry. 3. The advantages and disadvantages of voltammetric techniques like DPP, CV and Stripping voltammetry of analysis. 4. Students are expected to learn the basic concepts and instrumentation of ^1H, ^{13}C, ^{19}F, and ^{31}P NMR and Mass Spectrometry. 5. Also the applications of such analytical techniques in various fields like pharma, medical, academia and research. 6. Able to learn about the basic concept of XRA, XRF and XRD techniques and its applications in the various fields. 7. Able to understand the the automation processes in analytical instrumentation and some hyphenated techniques in detail like GC-MS and LC-MS.			

ANALYTICAL CHEMISTRY-II

Unit-I ELECTROANALYTICAL CHEMISTRY[15L]

- 1.1 Ion selective potentiometry: Basic concept, solid state, precipitate and liquid-liquid membrane, enzyme and gas sensing electrodes with applications. [8L]
- 1.2 Introduction to modern voltammetric techniques viz., Differential pulse polarography, Cyclic voltammetry and Stripping (cathodic & anodic) voltammetry. [7L]

Unit-II SPECTROSCOPIC METHODS [15L]

- 1.1 **Magnetic resonance spectroscopy:**
Basic principles, instrumentation and sample handling, Quantitative applications of proton NMR, Introduction to Carbon-13, Phosphorous-31 and Fluorine-19 with applications. [8L]
- 1.2 **Mass spectrometry:**
Recapitulation, instrumentation; ion sources for molecular studies; EICI, FI, ESI, APCI, FAB & MALDI sources. Mass analyzers: quadrupole, time of flight and ion trap, Applications. [7L]

Unit-III MISCELLANEOUS TECHNIQUES [15L]

- 3.1 **X-ray Techniques:**
Principles, instrument components and applications of X-ray fluorescence, absorption and diffraction methods. [10L]
- 3.2 Introduction to surface analytical techniques: ESCA [5L]

Unit-IV: AUTOMATION IN CHEMICAL ANALYSIS AND Process Analytical Techniques [15L]

- 4.1 An overview of automated instruments and instrumentation, process control analysis; Types of automatic analytical systems: Flow injection analysis, automatic organic elemental analyzers, Gas monitoring equipment. [8L]
- 4.2 Process Analytical Techniques [4L]
- 4.3 Introduction to hyphenated techniques: GC-MS and LC-MS [3L]

Reference books:

1. D. A. Skoog, F. J. Holler, and T. A. Nieman, *Principles of Instrumental Analysis*, 5th ed., Philadelphia: Saunders College Publishing, 1998.
2. D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch, *Fundamentals of Analytical Chemistry*, 8th ed., Philadelphia: Saunders College Publishing, 2004.
3. G. D. Christian, *Analytical Chemistry*, 6th ed., John Wiley and Sons, New York, 2003.
4. G. H. Jeffery, J. Bassett, J. Mendham and R. C. Denney, *Vogel's Textbook of Quantitative Chemical Analysis*, 6th ed., ELBS, Longman Scientific & Technical, England, 2002.
5. H. H. Willard, L. L. Merrit, jr., J. A. Dean and F. A. Settle, Jr., *Instrumental Methods of Analysis*, 6th ed., CBS 1986.
6. R. D. Braun, *Introduction to Instrumental Analysis*, McGraw Hill, 1987.
7. G. H. Morrison and H. Freiser, *Solvent Extraction in Analytical Chemistry*, John Wiley & Sons, New York, 1966.

8. S. M. Khopkar, *Basic concept of Analytical Chemistry*, 3rd ed., Age International Publisher 2008.
9. T. Sekine and Y. Hasegawa, *Solvent Extraction chemistry*, Marcel Dekker, 1977.
10. P. G. Swell and B. Clarke, *Chromatographic Separations, Analytical Chemistry by open learning*, John Wiley & Sons, New York, 1987.
11. S. Sindsay, *High Performance Liquid Chromatography, Analytical Chemistry by open learning*, John Wiley & Sons, New York, 1987.
12. A. J. Bard and L. R. Faulkner, *Electrochemical Methods*, Wiley, New York, 1980
13. A. M. Bond, *Modern Polarographic Methods in Analytical Chemistry*, Marcel Dekker, New York, 1980.
14. L. C. Thomas and G. J. Chamberline, *Colorimetric Analytical Methods*, 9th ed., The Fintometer Ltd., Salisbury, England, 1980.
15. T. C. Morrili, R. m. Silverstein and G. C. Bassler, *Spectrometric Identification of Organic Compounds*, Wiley, 1981.
16. Vogel's Text Book of Quantitative Organic Analysis, 2th ed. ELBS.
17. R. A. Day, Jr. and A. L. Underwood, *Quantitative Analysis*, 6th ed., Prentice Hall of India Pvt. Ltd., New Delhi, 1993.
18. Jared L. Anderson, Alain Berthod, Veronica Pino, and Apryll M. Stalcup (ed), *Analytical Separation Science (Volume 1-5)*. WILEY-VCH 2015.
19. Jack Cazes (ed) *Ewing's Analytical Instrumentation Handbook*, 3rd edition, Marcel Dekker 2009.
20. R. Kellner, J.M. Mermet, M. Oto, M. Valcarcel, H. M. Widmer (ed), *Analytical Chemistry: A modern Approach to Analytical Science* 2nd edition. WILEY-VCH 2004.

PROGRAM(s): M.Sc.-I			SEMESTER: II
			Course Code: (CHEM 51112/112016251112) Course Title:-Applied Industrial Chemistry-II
Teaching Scheme			Evaluation Scheme
Lectures (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 50)	Semester End Examination (Marks- 50)
04	04	50	50
Course Objectives: 1. To enable learners to have comprehensive knowledge, understanding of the types of instruments with operations and automated methods of analysis. 2. To apply the basic knowledge of quality systems, quality audit and quality managements,. 3. To enable learners to perform various tasks assigned to them at the workplace in industry and academia to meet the job requirements as per global standards. 4. To provide solutions to problems encountered in the field of analysis and research.			
Course Learning Outcomes. After completing the course students will be able to: 1. predict the reactivity of organic compound from its structure. 2. understand different methods used for determination of Organic Reaction Mechanism 3. understand the fundamental concept in stereochemistry by applying various symmetry elements of organic molecule. 4. acquire the knowledge of chirality by taking examples of symmetrical and unsymmetrical molecule. 5. develop interest in stereochemistry by studying stereochemical features of different classes of organic compounds 6. identify the nomenclature of various stereochemical phenomena			

Course Code: CHEM 51112 / 112016251112
Applied Industrial Chemistry-II

Unit-I [15L]

Sugar industry-based chemicals and Industrial gases:

Introduction, manufacturing process of sugar, manufacture processes, properties and uses of oxalic acid, citric acid, ethanol, furfural from sugar by product. Introduction, application of hydrogen, nitrogen, oxygen, carbon dioxide, and liquefied gases.

Unit-II [15 L]

Agrochemicals:

Pesticides: history, invention, development, definition, and importance. Classification: General, based on the mode of action, according to target species and chemical nature. Formulations: conventional and advanced types, uses, and current trends. Pesticide residues, toxicity, warning symbols, safety with pesticides, first aid and antidotes.

Fertilizers: Introduction, Manufacture, and uses of nitrogenous, phosphatic and potassic fertilizers, compound fertilizers, Mixed fertilizers: method of preparation and formulation.

Fluid fertilizers: Introduction, manufacturing of nitrogenous and mixed fluids.

Unit-III [15 L]

Corrosion and Protective Coating:

Introduction dry and wet corrosion(mechanism), galvanic corrosion passivity, pitting corrosion, intergranular corrosion, waterline corrosion, stress corrosion, galvanic series, factors affecting corrosion, and corrosion control.

Introduction to metallic and electroplating, electroplating methods, chemical conversion coating, organic coating, paints, formulation of paints, varnishes, enamels, lacquers, emulsion paints, and special paints.

Unit-IV [15 L]

Lubricant and Adhesives:

Introduction, classification of lubricants, liquid, semisolid and solid lubricants, synthesis, properties, and application of lubricants. Introduction to adhesives, classification, adhesive action, physical and chemical factors affecting adhesives action, and bonding processes.

Recommended Books

1. R. W. Thomos and P. Farago, Industrial chemistry, 1973
2. P. G . More, Comprehensive Industrial Chemistry, Pragati Prakashan 2018.
3. S. K. Handa, Principles of pesticide chemistry, Agrobios (India); 2012.
4. A. Knowles, New developments in crop protection product formulation.T and F Informa UK Ltd. 2005.
5. D.S.Hill, Agricultural insect pests of the tropics and their control. CUP Archive; 1983.
6. S. B.Chattopadhyay, Principles and procedures of plant protection, Oxford & IBH Publishing Company, Pvt. Limited; 1991.
7. Ó. López, J. Fernandez-Bolanos, Green trends in insect control, Royal Society of Chemistry; 2011.
8. U. S. Sree Ramulu, Chemistry of Insecticides and Fungicides, Oxford and IBM Pub., 1979

9. P. S. Magee, G. K. Kohn, J. J. Menn, Pesticides Synthesis through Rational Approaches, American Chemical Society, 1979.
10. M. G. Rao and M. Marshall, Dryden's Outline of Chemical Technology, East west press, 1997.
11. K. S. Yawalkar, J. P. Agrawal, S. Bokde, Manures and Fertilizers, 1967.
12. D. A. Palgrave, Fluid Fertilizers, 1993.
13. G. H. Collings, Commercial Fertilizers, 2002.
14. P.C. Jain, Engineering chemistry, Dhanpat Rai publishing company private Ltd, New Delhi, 16th edition, 2014.
15. S. S. Dara and S. S. Umare, A textbook of Engineering Chemistry, S. Chand & Company Ltd, New Delhi, 20th Edition, 2013.

Course: On Job Training/ Field Projects**Course Code: CHEM 512 / 112016251211**

PROGRAM(s): M.Sc-I			SEMESTER: II		
Course: On Job Training/ Field Projects			Course Code: CHEM 512 / 112016251211		
Teaching Scheme					Evaluation Scheme
Lectures (Hours per week)	Practical (Hours per week)	Tutorial (Hours per week)	Credit	Continuous Assessment (CA) (Marks- 50)	Semester End Examination (Marks- 50)
NA	08	–	04	50	50
Learning Objectives: 1) To provide students the opportunity to test their interest in a particular career before permanent commitments are made. 2) To develop skills in the application of theory to practical work situations. To develop skills and techniques directly applicable to their careers.					
Course Outcomes: At the end of the Course, 1) Understand the Organizational Structure of a company. 2) Develop work habits and attitudes necessary for job success (technical competence, professional attitude, organization skills etc.) 3) Develop written communication and technical report writing skills.					

For on job training students will be sent to the industries listed below with the consent and approval from the industry;

1. IRMRA, Thane
2. WRIC, University of Mumbai
3. Galaxy surfactants, Mumbai
4. RCF, Mumbai
5. BASF, Mumbai
6. Aarti Chemicals, Mumbai
7. Bio Era, Pune
8. Shimadzu, Mumbai
9. Mettler Toledo, Mumbai
10. Asian Paints, Mumbai
11. Reliance Laboratories, Mumbai
12. Anchrom, Mumbai
13. Deepak Fertilizers, Mumbai

14. TIFR, Mumbai
15. BARC, Mumbai
16. IIT, Mumbai
17. ONGC, Mumbai
18. Forensic Science Laboratory, Mumbai
19. NMRL, Ambarnath
20. NEERI, Mumbai
21. USV Ltd, Mumbai
22. CIPLA, Mumbai
23. MERCK, Mumbai
24. Glenmark, Mumbai

SEMESTER-III: PHYSICAL CHEMISTRY

Course Code	Title of the Course	No. of Credits	No. of hours per SEMESTER	Examination		Total Marks
				Continuous Evaluation Marks	End-Sem Marks	
CHEM 311	Solid State Chemistry	4	60	40	60	100
CHEM 312	Spectroscopy	4	60	40	60	100
CHEM 313	Statistical Thermodynamics, Thermodynamics of Biological Systems & Electrochemistry-I	4	60	40	60	100
CHEM 314 EC-I	Interfacial Science	4	60	40	60	100
CHEM 315 EC-II	Some Selected Topics in Physical Chemistry	4	60	40	60	100
CHEM 316	Physical Chemistry Practical III	4	-	-	100	100
CHEM 317	Physical Chemistry Practical IV	4	-	-	100	100

No. of CREDITS: 24 TOTAL MARKS: 600

**Students will have to select one of the electives i.e. CHEM 314 or CHEM 315
Practical component involves 16 hr per week of laboratory work for 15 weeks.**

SEMESTER-III: PHYSICAL CHEMISTRY

CHEM 311: SOLID STATE CHEMISTRY

- Unit-I:** **BONDING, STRUCTURE AND PREPARATIVE METHODS** **[15L]**
- Bonding and Structure:** Classification of solids based on nature of forces (Ionic, Covalent, Metallic, van der Waals, Hydrogen-bonded), Crystal Structures: Symmetry and Choice of Unit- cell, Bravais lattice, Miller indices, Point groups and space groups, Close packing, Lattices and Unit- cells, Crystalline solids, ionic radii, radius ratio rule, lattice energy, crystal structure determination by powder diffraction and single crystal X-ray diffraction.
- Preparative Methods:** Solid state reactions (General Principles, precursor methods), Crystallization of solutions, melts, glasses and gels, vapour phase transport methods, Preparation of thin films, growth of single crystals, high pressure and hydrothermal methods.
- Some important solid-state materials: Magnetoresisters, Zeolites, Intercalation compounds, fullerides.
- Unit-II:** **DEFECTS AND DIFFUSION IN SOLIDS** **[15L]**
- Defects and non-stoichiometry:** Types of Defects: Point defects, plane defects, line defects. Thermodynamics of defects, Solid solutions.
- Diffusion in solids:** Mechanisms, Steady state and non-steady state diffusion, factors affecting diffusion, Kirkendall effect.
- Unit-III:** **ELECTRICAL AND MAGNETIC PROPERTIES** **[15L]**
- Electrical Properties:**
- Electrical conductivity of metals, Free electron theory, semiconductors, Intrinsic and extrinsic semiconductivity, Band theory, Superconductivity: Conventional Superconductors, Bardeen-Cooper-Schrieffer (BCS) theory, High temperature Superconductors, Ferromagnetic Superconductors, Uses of High temperature Superconductors.
- Magnetic Properties:**
- Diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism, ferrimagnetism. Calculation of magnetic moments, influence of temperature on magnetic behaviour, domains and hysteresis, Soft and hard magnetic materials.
- Unit-IV:** **OPTICAL PROPERTIES, DIELECTRIC PROPERTIES AND PHASE TRANSFORMATIONS IN SOLIDS** **[15L]**
- Optical Properties:**
- Electron emission in Metals, Photovoltaic effect, Luminescence, Laser and Maser actions, The Ruby laser, Light emitting diodes, Optical

fibers.

Dielectric Properties:

Dielectric constant, Clausius-Mosotti equation, Piezoelectricity, Ferroelectricity, Antiferroelectricity, Ferrielectricity.

Phase transformations in solids:

Buerger's classification, Thermodynamic classification, Kinetics of phase transitions, temperature and pressure induced transformations, Martensitic transformations, Order-disorder transitions.

*** Numericals/Problems are expected from each Unit-**

Reference books:

1. H. V. Keer, *Principles of the Solid State*, New Age International Publishers,
2. A. R. West, *Solid State Chemistry and its Applications*, John Wiley and Sons (Asia) Pte. Ltd.,
3. L. E. Smart and E. A. Moore, *Solid State Chemistry – An Introduction*, 3rd Ed., Taylor and Francis, 2005.
4. V. Raghavan, *Materials Science and Engineering*, Fifth Ed., Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.
5. William D. Callister, Jr., *Materials Science and Engineering, An Introduction*, Fifth Ed., John Wiley and Sons (Asia) Pte. Ltd., 2001.
6. S. O. Pillai, *Solid State Physics*, Fifth Ed., New Age International Publishers, 2002.
7. Leonid V. Azaroff, *Introduction to Solids*, Tata-McGraw-Hill Publishing Co. Ltd., New Delhi, 1977.
8. Sandra E. Dann, *Reactions and Characterization of Solids*, Royal Society of Chemistry, 2000.

CHEM 312: SPECTROSCOPY

Unit-I **BASIC PRINCIPLES OF SPECTROSCOPY** **[15L]**

Absorption and Emission of Radiation, Width and intensity of spectral lines, transition probability and selection rules, Fourier transform spectroscopy, computer averaging of signals (CAT), lasers.

Microwave spectroscopy: Rotational spectra of diatomic (non-rigid) molecules, Population of rotational levels and intensity of rotational lines, effect of isotopic substitution, rotational spectra of polyatomic molecules (linear and symmetric top), Stark effect.

Unit-II **INFRARED SPECTROSCOPY** **[15L]**

Anharmonic oscillator, Rotational-vibrational spectrum, Breakdown of Born-Oppenheimer approximation, combinational differences, vibrations of polyatomic molecules, rotational fine structure of vibrational spectrum of polyatomic molecules.

Raman spectroscopy:

Classical and quantum theory of Raman scattering, Experimental Methods, Pure rotational, vibrational and rotational-vibrational Raman spectrum of diatomic and polyatomic molecules, polarization

and depolarization of Raman lines, correlation of infrared and Raman spectra, normal modes and symmetry, Resonance Raman Scattering, Surface Enhanced Raman Scattering

Unit-III **ELECTRONIC SPECTROSCOPY:** **[15L]**

Vibrational course structure, Progressions and sequences, The Franck-Condon principle, Deslandres tables, Dissociation energies, Birge-Sponer extrapolation, Rotational fine structure, Fortrat diagram, Predissociation, Electronic spectra of polyatomic molecules.

Nuclear magnetic resonance spectroscopy: Chemical shift, spin-spin coupling, Chemical and magnetic equivalence, first and second order spectra, pulsed NMR, relaxation times, multipulse techniques, spin echoes, two- and three- dimensional NMR, NMR of nuclei other than proton, nuclear overhauser effect.

Unit- IV **NUCLEAR QUADRUPLER RESONANCE:** **[15L]**

Principle, Transitions for axially and non-axially symmetric systems, applications.

Electron spin resonance spectroscopy:

Basic theory, Instrumental Aspects, The g – factor, hyperfine structure, applications to free radicals, inorganic radicals, transition metal complexes.

Mössbauer Spectroscopy:

Principles, Recoilless emission and absorption of γ -rays, experimental methods, isomer shift, hyperfine structure (quadrupole interaction), magnetic hyperfine interaction, applications.

Reference books:

1. C. N. Banwell and E. M. McCash, *Fundamentals of Molecular Spectroscopy*, 4th Ed., Tata-McGraw-Hill, 1994.
2. M. L. Gupta, *Atomic and Molecular Spectroscopy*, New Age International Publishers, 2001.
3. H. S. Randhawa, *Modern Molecular Spectroscopy*, McMillan India Ltd., 2003
4. G. Aruldas, *Molecular Structure and Spectroscopy*, Prentice-Hall of India, 2001.
5. J. Michael Hollas, *Modern Spectroscopy*, 4th Ed., John Wiley and Sons, 2004.

List of Books for further reading:

1. R. Drago, *Physical Methods for Chemists*, Saunders, Philadelphia, 1992.
2. B. P. Straughan and S. Walker (Eds.), *Spectroscopy – Vol 1-3*, Chapman and Hall, New York, 1976.
3. R. K. Harris, *Nuclear Magnetic Resonance Spectroscopy*, Pitman, London, 1983.
4. Donald L. Pavia, Gary M. Lampman and George S. Kriz, *Introduction to Spectroscopy*, 3rd ed., Thomson, Brooks/Cole, 2001.

CHEM 313: STATISTICAL THERMODYNAMICS, THERMODYNAMICS OF BIOLOGICAL SYSTEMS & ELECTROCHEMISTRY-I

Unit-I **FUNDAMENTALS OF STATISTICAL THERMODYNAMICS** **[15L]**

Permutations, probability, microstates and configurations, the most probable distribution, ensembles, distribution laws: Boltzmann distribution, Bose-Einstein statistics, Fermi-Dirac statistics. Partition function, evaluation of translational, rotational, vibrational and electronic partition functions for ideal gases

Unit- II **APPLICATIONS OF STATISTICAL THERMODYNAMICS IN CHEMICAL SYSTEMS** **[15L]**

Calculation of thermodynamic properties (Energy, Heat capacity, Enthalpy, Entropy, Helmholtz energy, Gibbs energy) in terms of partition functions for mono, di and polyatomic gases, equilibrium constants, residual entropies, heat capacities of ideal gases, heat capacities of solids.

Unit-III **THERMODYNAMICS OF BIOLOGICAL SYSTEMS** **[15L]**

Thermodynamics of biopolymer solutions, thermodynamics of biochemical reactions involving adenosine triphosphate (ATP), osmotic pressure, membrane equilibrium, muscular contraction and energy generation in mechano-chemical systems.

Structures and functions of cell membrane, ion transport through cell membrane and irreversible thermodynamic treatment of membrane transport.

Biological Buffers.

Unit-IV **ELECTROCHEMISTRY-I** **[15L]**

Batteries: Working, principle, cell reactions and cell performances of Lithium Ion Batteries, and their applications.

Fuel cells: Classification, H_2-O_2 fuel cell, choice of electrolyte, advantages, disadvantages.

Electroplating: Electroplating of metals, throwing power of an electroplating bath, mechanism of electro-deposition, typical electroplating processes and applications of electroplating metal.

Super Capacitors: Introduction, classification, and applications

Reference books:

1. D. A. McQuarrie and J. D. Simon, *Molecular Thermodynamics*, Viva Books Private Limited, First Indian Ed., 2004.
2. D. A. McQuarrie and J. D. Simon, *Physical Chemistry, a Molecular Approach*, Viva Books Private Limited, First South Asian Ed., 1998. Chap.
3. E. D. Kaufmann, *Advanced Concepts in Physical Chemistry*, McGraw-Hill, 1966.
4. Robert P. H. Gasser and W. Graham Richards, *An Introduction to Statistical Thermodynamics*, World Scientific Publishing Co. Pte. Ltd., 1995.

5. William Blum and George B. Hogaboom, *Principles of Electroplating and Electroforming*, 3rd ed., McGraw-Hill Book Co., 1949.
6. Frederick A. Lowenheim, *Modern Electroplating*, 3rd ed. John Wiley Sons, Inc., 1974.
7. L. I. Antropov, *Theoretical Electrochemistry*, Mir Publishers, Moscow, 1972.
8. H. H. Uhlig and R. W. Rewic, *Corrosion and Corrosion Control*, John Wiley and Sons, New York, 1985.
9. Mars G. Fortana, *Corrosion Engineering*, 3rd ed., McGraw-Hill Book Co., 1987.
10. Nester Perez, *Electrochemistry and Corrosion Science*, Kluwer Academic Publisher, 2004.
11. R. Narayan and B. Vishwanathan, *Chemical and Electrochemical Energy Systems*, Universities Press (India) Ltd., 1998.
12. C. R. Cantor and P. R. Schimmel, *Biophysical Chemistry: Part I, II and III*, W. H. Freeman and Co., 1980.
13. R. B. Martin, *Introduction to Biophysical Chemistry*, McGraw-Hill New York, 1964.
14. S. Ramakrishnan, *Biophysical Student Mannual*, T. R. Publications (Madras), 1994.
15. J. H. Weil, *General Biochemistry*, New Age International Publishers, New Delhi.

CHEM 316: PHYSICAL CHEMISTRY PRACTICAL-III

Major Experiments

Distribution Methods:

1. To determine the formula of copper ammonia complex.
2. To determine the formula of silver ammonia complex.

Phase Equilibrium:

1. To determine the freezing point curve of two component simple eutectic system.
2. To determine the freezing point curve of two component compound forming system.

Reaction Kinetics:

1. To study the kinetics of hydrolysis of methyl acetate catalyzed by hydrochloric acid at different temperatures and to determine the thermodynamic parameters.
2. To study the influence of ionic strength on the rate of reaction between potassium persulphate and potassium iodide in solution.
3. To study the kinetics of reaction between potassium persulphate and potassium iodide in solution at different temperatures and determine the thermodynamic parameters.

CHEM 317: PHYSICAL CHEMISTRY PRACTICAL-IV

Minor Experiments

Solubility:

Study the variation of solubility of calcium hydroxide in the presence of sodium hydroxide and hence determine the solubility product at room temperature.

Viscosity Measurements:

1. To determine limiting viscosity number of polystyrene.
2. To determine chain linkage in polyvinyl alcohol from viscosity measurements.
3. To determine relative molecular mass of polystyrene from viscosity measurements.

Surface Chemistry:

1. To determine the critical micelle concentration (CMC) of sodium lauryl sulphate/N-cetyl-N,N,N-trimethyl ammonium bromide (CTAB) from measurements of conductivities at different concentrations.

2. To determine the critical micelle concentration (CMC) of sodium lauryl sulphate/N-cetyl-N,N,N-trimethyl ammonium bromide (CTAB) from measurements of surface tensions at different concentrations.

Potentiometry / pH metry:

1. To determine the stability constant of the silver-ammonia complex.
2. To determine the transport number of silver and nitrate ions in aqueous solution from the cell potential of the concentration cell with liquid junction potential.
3. To determine the substitution constants in Hammett equation for 3-aminobenzoic acid/4-aminobenzoic acid and 3-nitrobenzoic acid/4-nitrobenzoic acid.

Spectrophotometry:

1. To determine the ionization constant of methyl red/ bromophenol blue.

Interpretation of spectra/data-I:

1. Interpretation of vibrational-rotational spectra of rigid and non-rigid diatomic molecules
2. Interpretation of electronic spectra of diatomic molecules.
3. Interpretation of electronic spectra of simple polyatomic molecules.
4. Interpretation of ESR spectra.
5. Interpretation of Mössbauer spectra.
6. Analysis of XRD pattern of cubic system
7. Interpretation of DTA, TG, DTG curves.

Interpretation of spectra/data-II:

Spectral analysis: Structure elucidation with a given set of spectra, Determination of the degree of un-saturation from molecular formula. Systematic interpretation of set of spectra including some or all of the following: UV-Vis, IR, PMR, CMR, DEPT, Mass. Identification of the compound based on systematic interpretation of spectral data would be preferred.

Demonstration of Voltammograms

CV, LSV, DPV, and SWV of the redox system ($K_3[Fe(CN)_6]/K_4[Fe(CN)_6]$)

List of reference Books for Practicals and Spectral Interpretation:

1. B. Vishwanathan and P. S. Raghavan, Practical Physical Chemistry, Viva Books Private Limited, 2005.
2. A. M. James and F. E. Prichard, *Practical Physical Chemistry*, 3rd ed., Longman, 1974.
3. B. P. Lewitt (ed.), *Findlay's Practical Physical Chemistry*, 9th ed., 1973.
4. C. D. Brennan and C. F. H. Tipper, *A Laboratory Manual of Experiments in Physical Chemistry*, McGraw-Hill, 1967.
5. C. N. Banwell and E. M. McCash, *Fundamentals of Molecular Spectroscopy*, 4th Ed., Tata-McGraw-Hill, 1994.
6. *Introduction to Spectroscopy*, Donald L. Pavia, Gary M. Lampman, George S. Kriz, Thomson Brooks.
7. *Spectrometric Identification of Organic Compounds*, R. Silverstein, G.C Bassler and T.C. Morrill, John Wiley and Sons.
8. *Organic Spectroscopy*, William Kemp, W.H. Freeman & Company.

9. *Organic Spectroscopy-Principles and Applications*-Jagmohan, Narosa Publication.
10. *Organic Spectroscopy*, V.R. Dani, Tata McGraw Hill Publishing Co.
11. *Spectroscopy of Organic Compounds*, P.S. Kalsi, New Age International Ltd.
12. *Organic Structures from Spectra*, 4th ed., L. D. Field, S. Sternhell and J. R. Kalman, Wiley.

ELECTIVE COURSES

CHEM 314: EC-I: INTERFACIAL SCIENCE

Unit-I **HETEROGENEOUS CATALYSIS** **[15L]**

Adsorption on solid surfaces, Chemisorption at metal surfaces and oxides, Kinetics of catalyst reactions, structure, preparation and uses of heterogeneous catalysts, Application of catalysis in energy conversion, petroleum industry and atmospheric pollution control.

Unit-II **CATALYSIS AND GREEN CHEMISTRY** **[15L]**

Comparison of catalyst types, heterogeneous catalysts, zeolites-composition and structures, synthesis of zeolites, structure determination, uses of zeolites, zeolites as catalyst, zeolites and the bulk chemical industry, catalysts in fine chemicals and pharmaceutical industries, catalytic converters, homogeneous catalysts -transition metal catalysts with phosphine ligands-Wilkinson's Catalyst, greener Lewis acids, asymmetric catalysis, phase transfer catalysis, bio catalysis, photo catalysis.

Unit-III **NANOCHEMISTRY** **[15L]**

Introduction, Properties of materials & nanomaterials, role of dimensions in nanomaterials, advantages of nanosize over micron size, need of surface/encapsulation of nanomaterials, some important properties of nanomaterials, Techniques for synthesis of nanomaterials- Physical method and chemical method.

Nanocomposites:

Comparison with conventional composites. Manufacture and Characteristics of thermoplastic and thermoset nanocomposites products: Fibre reinforced nanocomposites, copolymer / clay nanocomposites, latex / ZnO nanocomposites, hybrid nanocomposites, PVC / CaCO₃ nanocomposites, etc. Effect of modifier concentration on structure, mechanical and viscoelastic properties of nanocomposites, Development and Optimization of Polymer melt process, Nanocomposites preparation by injection moulding

Unit-IV **SURFACE CHARACTERIZATION TECHNIQUES** **[15 L]**

Principles, instrumentation and applications of:
Electron spectroscopy: ESCA, AUGER and UPS.

Electron microscopy: Scanning electron microscopy, Scanning probe microscopes: The Scanning Tunneling Microscope, Atomic force Microscope.

Reference Books:

1. R.P.W.Scott, *Tandem Techniques*, Wiley India Pvt.Ltd. Reprint 2009.
2. J. Barker, *Analytical chemistry for open learning, Mass spectrometry*, Wiley IndiaED.
3. H. J. Arnika, *Essential of Nuclear Chemistry*, New Age International, 1995.
4. G. C. Bond, *Heterogeneous Catalysis*, 2nd ed., Clarendon Press, Oxford, 1987.
5. Mike Lancaster, *Green Chemistry: An Introductory Text*, Royal Society of Chemistry, 2002.
6. Paul T. Anastas and John C. Warner, *Green Chemistry – Theory and Practice*, Oxford University Press, 1998.
7. Albert S. Matlack, *Introduction to Green Chemistry*, Marcel Dekker, Inc., 2001.
8. Text/Reference books
9. Novel Nanocrystalline Alloys and Magnetic Nanomaterials- Brian Cantor
10. Nanomaterials Handbook- Yury Gogotsi
11. Encyclopedia of Nanotechnology- Hari Singh Nalwa
12. Introduction to Nanotechnology - Charles P. Poole Jr. and Franks. J. Qwens
13. Microwave Properties of Magnetic Films - Carmine Vittoria.
14. Physics of Magnetism - S. Chikazumi and S.H. Charap
15. Physical Theory of Magnetic Domains - C. Kittel
16. Magnetostriction and Magnetomechanical Effects - E.W. Lee
17. Springer Handbook of Nanotechnology - Bharat Bhushan
18. Chemistry of nanomaterials: Synthesis, properties and applications by CNR Rao
19. Synthesis of Nanostructured Materials –Cao
20. Handbook of Nanoscience, Engineering- Goddard et al
21. Nano Engineering in Science & Technology: An introduction to the world of nano design by Michael Rieth.
22. Introduction to Solid State Chemistry – A. R. West
23. Nanocomposites Science and Technology - P. M. Ajayan, L.S. Schadler, P. V. Braun
24. Physical Properties of Carbon Nanotubes- R. Saito
25. Carbon Nanotubes (Carbon , Vol 33) - M. Endo, S. Iijima, M.S. Dresselhaus
26. The search for novel, superhard materials- Stan Veprjek (Review Article) JVST A, 1999.

CHEM 315: EC-II: SOME SELECTED TOPICS IN PHYSICAL CHEMISTRY

Unit-I COLLOIDAL SCIENCE

[15L]

Applied colloids-Surface chemistry and nanocatalysts:

Introduction to the nature of colloidal solution, Surface Tension, Wetting, Solubilisation, Dispersion, Detergency, contact angle measurement, lotus effect, Surfactants and Self-assembly, Emulsions and Micro emulsion, Role of surfactants in synthesis of nanoparticles

Nanocatalysts:

Role of transition metals & metal oxides in homogeneous and heterogeneous catalysis and their mechanism of catalysis, manufacture of these catalysts in nano-form and their characterization.

Unit-II **GREEN CHEMISTRY** **[15L]**

Principles and Concepts of Green Chemistry:

Sustainable development and green chemistry, Atom economy, examples of atom economic and atom un-economic reactions, reducing toxicity.

Waste:

Production, Problems and Prevention: Sources of waste from chemical industry, waste minimization techniques, on-site waste treatment (Physical treatment, Chemical treatment and bio-treatment plants), and design for degradation: Degradation and surfactants, DDT, Polymers, rules for degradation.

Organic solvents:

Environmentally benign solutions: solvent free systems, supercritical fluids- Supercritical carbon dioxide, decaffeination process, ScCO_2 as reaction solvent, Supercritical water, ionic liquids as catalysts and solvents.

Unit-III **INSTRUMENTAL METHODS OF CHEMICAL ANALYSIS** **[15L]**

Hyphenated Techniques:

Introduction, need for hyphenation, possible hyphenation, interfacing devices and applications of the following: GC-MS, GC-IR, MS-MS, LC-MS, ICP-MS and Spectro-electrochemistry.

Radio-chemical methods: Auto, X-ray and gamma radiography.

Unit-IV **ADVANCED INSTRUMENTAL TECHNIQUES** **(15L)**

Electron microprobe method, Reflectance spectroscopy, Chemiluminescence method, Photoacoustic spectroscopy,

Polarimetry: ORD, CD.

Reference books:

1. Novel Nanocrystalline Alloys and Magnetic Nanomaterials- Brian Cantor
2. Nanomaterials Handbook- Yury Gogotsi
3. Encyclopedia of Nanotechnology- Hari Singh Nalwa
4. Introduction to Nanotechnology - Charles P. Poole Jr. and Franks. J. Qwens
5. Microwave Properties of Magnetic Films - Carmine Vittoria.
6. Physics of Magnetism - S. Chikazumi and S.H. Charap
7. Physical Theory of Magnetic Domains - C. Kittel
8. Magnetostriction and Magnetomechanical Effects - E.W. Lee
9. Springer Handbook of Nanotechnology - Bharat Bhushan
10. Chemistry of nanomaterials: Synthesis, properties and applications by CNR Rao
11. Synthesis of Nanostructured Materials –Cao
12. Handbook of Nanoscience, Engineering- Goddard et al
13. Nano Engineering in Science & Technology: An introduction to the world of nano design by Michael Rieth.
14. Introduction to Solid State Chemistry – A. R. West

15. Nanocomposites Science and Technology - P. M. Ajayan, L.S. Schadler, P. V. Braun
16. Physical Properties of Carbon Nanotubes- R. Saito
17. Carbon Nanotubes (Carbon , Vol 33) - M. Endo, S. Iijima, M.S. Dresselhaus
18. The search for novel, superhard materials- Stan Veprjek (Review Article) JVST A, 1999.
19. Mike Lancaster, *Green Chemistry: An Introductory Text*, Royal Society of Chemistry, 2002.
20. Paul T. Anastas and John C. Warner, *Green Chemistry – Theory and Practice*, Oxford University Press, 1998.
21. Albert S. Matlack, *Introduction to Green Chemistry*, Marcel Dekker, Inc., 2001.
22. R.P.W.Scott, *Tandem Techniques*, Wiley India Pvt.Ltd. Reprint 2009.
23. J. Barker, *Analytical chemistry for open learning, Mass spectrometry*, Wiley IndiaED.
24. H. J. Arnikar, *Essential of Nuclear Chemistry*, New Age International, 1995.
25. G. C. Bond, *Heterogeneous Catalysis*, 2nd ed., Clarendon Press, Oxford, 1987.

SEMESTER-III: INORGANIC CHEMISTRY

Course Code	Title of the Course	No. of Credits	No. of hours per SEMESTER	Examinations		Total Marks
				Continuous Evaluation Marks	End-Sem Marks	
CHEM 321	Solid State Chemistry - I	4	60	40	60	100
CHEM 322	Coordination and Bio-Inorganic Chemistry	4	60	40	60	100
CHEM 323	Instrumental Methods and Spectroscopy	4	60	40	60	100
CHEM 324 EC-I	Advances In Inorganic Chemistry	4	60	40	60	100
CHEM 325 EC-II	Applied Inorganic Materials	4	60	40	60	100
CHEM 326	Inorganic Chemistry Practical III	4	-	-	100	100
CHEM 327	Inorganic Chemistry Practical IV	4	-	-	100	100

No. of CREDITS: 24 TOTAL MARKS: 600

**Students will have to select one of the electives i.e. CHEM 324 or CHEM 325
Practical component involves 16 hr per week of laboratory work for 15 weeks.**

CHEM 321: SOLID STATE CHEMISTRY-I

Unit-I

[15L]

(a) Crystal Chemistry:

Recapitulation of common structures (AB and AB₂). Structures of the compounds of different types: AB (PbO and CuO), AB₂ (β -cristobalite, CaC₂ and Cs₂O), A₂B₃ (Cr₂O₃ and Bi₂O₃), AB₃ (ReO₃ and Li₃N), ABO₃ (perovskite, BaTiO₃), oxide bronzes, ilmenite structure, AB₂O₄ (normal and inverse and random spinel structures).

(b) Linked polyhedra:

Factors affecting linking of polyhedra, Corner sharing: tetrahedral structure (silicates) and octahedral structure (ReO₃), Edge sharing: tetrahedral structure (SiS₂) and octahedral structures of BiI₃ and AlCl₃, etc.

Unit-II

[15L]

(a) Synthesis of Inorganic Materials: Aspects of inorganic synthesis, choosing a method; Preparation methods: (i) Chemical method (Introduction to ceramic, sol-gel and precursor methods, Topochemical redox reactions, Ion exchange reactions), (ii) High pressure methods, (iii) Arc technique and (iv) Skull melting.

(b) Different methods for single crystal growth:

- (i) Crystal growth from solution and flux (Flux growth technique).
- (ii) Crystal growth from melt- Bridgman and Stockbarger method, Czochralski technique, Kyropoulos method, Vernuil technique and Zone refining technique.
- (iii) Crystal growth from vapor phase: Epitaxial growth methods, chemical vapour transport.

(c) Thin Film Preparation: (i) Chemical and electrochemical methods, (ii) Physical methods.

Unit-III

[15L]

(a) Solid Solutions: Formation of substitutional, interstitial and complex solid solutions, study of solid solutions by X-ray powder diffraction and by density measurement.

(b) Liquid Crystals: Introduction and classification of liquid crystals, microscopic and optical properties of nematic, smectic and cholesteric liquid crystals, applications of liquid crystals, inorganic liquid crystals.

Unit-IV

[15]

Crystal defects and non-stoichiometry:

Perfect and imperfect crystals;

Types of defects:

- (i) **Point defects-** Vacancy, Self interstitial, Schottky defect, Frenkel defect, thermodynamics of formation of these defects (mathematical derivations to find defect concentration and numerical problems expected), defects in non-stoichiometric compounds: Metal excess defects, Metal deficient defects.
- (ii) **Line defects-** Edge dislocation and Screw dislocation
- (iii) **Plane defects-** Grain boundaries and Stacking faults

Defect clusters, interchanged atoms; Extended atom defects-crystallographic shear structures, subgrain boundaries and antiphase domains.

CHEM 322: COORDINATION AND BIO-INORGANIC CHEMISTRY

Unit-I: INORGANIC PHOTOCHEMISTRY

[15L]

Transitions between energy states, decay process, photophysical pathways (fluorescence and phosphorescence), Jablonski diagram, photochemical pathways (unimolecular or intramolecular process and bimolecular or intermolecular process), quantum yield, Kasha's rule and Stoke shifts, identification of excited states, examples of main photochemical processes: non-redox processes (photoisomerization, photodissociation, photosubstitution), photoredox processes: general aspects and mechanism.

Photosynthesis reactions (mechanism and salient features of photosynthesis reaction I and II).

Unit-II: MAGNETIC PROPERTIES OF COMPLEXES

[15L]

Origin of magnetism, classification of substances according to the magnetic properties: diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism and ferrimagnetism. magnetic moment from magnetic susceptibility, Curie equation and Curie temperature, Curie-Weiss law, Neel temperature, thermal energy and magnetic moment: multiplet width greater than kT , multiplet width large than kT , temperature independent paramagnetism, magnetic susceptibility and spin only formula, spin and orbital contribution to magnetic moment, spin cross-over.

Magnetic properties of transition metal and lanthanide complexes, diamagnetic correction using Pascal constants and calculation of magnetic moment. Methods of determination of magnetic susceptibility.

Unit-III: ELECTRONIC SPECTRA OF COMPLEXES

[15L]

Determination of spectral terms for ground state and excited state using pigeon hole diagram, energy of terms, Hund's rules, spin orbit (L-S) coupling, selection rules and intensities, crystal field splitting of the terms in ligand field, construction of Orgel diagram and Tanabe Sugano diagram. Calculation of crystal field parameters ($10Dq$, B' , β , β^0) from electronic absorption spectra of octahedral complexes (d^1 - d^9) Comparing the spectra of octahedral, tetrahedral and square planar complexes of Nickel(II).

Unit-IV: BIOINORGANIC CHEMISTRY

[15L]

Molybdenum enzyme: reaction mechanism for xanthine oxidase, reaction cycle of sulfite oxidase; Zn in biological systems: Carbonic anhydrase, protolytic enzymes, e.g. carboxy peptidase, Zinc finger. Role of metal ions in biological electron transfer processes. Copper containing proteins and enzymes. Less common ions in biology e.g. V, Co, Ni. Metallothionines, Biomineralization.

CHEM 323: INSTRUMENTAL METHODS & SPECTROSCOPY

Unit-I: X-RAY DIFFRACTION

[15]

Introduction to X-ray diffraction, generation of X-rays (K-shell knockout), Bragg condition, Miller indices, relationship between Miller indices and inter planar spacing. Methods of diffraction: Laue method, Debye-Scherrer method of X-ray structural analysis of crystals, introduction to JCPDS format, index reflections, identification of unit-cells from systematic absences in diffraction pattern, uses of powder X-ray diffraction, description of the procedure for an X-ray structure analysis, density and crystallite size determination (numerical problems are expected).

Unit-II:

[15L]

(a) Electron Diffraction:

Electron beam-specimen interaction, SAED pattern for single crystal, polycrystalline and amorphous material, difference between X-ray and electron, experimental technique, applications of electron diffraction, low energy electron diffraction, reflection high energy electron diffraction.

(b) Neutron diffraction:

Properties of neutron, principle of neutron scattering, comparison with X-rays, advantages of neutron scattering, scattering of neutron by solids and liquids, experimental technique with essential components, detection of neutrons, monochromatic technique, time of flight technique, magnetic scattering, applications of neutron scattering.

Unit-III: ELECTRON SPIN RESONANCE SPECTROSCOPY

[15L]

Introduction, principle, instrumentation, selection rule, relaxation processes and line width in ESR transitions, hyperfine splitting, zero field splitting and Kramer's degeneracy, factors affecting g-value. Calculation of g-values with examples. Intensities of $g_{\parallel}$ and $g_{\perp}$ peaks.

Applications of ESR to the study of simple free radicals and metal complexes like methyl($\bullet\text{CH}_3$), cyclopentadienyl ($\bullet\text{C}_5\text{H}_5$), hydroxyl methyl ($\bullet\text{CH}_2\text{OH}$), ammonia ($\bullet\text{NH}_3$), 1,1-diphenyl-2-picryl hydrazyl (DDPH), pyrazine anion (C_4N_2^-), benzene anion (C_6H_6^-), bis(salicylaldiminato)copper(II), IrCl_6^{2-} , copper acetate dehydrate and $[\text{VO}(\text{5-chlorosalicylaldehyde-aniline})_2]$.

Unit-IV: MOSSBAUER SPECTROSCOPY

[15L]

Basic principle, recoil energy and Doppler shift. Instrumentation: sources and absorber; motion devices, detection, quadrupole interaction, magnetic interaction, electronegativity and chemical shift.

Applications:

Iron compounds: low spin and high spin Fe(II) and Fe(III) compounds and complexes, effect of pi-bonding, mono and poly nuclear Iron complexes, spinel oxides and iron-sulphur proteins.

Tin compounds: tin halides and tin oxides, organotin compounds.

CHEM 326: INORGANIC CHEMISTRY PRACTICAL-III

I. Separation and estimation of metal ions

1. Separation of Mn and Fe using isoamyl alcohol and estimation of Mn
2. Separation and estimation of Cu(II) and Zn(II) in a mixture using anion exchange resin.
3. Separation and estimation of Cu(II) and Ni(II) by forming salicylaldoximinato complexes by varying pH.

II. Analysis of the commercial samples

1. Calcium tablet for its calcium content by complexometric titration.
2. Iron tablet for its iron content colorimetry by 1,10-phenanthroline method.
3. Fasting salt for chloride content conductometrically.
4. Cement for its Iron content by redox titration.
5. Washing soda for its Na_2CO_3 content by pH metry.

CHEM 327: INORGAIC CHEMISTRY PRACTICAL-IV

III. Coordination Chemistry

1. Determination of Stability constant of $[\text{Zn}(\text{NH}_3)_4]^{2+}$ by potentiometry
2. Determination of CFSE values of $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$ and $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$ complexes.
3. Determination of Racah parameters and verification of the spectrochemical series for $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$, $[\text{Ni}(\text{NH}_3)_6]^{2+}$ and $[\text{Ni}(\text{en})_3]^{2+}$ complexes.

IV. Synthesis and characterization of Inorganic compounds and materials.

1. Preparation of $[\text{Mn}(\text{acac})_3]$ and its characterization by IR and conductivity measurement.
2. Preparation of Hexamine cobalt (III) chloride and its characterization by IR, and conductivity measurement.
3. Preparation of CuO/ZnO/MnO₂ nanoparticles and its characterization by UV-Visible and XRD techniques.
4. Synthesis of tris(acetyl acetonato)aluminium (III) complex and its characterization by NMR.
5. Synthesis of bis(salicyl aldiminato)copper (II) complex and its characterization by ESR.
6. Synthesis of calcium oxalate and its characterization by TGA/DTA.

ELECTIVE COURSES

CHEM 324: EC-I: ADVANCES IN INORGANIC CHEMISTRY

Unit-I: CHEMISTRY OF GROUP 13 & 14 ELEMENTS [15L]

Introduction to physical and chemical properties of group 13 and 14 elements. Preparations of various compounds of Al, Ga, In, Tl, Si, Ge, Sn and Pb with special emphasis on hydrides, oxides, halides, sulphides and coordination compounds.

Unit-II: [15L]

(a) Chemistry of Group 15 and 16 elements:

Introduction to physical and chemical properties of group 15 and 16 elements. preparations of various compounds of P, As, Sb, Bi, S, Se, and Te, with special emphasis on hydrides, oxides, halides, sulphides, carbides, study of metal nitrides, phosphides, arsenides, antimonides and bismuthides and its applications. Preparation and uses of important compounds like phosphine, azide, hydrazine and hydroxylamine; study of metal sulphides, selenides, tellurides and polonides, ring and cluster compounds, polyanions, polycations and S-N compounds.

(b) Chemistry of Group 17 elements:

Introduction to physical and chemical properties of group 17 elements. reactivity, uses, special properties of fluorine compounds, interhalogens, cationic interhalogens, halogen complex and polyhalides, halogen oxides and fluorocarbons.

Unit-III: [15L]

(a) Preparation of coordination compounds by:

(i) Addition reaction, (ii) Substitution reaction, (iii) Redox reaction, (iv) Thermal dissociation of solid complexes, (v) Reaction in the absence of oxygen, (vi) Reaction of coordinated ligands, (vii) Trans effect.

(b) Stereochemistry, Chirality and Fluxionality of coordination compounds with:

Higher coordination numbers, Isomerism and polymorphism in coordination compounds

(c) Crystal Engineering: Metal organic frameworks (MOFs):

Strategies in Coordination Chemistry (Node-and-Spacer Approach), General analysis of Framework Structures (1D, 2D and 3D framework structures), MOFs with Polydentate ligands. Applications of MOFs.

Unit-IV: METALLURGY [15L]

Occurrence, extraction and metallurgy of Zirconium, Hafnium, Niobium, Tantalum, Palladium and Platinum. Physical and chemical properties and applications of these metals, compounds of these metals, alloys and their uses.

CHEM-325: EC-II: APPLIED INORGANIC MATERIALS

Unit-I:

[15L]

(a) Inorganic Materials:

Classification, manufacture and applications of (i) Inorganic fibers, and (ii) Inorganic fillers. Study of (i) Condensed phosphates, and (ii) Coordination polymers.

(b) Preparation, properties and uses of industrially important chemicals: Sodium peroxide, sodium hydrosulphide, sodium thio sulphate, bleaching powder, hydrogen peroxide, Sodium hydroxide, chlorine and lime.

Unit-II:

[15L]

(a) Supramolecular chemistry:

Definitions, intermolecular bonds, concepts and perspectives, cationic recognition, anionic recognition, neutral molecular recognition: self-assembly concept and its application in molecular and supramolecular chemistry, supra molecular devices and machines.

(b) Inorganic Pharmaceuticals:

Lithium drugs, gold antiarthritic drugs, bismuth drugs in treatment of gastric ulcers, Cyclams as anti-HIV agents, radio diagnostic agents, contrast agents for X-ray and MRI imaging.

Unit-III: MANUFACTURING & APPLICATIONS OF THE FOLLOWING

[15L]

(i) Fertilizers and nutrients (ii) Glass (iii) Paints and pigments (iv) Zeolites: synthesis, characterization, determination of surface acidity, shape selectivity, characterizations and applications.

Unit-IV MISCELLANEOUS TOPICS **[15L]**

(i) Isopoly and heteropoly acids (ii) Intercalation compounds, (iii) Ceramics and refractory materials (iv) Cement (v) Inorganic explosives (lead azide and mercury fulminate).

Reference books:

CHEM 321:

Unit-I:

1. U. Muller, *Inorganic structural chemistry*, 2nd edition, Wiley (2007).
2. A. F. Wells, *Structural inorganic chemistry*, 5th edition, Clarendon press, Oxford (1984).
3. A. R. West, *Solid state chemistry and its chemical applications*, 2nd edition, Wiley (2014).

Unit-II:

1. A. R. West, *Solid state chemistry and its chemical applications*, John Wiley & Sons, (1984).
2. Lesley E. Smart and Elaine A. Moore, *Solid state chemistry – An introduction*, 3rd Ed., Taylor and Francis, (2005).
3. C. N. R. Rao and J. Gopalakrishnan, *New directions in solid state chemistry*, Cambridge university press, (1986).

Unit-III:

1. A. R. West, *Solid state chemistry and its chemical applications*, 2nd edition, Wiley (2014).
2. C. N. R. Rao and J. Gopalakrishnan, *New directions in solid state chemistry*, Cambridge university press, (1986).

Unit-IV

1. A. R. West, *Solid state chemistry and its chemical applications*, John Wiley & Sons, (1984).
2. H. V. Keer, *Principles of the solid state*, Wiley Eastern Ltd, (1994).
3. Lesley E. Smart and Elaine A. Moore, *Solid state chemistry – An introduction*, 3rd Ed. Taylor and Francis, (2005).

CHEM 322:

Unit-I:

1. J. R. Gispert, *Coordination Chemistry*, Wiley-VCH (2008).
2. D. Banerjea, *Coordination chemistry*, 3rd edition, Asian Books Pvt. Ltd. (2009).
3. R. Gopalan and V. Ramalingam, *Concise coordination chemistry*, Vikas Publising House Pvt. Ltd. (2007).
4. Gary Wulfsberg, *Inorganic chemistry*, Viva Books Pvt., Ltd. (2002).
5. B. Douglas, D. McDaniel and J. Alexander, *Concepts and models of inorganic chemistry*, 3rd editions, John Wiley & Sons, Inc.(2001).

Unit-II:

1. R. A. Dutta & A. Syamal, *Elements of magnetochemistry*, 2nd edition, Affiliated East-West Press Pvt. Ltd. (1993).
2. D. Banerjea, *Coordination chemistry*, 3rd edition, Asian Books Pvt. Ltd. (2009).
3. R. Gopalan and V. Ramalingam, *Concise coordination chemistry*, Vikas Publising House Pvt. Ltd. (2007).

Unit-III:

1. J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, *Inorganic chemistry- Principles of structure and reactivity*, 4th edition, Pearson (2006).
2. A. B. P. Lever, *Inorganic electronic spectroscopy*, Elsevier Publishing Company (1968).
3. R. Gopalan and V. Ramalingam, *Concise coordination chemistry*, Vikas Publishing House Pvt. Ltd. (2007).
4. J. E. House, *Inorganic chemistry*, Academic press, 2nd edition, 2013.

Unit-IV:

1. S. J. Lippard and J. M. Berg, *Principles of bioinorganic chemistry*, University Science Publications, Mill Valley, Caligronic, (1994).
2. R. R. Crichton, *Biological Inorganic Chemistry, A new introduction to molecular structure and function*, 2nd Edition, Elsevier, (2012).
3. I. Bertini, H. B. Gray, S. J. Lippard and J. S. Valentine, *Bioinorganic chemistry*, First South Indian Ed., Viva Books, New Delhi, (1998).
4. G. N. Mukherjee and A. Das, *Elements of bioinorganic chemistry*, Dhuri and Sons, Calcutta, (1988).
5. R. W. Hay, *Bioinorganic chemistry*, Ellis Harwood, England, (1984).
6. J. A. Cowan, *Inorganic biochemistry-An introduction*, VCH Publication, (1993).

CHEM 323:

Unit-I-IV:

1. Lesley E. Smart and Elaine A. Moore, *Solid state chemistry – An introduction*, 3rd Ed., Taylor and Francis, (2005).
2. Fmiza Hammer, *Inorganic spectroscopy and related topics*, Sarup & Sons (2008).
3. R. S. Drago, *Physical methods for Chemists*, 2nd edition, Saunders college publishing (1992).
4. R. S. Drago, *Physical methods in Inorganic chemistry*, Affiliated East-West Press Pvt. Ltd; New Delhi.
5. R. A. Scott and C. M. Lukehart, *Applications of physical methods to inorganic and bioinorganic chemistry*, John Wiley & Sons Ltd. (2007).
6. D. N. Sathyanarayana, *Introduction to magnetic resonance spectroscopy ESR, NMR, NQR*, I. K. Intenational publishing house pvt. Ltd. (2009).
7. K. Burger, *Coordination chemistry: Experimental methods*, London Butterworths, (1973).
8. R. V. Parish, *NMR, NQR, EPR and Mossbauer spectroscopy in Inorganic Chemistry*, Ellis Horwood. (1990).

CHEM 324 (EC-I):

Unit-I:

1. Gopalan, Universities Press India Pvt.Ltd. *Inorganic Chemistry for Undergraduates*, (2009).
2. P. L. Soni, *Textbook of Inorganic Chemistry*. Sultan Chand & Sons Publisher, 15th Edition (1984).
3. J. D. Lee, 5thEdn.,*Concise Inorganic Chemistry*, ELBS, (2010).
4. M. Weller, T. Overton, J. Rourke and F. Armstrong, *Inorganic chemistry*, 6thedition, Oxford University Press (2015).

Unit-II:

1. M. Weller, T. Overton, J. Rourke and F. Armstrong, *Inorganic chemistry*, 6th edition, Oxford University Press (2015).
2. P. L. Soni, *Textbook of Inorganic Chemistry*. Sultan Chand & Sons Publisher, 15th Edition (1984).
3. J. D. Lee, 5th Edn., *Concise Inorganic Chemistry*, ELBS, (2010).

Unit-III:

1. S. F. A. Kettle, *Coordination compounds*, Thomas Nelson and Sons Ltd. (1975).
2. D. Banerjee, *Coordination chemistry*, 3rd edition, Asian Books Pvt. Ltd. (2009).
3. R. Gopalan and V. Ramalingam, *Concise coordination chemistry*, Vikas Publishing House Pvt. Ltd. (2007).
4. J. R. Gispert, *Coordination Chemistry*, Wiley-VCH (2008).

Unit-IV:

1. R. Gopalan, Universities Press India Pvt. Ltd. *Inorganic Chemistry for Undergraduates*, (2009).
2. P. L. Soni, *Textbook of Inorganic Chemistry*. Sultan Chand & Sons Publisher, 15th Edition (1984).
3. J. D. Lee, 5th Edn., *Concise Inorganic Chemistry*, ELBS, (2010).

CHEM 325 (EC-II):

Unit-I:

1. J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, *Inorganic chemistry- Principles of structure and reactivity*, 4th edition, Pearson (2006).
2. P. L. Soni, *Textbook of Inorganic Chemistry*. Sultan Chand & Sons Publisher, 15th Edition (1984).

Unit-II:

1. J. R. Gispert, *Coordination Chemistry*, Wiley-VCH (2008).
2. J. M. Lehn, *Supramolecular Chemistry: Concepts and Perspectives*, VCH, 38 Weinheim, (1995).
3. D. F. Shriver and P. W. Atkins, *Inorganic chemistry*, 3rd edition, Oxford University Press (1999).
4. J. H. Block, E. B. Roche, T. O. Soine and C. O. Wilson, *Inorganic medicinal and pharmaceutical chemistry*, Lea and Febiger, (1974).

Unit-III:

1. P. L. Soni, *Textbook of Inorganic Chemistry*. Sultan Chand & Sons Publisher, 15th Edition (1984).
2. Lesley E. Smart and Elaine A. Moore, *Solid state chemistry – An introduction*, 3rd Ed., Taylor and Francis, (2005).

Unit-IV:

1. J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, *Inorganic chemistry- Principles of structure and reactivity*, 4th edition, Pearson (2006).
2. P. L. Soni, *Textbook of Inorganic Chemistry*. Sultan Chand & Sons Publisher, 15th Edition (1984).

CHEM 326 and CHEM 327:

Reference books for practicals:

1. A. I. Vogel, *Quantitative Inorganic Analysis*.
2. J. D. Woolins, *Inorganic Experiments*.
3. Palmer, *Inorganic Preparations*.
4. G. Raj, *Advanced Practical Inorganic Chemistry*.
5. J. E. House, *Inorganic chemistry*, Academic press, 2nd edition, (2013).

SEMESTER-III: ORGANIC CHEMISTRY

Course Code	Title of the Course	No. of Credits	No. of hours per SEMES-TER	Examination		Total Marks
				Contin uous Evalua tion Marks	End-Sem Marks	
CHEM 331	Photochemistry, Stereochemistry, Physical Organic Chemistry, and Pericyclic Reactions	4	60	40	60	100
CHEM 332	Ylids, A-C-H activation and Reactions, Radicals and Organometallic Chemistry	4	60	40	60	100
CHEM 333	Heterocyclic Chemistry And Advanced Spectroscopic Techniques-I	4	60	40	60	100
CHEM 334 EC-I	Medicinal, Green & Bioorganic Chemistry	4	60	40	60	100
CHEM 335 EC-II	Enzymes, Coenzymes & Biogenesis	4	60	40	60	100
CHEM 336	Organic Chemistry Practical III	4	-	-	100	100
CHEM 337	Organic Chemistry Practical IV	4	-	-	100	100

No. of CREDITS: 24 TOTAL MARKS: 600

**Students will have to select one of the electives i.e. CHEM 334 or CHEM 335
Practical component involves 16 hr per week of laboratory work for 15 weeks.**

SEMESTER-III: ORGANIC CHEMISTRY

CHEM 331: PHOTOCHEMISTRY, STEREOCHEMISTRY, PHYSICAL ORGANIC CHEMISTRY, AND PERICYCLIC REACTIONS

Unit-I PHOTOCHEMISTRY

[15L]

1. Photochemistry:

- 1.1 **General Principles**-Importance and applications of photochemical processes, Mechanism of absorption of photochemically relevant radiation, Excitation and deactivation of molecules, Electronic transitions and states, Selection rules, notations, types and characteristics, Electron energy transfer, photosensitization and quenching processes. [3L]
- 1.2 Photochemistry of carbonyl compounds, $\pi \rightarrow \pi^*$, $n \rightarrow \pi^*$ transitions, Norrish type-I and Norrish type-II cleavages, Paterno-Buchhi reactions, photoreductions, photochemistry of enones, cyclohexadienones, rearrangements of α , β -unsaturated ketones. [4L]
- 1.3 Photochemistry of unsaturated system-olefins, cis-trans isomerizations and, Di- π methane rearrangement. [3L]
- 1.4 Photochemistry of arenes, 1, 2; 1,3 and 1,4 additions. [1L]
- 1.5 Singlet oxygen and photooxygenation reactions. [1L]
- 1.6 **Intramolecular Rearrangements:** Rearrangements with trimesityl compound to enol ether, o-nitrobenzaldehyde to o-Nitrosobenzoic acid.

Determination of photochemical mechanisms:

1. Use of emission (fluorescence and phosphorescence) and absorption spectroscopy. Energy and life time of singlet and triplet states.
2. The study of quantum yields: primary quantum yields, product quantum yields. [3L]

Unit-II STEREOCHEMISTRY

[15L]

- 2.1 Stereochemistry of decalins, hydrindanes, steroids and Bridged ring compounds, Bredt's rule, discussion on non-classical carbocation [4L]
- 2.2 Transannular effects, Addition reactions, elimination reactions [2L]
- 2.3 Classification of point groups based on symmetry elements with appropriate examples [non-mathematical treatment] [2L]
- 2.4 **Molecular dissymmetry and chiroptical properties:** [4L]
Linearly and circularly polarized light, Circular birefringence and Circular dichroism, ORD and CD curves and their applications, The Octant rule and its applications, Applications of CD in conformational studies of biopolymers.
- 2.5 **Structures, symmetry and synthesis of 3-prismane and cubane:** [3L]
Reactions of cubane and its derivatives, Structures and symmetry of 4/5/6 prismanes and general methods of synthesis of Helicenes and their chiral applications.

Unit-III REACTIVE INTERMEDIATES & PHYSICAL ORGANIC CHEMISTRY [15L]

3.1 Organic reactive intermediates:

[8L]

Methods of generation, Structure, Stability and important reactions of Carbocations [including NGP and non-classical carbocations], Carbenes, Arynes, Nitrenes, ketenes.

3.2 Acid-base catalysis-General and specific acid and base catalysed reactions, Acidity functions and acidity strength, Reaction rates and acidity scales, Mechanism of acid-base catalysis. [3L]

3.3 Potential Energy surfaces, Bell-Evans Polanyi principle, Marcus theory, Curtin-Hammett principle [2L]

3.4 Kinetic methods:

Determination of reaction order and rate constants, Empirical rate equations for parallel reactions, Sequential reactions. [2L]

Unit-IV PERICYCLIC REACTIONS [15L]

4.1 Role of FMOs in organic reactivity:

Hard and Soft electrophiles and nucleophiles, Ambident nucleophiles, ambident electrophiles, the α effect. [3L]

4.2 Classification of pericyclic reactions: [1L]

Thermal and photochemical reactions

4.3 Three approaches: [2L]

(1) Conservation of orbital symmetry/Correlation Diagram

(2) Frontier Molecular Orbital approach [FMO] and (3) Aromatic [Huckel and Mobius] Transition state approach.

4.4 Cycloaddition reactions: [3L]

$4n$ and $(4n+2)$ π electron systems. Diels-Alder reactions, 1,3-Dipolar cycloadditions and Cheletropic reactions, retro-Diels-Alder reaction. Rates of Diels –Alder reaction based on FMOs; regioselectivity, periselectivity and site selectivity in Diels-Alder reactions.

4.5 Electrocyclic reactions: [2L]

Conrotatory and disrotatory motions, $4n$ and $(4n+2)$ π electron systems and other systems.

4.6 Sigmatropic rearrangements: [3L]

H-Shifts and C-shifts, supra and antarafacial migrations. Retention and inversion of configurations. Cope and Claisen rearrangements

4.7 Diimide reduction reactions, *Group transfer reactions [1L]

CHEM 332: YLIDS, α -C-H ACTIVATION AND REACTIONS, RADICALS AND ORGANOMETALLIC CHEMISTRY

Unit-I YLIDS, α -C-H ACTIVATION & REACTIONS [15L]

1.1. Methods of preparations, structures and reactivity comparison of phosphorus, sulfur and nitrogen ylides, Reactions of P-, S- and N- ylides with carbonyl compounds and other substrates, including mechanism, stereochemistry and applications in natural product synthesis of Wittig reaction.

1.2. α - C-H activation by nitro, sulfoxide, sulfone and phosphonate groups: generation of carbanions by strong bases (LDA/ n -BuLi) and applications in C-C bond formations. Vicarious nucleophilic substitutions.

- 1.3. Bamford-Stevens Reaction, Julia-Kocienski Olefination, Ramberg-Bäcklund Reaction, Staudinger Reaction, Bestmann-Ohira Reagent, Barton-Kellogg olefination, Steven's rearrangement, Pummerer sulfoxide rearrangement

Unit-II RADICALS IN ORGANIC SYNTHESIS

[15 L]

2.1.General aspects:

Electrophilic and nucleophilic radicals and their reactivities with π -rich/deficient olefins.

- 2.2.Inter- and intramolecular aliphatic C-C bond formation via mercury hydride, tin hydride, carbon hydride, thio donor (Barton's radical decarboxylation reaction).

- 2.3.Cleavage of C-X, C-Sn, C-Co and C-S bonds in the generation of radicals.

- 2.4.Trapping by electron transfer reactions using $\text{Mn}(\text{OAc})_3$.

2.5.Radical–Radical processes:

oxidative couplings, single electron oxidation of Carbanions to generate radicals, dehydrodimerization and Reductive couplings.

2.6.C-C bond formation in aromatics:

Introduction, radical reactions on aromatics, electrophilic radical reactions, nucleophilic radicals, Radical reactions on heteroaromatics–alkylations and acylations.

- 2.7.Hunsdiecker halodecarboxylation, Barton-McCombie alcohol deoxygenation, Kuivila-Beckwith and Stork radical dehalogenation/cyclization, Bergman and Myers-Saito Cycloaromatization.

Unit-III METALS/NON-METALS IN ORGANIC SYNTHESIS

[15L]

- 3.1.Organolithium reagents, Prep and synthetic applications, including directed metallation. Organocuprate reagents.

- 3.2.Applications of boron: generation of diborane, hydroboration/oxidation of alkenes, alkynes – mechanism, regiochemistry and stereochemistry. Asymmetric hydroboration using chiral borane reagents, functional groups reduction by diborane.

- 3.3.Mercury in organic synthesis: Oxymercuration-demercuration of alkenes, mechanism and regiochemistry, solvomercuration and intramolecular mercuration. Mercuration of aromatics and transformation of aryl-mercurs to aryl halides.

- 3.4.Organosilicons: Important features of silicon governing the reactivity of C-Si compounds: Preparation and important C-C bond forming reactions of alkyl silanes, alkenyl silanes, aryl silanes and allyl silanes. Silyl enol ethers as enolate precursors. Iodo trialkyl silane and trialkylsilylcyanide in organic synthesis.

- 3.5.Organotin compounds: Preparation of alkenyl/aryl and allyl tin compounds and their acylation and Michael reactions.

- 3.6.Selenium in organic synthesis: preparation of selenols/selenoxide, selenoxide elimination to create unsaturation, selenoxide and seleno-acetals as α -C-H activating groups.

Unit-IV TRANSITION & RARE-EARTH METALS IN ORGANIC SYNTHESIS

[15L]

- 4.1.Basic concepts, 18 electron rule, oxidative addition, reductive elimination, substitution.

4.2.Pd and Rh in organic synthesis:

π -bonding of Pd and Rh with olefins, applications in C-C bond formations including Wacker process, Heck reaction, Negishi coupling reactions, Carbonylation, hydroformylation,

decarbonylation, olefin isomerism, aryl amination using Pd reagents. Olefin metathesis (RCM) using catalysis.

4.3.Applications of nickel, cobalt, iron and chromium carbonyls in organic synthesis

4.4.Selected applications of Samarium iodide, and Cerium (IV), in organic synthesis.

4.5.Eu(OTf)₃ and Sc(OTf)₃ as efficient, water tolerant Lewis acid catalysts in aldol condensation, Micheal reactions, Diels-Alder and aza-Diels-Alder reactions, acylation reactions .

CHEM 333: HETEROCYCLIC CHEMISTRY AND ADVANCED SPECTROSCOPIC TECHNIQUES-I

Unit-I HETEROCYCLIC CHEMISTRY-I [15L]

1.1 Introduction, Classification, IUPAC and common names of mono-and bicyclic fused Heteroaromatic compounds. [5L]

1.2Reactivity, important general methods of synthesis and selected applications of the following heterocycles: [10L]

Pyrazole, imidazole, oxazole, isoxazole, thiazole, benzimidazole, benzoxazole, benzthiazole,pyridine and pyridine N-oxide.

Unit-II HETEROCYCLIC CHEMISTRY-II [15L]

2.1.Reactivity, important general methods of synthesis and selected applications of the following Heterocycles:

Pyridazine, pyrimidine, pyrazine, oxazine, quinoline, isoquinoline, coumarin, indole, purine, s-triazine, benzodiazepine, piperidine, morpholine.

Unit-III ADVANCED SPECTROSCOPIC TECHNIQUES-I [15L]

3.1.FT-IR Spectroscopy: Principle and applications [2L]

3.2.NMR Spectroscopy: Relaxation phenomenon and relaxation time, First order, higher order spectra and their simplifications, Double resonance,NOE,NOE difference spectroscopy and chemical shift reagents. [3L]

3.3.Second order spectra: Spin system notation, AB, AX, AB₂-AX₂, ABX, AMX and A₂B₂-A₂X₂ spin system with suitable examples, Coupling in aromatic and heteroaromatic systems,long range coupling. [2L]

3.4.Spectra of diastereotopic systems [1L]

3.5.ESR: Fundamentals and applications [2L]

3.6.Fluorescence Spectroscopy : Principles and applications [2L]

3.7.Problems [3L]

Unit-IV ADVANCED SPECTROSCOPIC TECHNIQUES-II [15L]

4.1.FT-NMR:Pulse sequences,pulse widths,spins and magnetisation vectors. [1L]

4.2.¹³C -NMR:¹³C nucleus,¹³C- chemical shifts,Calculation of ¹³C- chemical shifts, proton coupled ¹³C - spectra,¹³C spectra Integration, proton decoupled ¹³C- spectra. Off- resonance decoupling,DEPT technique, heteronuclear coupling of carbon to ¹⁹F and ³¹P [3L]

4.3.¹⁹F-NMR: Principles and applications [2L]

4.4.³¹P- NMR: Principles and applications [2L]

4.5.Two dimensional NMR:

Introduction, COSY technique and overview of COSY experiment, how to read COSY spectra, HETCOR technique and overview of the HETCOR experiment, how to read HETCOR spectra. [2L]

4.6.NOESY, ROESY, HMBC, INADEQUATE techniques	[2L]
4.7. Problems	[2L]
4.8. Applications of NMR in medicine	[1L]

ELECTIVE COURSES

CHEM 334: EC-I: MEDICINAL, GREEN AND BIOORGANIC CHEMISTRY

Unit-I DRUG DISCOVERY/DESIGN & DEVELOPMENT & SYNTHESIS-I [15L]

1.1 General introduction to discovery of new drugs: [6L]

Drug discovery without a Lead: Penicillin and Librium.

Lead discovery:

Random screening, non-random (or Targeted) screening

Drug metabolism studies, clinical observations, Rational approach to lead discovery.

1.2 Lead Modification: Drug design and Development [6L]

Identification of pharmacophore, functional group modification, structure activity relationship, privileged structures and drug like molecules. Structural modification to increase potency and therapeutic index: Homologation. Chain branching, ring chain transformation, bioisosterism

1.3 Combinatorial Chemistry: [3L]

General concepts, split synthesis, peptide libraries, encoding combinatorial libraries.

Unit-II DRUG DISCOVERY/DESIGN & DEVELOPMENT & SYNTHESIS-II [15L]

2.1 Synthesis and application of following drugs: Atorvastatin, Linezolid, Nateglinide, S-omeprazole, Ramipril, Zidovudine (AZT). [10L]

2.2. Steric effect:

2.3. The Taft and other equations, methods used to correct regression parameters with biological activity.

Hansch analysis: A linear multiple regression analysis [5L]

Unit-III GREEN CHEMISTRY & ENZYMATIC PROCESSES [15L]

3.1. Green Chemistry:

Introduction, Basic principles of green chemistry with applications. [3L]

3.2. Examples of green synthesis/reaction

Green Starting materials

Green Reagents

Green Solvents and reaction conditions (Solvent replacement table, Supercritical fluids)

Green Catalysis (Traditional processes and green one)

Synthesis of Ibuprofen, Adipic Acid. [7L]

3.2. Enzyme catalyzed Organic Reactions: Hydrolysis, Hydroxylation, Oxidation and Reductions. [5L]

Unit-IV BIOORGANIC CHEMISTRY [15L]

4.1. Nucleic acids: [10L]

Structure and function of DNA and RNA, genetic code, protein biosynthesis, mutation

- 4.2. **Recombinant DNA synthesis:** [5L]
Phosphodiester, Phosphotriester, Phosphoramidite and H- phosphonate approach including solid phase approach.

CHEM 335: EC-II: ENZYMES, COENZYMES AND BIOGENESIS

Unit-I ENZYMES-I [15L]

1.1. Introduction and classification of enzymes.

Properties of enzymes: i) Enzyme efficiency ii) Enzyme specificity. [5L]

1.2. **Enzyme Kinetics:**

i) Effect of substrate ii) Other factors affecting enzyme kinetics such as temperature, pH etc. [5L]

1.3. **Enzymes as Catalyst:**

Specificity of Enzyme Catalyzed Reactions, Rate accelerators. [5L]

Unit-II ENZYMES-II [15L]

2.1.(i) Mechanism of enzyme action and Synthetic approach of enzyme, Mechanism of alcoholic fermentation.

(ii) Role of main enzymes involved in the synthesis and breakdown of glycogen.

(iii) Glycogen store diseases caused by enzyme deficiency [7L]

2.2. Chemical nature of selected enzymes: Co-carboxylase, Coenzyme A, Riboflavin phosphate, UDPG, Glucose-1, 6-diphosphate. [6L]

2.3. Bradford assay for enzyme characterization [2L]

Unit-III COENZYMES [15L]

3.1. Chemistry of Coenzymes: structures, mechanism of action and bio-modeling studies of the following coenzymes- thiamine pyrophosphate, lipoic acid, nicotinamide adenine dinucleotide, flavin adenine dinucleotide, pyridoxal phosphate, Vitamin B₁₂. [12L]

3.2. Oxygen activation in biological systems with reference to Cytochromes. [3L]

Unit-IV BIOGENESIS & BIOSYNTHESIS OF NATURAL PRODUCTS [15L]

4.1. **Biogenesis:** Precursors, Primary and secondary metabolites, Acetate hypothesis. Mevalonate and Shikimic acid pathways. [5L]

4.2. **Biosynthesis:** amino acids, alkaloids, steroids and terpenoids. [5L]

4.3. Biosynthesis of selected natural products: L-Tryptophan, Cephaline, Cholesterol, Ephedrine, Citranellal [5L]

CHEM 336: ORGANIC CHEMISTRY PRACTICAL-III

Separation and analysis of Ternary mixture: (Minimum 8)

A three component mixture of solids and liquids and belonging to same or different chemical classes. Detection and separation of ternary mixture of same or different physical states (solids and liquids) and same or different chemical classes. [Mixture with same chemical classes separable by physical methods can be given. Identification of all three components with preparation of derivatives for two of the components is expected.]

CHEM 337: ORGANIC CHEMISTRY PRACTICAL-IV

**One step preparations with column chromatography / steam distillation purification step
OR two step preparations: (Minimum 8)**

1. 1-Nitronaphthalene from naphthalene [purification by steam distillation].
2. P-Nitrophenol from phenol. [purification by column chromatography].
3. Acetyl ferrocene from ferrocene [purification by column chromatography].
4. M-Nitroaniline from m-dinitrobenzene [purification by column chromatography].
5. Flourenone from flourene [purification by column chromatography].
6. Anthracene-anthraquinone –anthrone
7. Benzoin-benzil-benzillic acid.
8. Acetophenone-acetophenone phenyl hyrazone-2-phenyl indole.
9. 2-Naphthol to 1-phenylazo-2-naphthol to 1-amino-2-naphthol.
10. Cyclohexanone- cyclohexanone oxime-caprolactum
11. Glucose-1,2,5,6-Di-O-diisopropylidene- α -D-glucofuranose

References Books:

1. Organic Chemistry, J. Claydens, N. Greeves, S. Warren and P. Wothers, Oxford University Press.
2. Advanced Organic Chemistry, F.A. Carey and R.J. Sundberg, Part A and B, Plenum Press.
3. Stereochemistry: Conformation and mechamism, P.S. Kalsi, New Age International, New Delhi.
4. Stereochemistry of carbon compounds, E.L Eliel, S.H Wilen and L.N Manden, Wiley.
5. Stereochemistry of Organic Compounds- Principles and Applications, D. Nasipuri. New International Publishers Ltd.
6. March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure, Michael B. Smith, Jerry March, Wiley.
7. Advanced Organic Chemistry: Reactions and mechanism, B. Miller and R. Prasad, Pearson Education.
8. Advanced Organic Chemistry: Reaction mechanisms, R. Bruckner, Academic Press.
9. Understanding Organic Reaction Mechanisms, Adams Jacobs, Cambridge University Press.
10. Writing Reaction Mechanism in organic chemistry, A. Miller, P.H. Solomons, Academic Press.
11. Principles of Organic Synthesis, R.O.C. Norman and J.M Coxon, Nelson Thornes.
12. Advanced Organic Chemistry: Reactions and mechanism, L.G. Wade, Jr., Maya Shankar Singh, Pearson Education.
13. Introduction to Spectroscopy, Donald L. Pavia, Gary M. Lampman, George S. Kriz, Thomson Brooks.

14. Spectrometric Identification of Organic Compounds, R. Silverstein, G.C Bassler and T.C. Morrill, John Wiley and Sons.
15. Organic Spectroscopy, William Kemp, W.H. Freeman & Company.
16. Organic Spectroscopy-Principles and Applications-Jagmohan, Narosa Publication.
17. Organic Spectroscopy, V.R. Dani, Tata McGraw Hill Publishing Co.
18. Spectroscopy of Organic Compounds, P.S. Kalsi, New Age International Ltd.
19. Mechanism in Organic Chemistry, Peter sykes, 6th edition onwards.
20. Physical Organic Chemistry, Neil Isaacs
21. Modern Physical Organic Chemistry, Eric V. Anslyn and Dennis A. Dougherty
22. Stereochemistry: A Three-Dimensional Insight by Anil V. Karnik and Mohammed Hasan.

SEMESTER-III: ANALYTICAL CHEMISTRY

Course Code	Title of the Course	No. of Credits	No. of hours per SEMESTER	Examination		Total Marks
				Continuous Evaluation Marks	End-Sem Marks	
CHEM 341	Separation Techniques	4	60	40	60	100
CHEM 342	Spectroscopic Techniques	4	60	40	60	100
CHEM 343	Electrochemical Techniques Sensors and Environmental Management	4	60	40	60	100
CHEM 344 EC-II	Special Topics in Analytical Chemistry	4	60	40	60	100
CHEM 345 EC-II	Special Topics In Analytical Chemistry	4	60	40	60	100
CHEM 346	Analytical Chemistry Practical III	4	-	-	100	100
CHEM 347	Analytical Chemistry Practical IV	4	-	-	100	100

No. of CREDITS: 24 TOTAL MARKS: 600

**Students will have to select one of the electives i.e. CHEM 344 or CHEM 345
Practical component involves 16 hr per week of laboratory work for 15 weeks.**

SEMESTER III: ANALYTICAL CHEMISTRY

CHEM 341: SEPARATION TECHNIQUES

Unit I	[15L]
1.1 Solvent Extraction: Extraction equilibria of Liquid cation exchangers, liquid anion exchangers and crown ethers. Nature of extracted species. Parameters influencing extraction including e.g. role of diluents, aggregation, third phase formation and counter ion. Applications of liquid-liquid extraction in metallurgy and biotechnology.	
Unit II	[15L]
2.1 Supercritical Fluid Extraction: Principles, instrumentation and applications.	[5L]
2.2 Solid Phase Micro Extraction: Sorbents, methodology, applications and automation.	[3L]
2.3 Ion Exchange Chromatography: Synthetic resin based ion exchangers. Type of resin matrices. Breakthrough volume and capacity. Inorganic ion exchangers, chelating ion exchangers, imprinted functional polymers, ligand exchange for separation of organic molecules and enantiomers.	[7L]
3.1 Unit III	[15L]
Ion Chromatography: Suppressor reactions, instrumentation, standard operating conditions, single column ion chromatography, coupled ion-chromatography. Applications.	[7L]
3.2 Size Exclusion Chromatography: Theory, type of packings, molecular mass determination. Large scale purification of large bio molecules.	[4L]
3.3 Super Critical Fluid Chromatography: Instrumentation, effect of pressure, mobile phases, comparison with LC and GC. Applications.	[4L]
4.1 Unit IV	[15L]
Method development in HPLC: Selection of stationary phases and mobile phases, gradient elution, polarity index, comparison of detectors, hybrid columns, chiral chromatography, separations in pharmaceuticals and agrochemicals and PLRP-S. Concept of Preparative chromatography and UPLC.	[7L]
4.2 Membrane based Separations: Principles and applications of microfiltration, ultrafiltration, reverse osmosis, dialysis and electrodialysis. Liquid membranes.	[8L]

Text/ References:

1. Solvent Extraction Separation of Elements with Liquid Ion Exchangers, S. M. Khopkar, New Age Science Ltd., (2009).
2. Solvent Extraction Principles and Practice, 2nd Edition, J. Rydberg, M. Cox, C. Musikas, G. Choppin, Marcel Dekker, New York, (2004).

3. Solvent Extraction in Biotechnology, K. Schugert, Springer-Verlag Berlin Heidelberg, New York, (1994).
4. Solvent Extraction Chemistry, T. Sekine, Y. Hasegawa, Marcel Dekker, New York, (1977).
5. Supercritical Fluid Extraction, L. Taylor, John Wiley, New York, (1996).
6. Membrane Separation Process, K. Nath, PHI learning Pvt. Ltd., (2008).
7. Analytical Separation Science (Volume 1-5), J. L. Anderson, A. Berthod, V. Pino, A. M. Stalcup, WILEY-VCH, (2015).
8. Ion Exchange Materials Properties and Applications, 1st Edition, A. A. Zagorodni, Elsevier, (2007).
9. Introduction to Instrumental Analysis, R. D. Brown, McGraw Hill, (1987).
10. Instrumental Methods of Analysis, H. H. Willard, L. L. Meritt, J. A. Dean, Affiliated East-West Press, (1977).
11. Introduction to Modern Liquid Chromatography, L. R. Snyder, J. J. Kirkland, J. W. Doland, John Wiley, New Jersey (2010).
12. Practical HPLC Method Development, L. R. Snyder, J. J. Kirkland, J. L. Glajch (2nd edition) John Wiley (1997).
13. A practical Handbook of Preparative HPLC, D. A. Wellings, Elsevier (2006)
14. Ultra-High Performance Liquid Chromatography and its Applications, Q. A. Xu (ed), John Wiley (2013).
15. Selection of the HPLC Method in Chemical Analysis, S. C. Moldoveanu, V. David, Elsevier, (2017).
16. Principles of Instrumental Analysis, D. A. Skoog, F. James Hollier, T. A. Naiman, Harcourt College Publishers, Harcourt India Pvt. Ltd., (1998).
17. Chemical Separations and Measurements Introduction to Separation Science, B. L. Kauger, L. R. Snyder, C. Howath, John Wiley, New York, (1973).

SEMESTER III: ANALYTICAL CHEMISTRY

CHEM- 342: SPECTROSCOPIC TECHNIQUES

Unit I:		[15]
1.1	Infra-Red Spectroscopy	
	Characteristic vibrational frequencies of alkanes, alkenes, alkynes, aromatic compounds, alcohols, ethers, phenols and amines. Study of vibrational frequencies of carbonyl compounds (ketones, aldehydes, esters, amides, acids, anhydrides, lactones, lactams and conjugated carbonyl compounds), Effect of hydrogen bonding, Solvent effect on vibrational frequencies, Overtones and Combination bands.	[10L]
1.2	Raman Spectroscopy	[5L]
	Classical and Quantum theory of Raman Scattering, Experimental Methods, Correlation of Infrared and Raman Spectra, Normal Modes of vibrations.	
Unit II:		[15]
2.1	Nuclear Magnetic Resonance Spectroscopy (¹H NMR)	[8L]

Chemical and magnetic equivalent protons, Chemical shift, Spin-spin coupling, Different types of coupling, Factors affecting to coupling constant, Karplus equation, Spin system (AB, AX, ABX, AMX), Shift reagents, Nuclear Overhauser Effect (NOE).

2.2 Nuclear Magnetic Resonance Spectroscopy (^{13}C NMR) [7L]

Introduction, Chemical shift of aliphatic, olefinic, alkyne, aromatic, heteroaromatic and carbonyl carbon, Effect of substituents on chemical shift.

Unit III: [15]

3.1 Mass spectrometry

Introduction, Ion analysis, Ion abundance, Factors affecting to the fragmentation, Fragmentation of different functional groups, Molecular ion peak, Isotopic peak, Metastable peak, Nitrogen rule, MacLafferty rearrangement, Retro-Diels-Alder reaction.

Unit IV: [15L]

4.1 Problems: Based on joint applications of IR, ^1H NMR, ^{13}C NMR, and Mass spectrometric techniques. [10L]

4.2 Electron Spin Resonance Spectroscopy

Introduction, Principle of ESR spectroscopy, Instrumental aspect, The 'g' factor, Factors affecting to the 'g' value, Hyperfine splitting in various structures, Zero field splitting, Kramers degeneracy, Applications to free radicals and transition metal complexes. [5L]

Text/ References:

1. Donald Pavia; Gary Lampman, Introduction to Spectroscopy, 4th Edition.
2. Barbara H. Stuart, Infra-red Spectroscopy: Fundamentals and Applications.
3. R. M. Silverstein; F. X. Webster, Spectroscopic Identification of Organic Compounds, 6th Edition, John Wiley and Sons.
4. William Kemp, Organic Spectroscopy
5. Harald Gunther, NMR Spectroscopy, Basic principles, Concepts and Applications in Chemistry.
6. Atta-Ur-Rehman; Verlag; Nuclear Magnetic Resonance: Basic Principles (1986).
7. Phillip Crews; Rodriguez; Jaspars; Organic structure Analysis, Oxford University Press (1998).
8. Joseph B. Lambert; Shurvell; Lightner; Cooks, Organic Structural Spectroscopy, Prentice-Hall (1998).
9. Jackmann and Sternhell S, NMR Spectroscopy of Organic compounds.
10. R. K. Harris, Nuclear magnetic Resonance, Pitman, London, 1983.
11. D. N. Sathyanarayana, Introduction to Magnetic Resonance Spectroscopy ESR, NMR, NQR, I K International Publishing House Pvt. Ltd 2009.
12. Edmond de Hoffmann; Vincent Stroobant, Mass Spectrometry: Principles and

SEMESTER III: ANALYTICAL CHEMISTRY
CHEM 343: ELECTROCHEMICAL TECHNIQUES SENSORS AND
ENVIRONMENTAL MANAGEMENT

Unit I: [15L]

1. **Voltammetry and polarography:** Necessity and development of new voltammetric techniques and their comparison with classical DC polarography, Current sampled (TAST) polarography, Pulse (normal, differential and differential double pulse) Polarography, AC and square wave, linear sweep voltammetry and cyclic voltammetry, criteria of reversibility of electrochemical reactions, Quasi reversible and irreversible processes.

Unit II: [15L]

- 2.1 Stripping voltammetry, adsorptive stripping voltammetry, voltammetry with ultra micro electrodes chemically modified electrodes. Applications of electrochemical methods in organic synthesis.
- 2.2 **Chronotechniques:** Chronopotentiometry and Chronoamperometry, Chronocoulometry
- 2.3 **Quartz crystal microbalance:** Principles, methodology and applications.

Unit III:

Chemical Sensors: [15L]

- 3.1 Introduction to principles of chemical sensing: Signal transduction; Physico-chemical and biological transducers; Sensor types and technologies. Screen-printed electrodes
- 3.2 **Physico-chemical sensors and transducers:** Thermal sensors; Electrochemical sensors (amperometric, potentiometric, conductimetric); Semiconductor transducers (ISFET); Optical transducers (absorption, fluorescence, bio/chemiluminescence, SPR); Piezoelectric and acoustic wave transducers; An Overview of Performance and Applications.
- 3.3 **Biochemical sensors**
Enzymes; Oligonucleotides and Nucleic Acids; Lipids (Langmuir-Blodgett bilayers, Phospholipids, Liposomes); Membrane receptors and transporters; Immunoreceptors.
- 3.4 **Applications:**
Environmental monitoring; Technological process control; Food quality control; Clinical chemistry; Test-strips for glucose monitoring; Screen printed electrodes; Implantable sensors for long-term monitoring; Forensic science.

Unit IV:

Environmental Management: [15L]

- 4.1 Solid waste management: Objectives of solid waste management, Hazardous wastes: Bio- medical, radioactive and E-waste, concept of recycle, reuse and recovery, disposal and management of solid industrial waste. Bioremediation

and phytoremediation.

- 4.2 Environmental impact assessment: concept, process and evaluation methodology for the same.

Reference Books:

1. Modern Polarographic Methods in Analytical Chemistry, A. M. Bond, Marcel Dekker, New York (1980).
2. Electrochemical Methods, A. J. Bard and L. R. Faulkner, John Wiley, New York (1980).
3. Electrochemical Methods, Allen J. Bard, Larry R. Faulkner and Henry S. White, Fundamentals and Applications, 3rd Edition, John Wiley, New York (2022).
4. Electrochemistry for Chemists, 2nd Ed., Donald T. Sawyer, A. Sobkowiak and J. L. Roberts, Jr., John Wiley, New York (1994).
5. Cyclic Voltammetry and the frontiers of Electrochemistry, M. Noel and K. I. Vasu, IBH, New Delhi. (1990).
6. Technique and Mechanism in Electrochemistry, P. A. Christensen and A. Hamnett, Blackie Academic and Professional (1994).
7. Electroanalytical Chemistry, Ed. A.J. Bard, Marcel Dekker, New York, A Series of volumes.
8. Electroanalytical Chemistry, J.J. Lingane, 2nd Ed., Interscience, New York (1958).
9. Principles of Instrumental Analysis, D.A. Skoog, F.J. Holler, and J.A. Nieman 5th Edition (1998).
10. Jiri Janata, Principles of Chemical Sensors, Plenum Press, 1990
11. Principles of Chemical and Biological Sensors, D. Diamond Editor, John Wiley& Sons, 2000.
12. Chemical Sensors and Biosensors, Brian Eggins, John Willey & Sons, 2002.
13. Sensors, Nanoscience, Biomedical Engineering, and Instruments. Richard Dorf Editor, CRC Taylor & Francis, 2006
14. Optical Biosensors. Present & Future. Editors: F. Ligler, C. Rowe Taitt, Elsevier, 2002.
15. Introduction to Bioanalytical Sensors, Alice Cunningham, John Wiley& Sons, 1998.
16. Chemical Sensors and Biosensors for Medical and Biological Applications, Ursula Spichiger-Keller, Wiley-VCH, 1998.
17. Environmental Chemistry, A.K. De, 2nd Ed., Wiley, 1989.
18. Fundamentals of Environmental Chemistry. S.E. Manahan, 3rd Ed., CRC Press, 2009.
19. Solid and Hazardous Waste Management. S.C. Bhatia, Atlantic Publishers & Distributers (P) Ltd. New Delhi, 2007.
20. Environmental pollution and Control. J. J. Peirce, R. F. Weiner and P. A. Vesilind, 4thEdn. Butterworth-Heinemann, USA, 1998.
21. E-waste: implications, regulations, and management in India and current global best practices. Rakesh Johri, TERI Press, New Delhi, 2009.

SEMESTER III: ANALYTICAL CHEMISTRY

ELECTIVE COURSES

CHEM 344: EC-I -SPECIAL TOPICS IN ANALYTICAL CHEMISTRY-I

Unit-I ANALYTICAL BIOCHEMISTRY

[15L]

1.1 **Body fluids:**

Composition of body fluids and detection of abnormal level of certain constituents leading to diagnosis of diseases.

Physiological and nutritional significances of water and fat soluble vitamins and minerals.

Analyses for constituents of physiological fluids, viz., urine & blood.

Analytical techniques for vitamins

1.2 **Immunological methods:**

General Processes of immune response, Antigen-antibody reactions, Precipitation reactions, radio, enzyme, and fluoro-immuno assays, affinity chromatography.

1.3 **Human nutrition:**

Biological values and estimation of enzymes, carbohydrates, essential amino acids, proteins, and lipids.

1.4 **Metabolites and Metabolomics**

[15L]

Analytical tools for measurement – NMR, HPLC, LC-MS (examples to be discussed)

Unit-II:CLINICAL CHEMISTRY: (APPLICATIONS OF BIOANALYTICAL APPROACH TO MEDICINES)

2.1 **Biologics:**

Brief introduction of drugs to biologics (pathway)

2.2 **Nuclear medicines:**

Role of radiopharmaceuticals in vivo metabolism of radiopharmaceuticals. Uses and adverse side effects.

Principles of various instruments used for diagnosis of various diseases eg. MRI, CT scan, etc.

Radiopharmaceuticals used in disease treatment (doses regulation) eg. For chemotherapy of cancer.

2.3 **Nanomedicines:**

Importance of nanomedicines: Analytical techniques for quantification of nanoparticles uptake by cells (transmission electron microscopy and flow cytometry).

Bioequivalence of nanomedicines.

Unit-IIIANALYTICAL CHEMISTRY IN FORENSIC SCIENCE

General idea

[15L]

3.1 **Biological:** Analysis of biological stains and materials including blood, semen

and saliva (qualitative and quantitative).

3.2 **Analytical toxicology:** isolation, identification and determination of the following:

Narcotics: Heroin, morphine and cocaine.

Stimulants: amphetamines, cocaine 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 post-mortem blood, for poisons like cyanide, arsenic, mercury, insecticides, and pesticides.

Unit-IVMEMBRANE SCIENCE & TECHNOLOGY

[15]

- 4.1 Membranes for saline water treatment
- 4.2 Ceramic membrane
- 4.3 Recovery of valuables from waste using liquid membrane methods
- 4.4 Membrane based separations in chemical and nuclear technology
- 4.5 Membrane based chemical sensors.
- 4.6 Track etched membrane.

Reference books:

1. West, E S & Todd, W R, Textbook of Biochemistry, Published by The Macmillan Co, 1956.
2. Parikh's text book of medical Jurisprudence and toxicology, C.K. Parikh, CBS Publishers (1990).
3. Clarke's Isolation and identification of Drugs in Pharmaceuticals, body fluids and post-mortem material, Clarke E.G.C., The Pharmaceutical Press, London.
4. Analytical methods in Forensic chemistry Ed. Math. Ho, Ellis Horwood (1990).
5. Methods of Forensic Science, Ed. F. Landquist, Interscience (1962).
6. High performance liquid chromatography in Forensic Chemistry. E.S. Lurie and J.W. Wittner, Jr, Marcel Dekker N.Y. (1983).
7. Analytical Toxicology Methods Manual Ed. H. Stahr, Iowa State University Press (1977).
8. Official Methods of Analysis of the Association of official Analytical Chemists (AOAC), 14TH Ed. (1984).
9. Linda Fossati Wood, MaryAnn Foote, Targeted regulatory writing techniques: Clinical documents for drugs and biologics.
10. Jeanne Yang: A Pathway to Follow-On Biologics, Hasting Science & Technology Law Journal.
11. Gopal Subramanian, Society of Nuclear Medicine, [Radiopharmaceuticals](#).
12. Harry F. Tibbals, Medical Nanotechnology and Nanomedicine.

SEMESTER III: ANALYTICAL CHEMISTRY

CHEM 345: EC-II- SPECIAL TOPICS IN ANALYTICAL CHEMISTRY-II

Unit-I

[15L]

1.1 **Radiochemical methods:**

Isotope dilution method and activation analysis, radiometric and radio release methods.

Auto, X-ray and gamma radiography.

1.2 **Thermal Methods:**

Simultaneous thermal analysis, Evolved gas analysis: Definition, Instrumentation, Classification of methods (Physical, Chemical and Spectroscopic: mass spectrometry and infrared), Applications.

Unit-II GREEN CHEMISTRY

[15L]

2.1 **Principles and Concepts of Green Chemistry:**

Sustainable development and green chemistry, Atom economy, examples of atom economic and atom un-economic reactions

2.2 **Waste:**

Production, Problems and Prevention; Sources of waste from chemical industry, on-site waste treatment (Physical treatment and Chemical treatment), design for degradation.

2.3 **Catalysis and Green Chemistry:**

Comparison of catalyst types, Heterogeneous catalysts (zeolites and the bulk chemical industry, catalysts in fine chemicals and pharmaceutical industries, catalytic converters), homogeneous catalysts (transition metal catalysts with phosphine ligands, greener Lewis acids, asymmetric catalysis), phase transfer catalysis, Biocatalysis, Photocatalysis

2.4 **Organic solvents:**

Environmentally benign solutions: solvent free systems, supercritical fluids, ionic liquids as catalysts and solvents.

Unit-III COSMETIC, SOAP & DETERGENT ANALYSIS

[15L]

3.1 **Cosmetic Analysis:**

Introduction to cosmetics

Hair tonic: 2,5-diaminotoluene, potassium bromate, sodium perborate, pyrogallol, resorcinol, salicylic acid, dithioglycollic acid (in permanent wavers).

Creams and lotions: types of emulsions, chloroform soluble material, glycerol, pH emulsion, ash analysis, non-volatile matter by IR spectroscopy.

3.2 **Soap and Detergents analysis:**

Analysis of soaps and detergents: General scheme of analysis, sampling, alcohol soluble materials, moisture and volatile matter, active ingredient and equivalent combined SO_3^{3-} .

Tests for soaps: total fatty acids, fatty anhydride combined alkali, and anhydrous soap, Unsaponified and unsaponifiable matter, Free alkali or free acid, titer test, Iodine value, saponification value, free glycerol.

Tests for synthetic detergents: Unsulfonated or unsulfated matter, ester SO_3 , Combined alcohols, total combined SO_3 , Alkalinity, chlorides, silicate, phosphate, borates.

UV spectroscopic analysis of detergents: Biodegradability of detergents, Determination of sodium alkyl benzene sulfonate, determination of sodium

toluene sulfonate, determination of sodium xylene sulfonate, determination of germicides in soaps and detergents.

Unit-IV ANALYSIS OF HERBAL BASED PRODUCTS

[15L]

- 4.1 AYUSH - Introduction
- 4.2 **Herbs as a raw material:**
Definition of herb, herbal medicine, herbal medicinal products, herbal drug preparation.
Sources of herbs
Selection, identification and authentication of herbal materials, drying and processing of herbal raw material.
- 4.3 **Extraction of herbal materials:**
Choice of solvent for extraction
Methods used for extraction and principles involved in extraction.
- 4.4 **Standardization of herbal formulation and herbal extracts:**
Standardization of herbal extract as per WHO cGMP guidelines.
Physical, chemical, spectral and toxicological standardization, qualitative and quantitative estimations. Determination of metals
- 4.5 **Various chromatographic techniques for the separation, identification, purification and estimation.**

Reference books:

1. Nuclear and Radiochemistry, 3rd Edition, G. Friedlander, J. W. Kennedy, E. S. Macias and J. M. Miller, Wiley, New York, 1981.
2. Nuclear and radiochemistry, K. H. Lieser, 2nd Edition, Weinheim, Germany, Wiley VCH, 2001.
3. Radiochemistry and Nuclear Methods of Analysis, W. D. Ehmann and D. E. Vance, Wiley, New York 1981.
4. Thermal Methods of Analysis, P. J. haines, Blackie, London, 1995.
5. Thermal Analysis, 3rd Edition, W. W. Wendlandt, Wiley, New York, 1985
6. [Paul T. Anastas](#), John C. Werner, Green chemistry: Theory and Practice, Oxford University Press, 1998.
7. Mike Lancaster, Green Chemistry: An Introductory Text, RSC Paperbacks. Chemistry of Natural Products, V. K. Ahluwalia, L. S. Kumar, S. Kumar, Ane Books, India, (2006).
8. High-Performance Thin Layer Chromatography (HPTLC), M. Shrivastav, Springer-Verlag Berlin Heidelberg, New York, (2011).
9. Traditional and Folk Herbal Medicine, Vol. 1, Dr. V. K. Gupta, Daya Publishing House, (2012).
10. A Selection of Prime Ayurvedic Plant drugs-Ancient Modern Concordance, S. Dev, Anamaya Publishers, New Delhi, (2006). F.J. Welcher, Standard methods of chemical analysis, volume 3, part-B, (Soap and Detergents).

CHEM 346: ANALYTICAL CHEMISTRY PRACTICAL III

Organic, medicinal, food, detergents, biochemical, electroanalytical:

Organic analysis:

1. Determination of Sulphur compounds eg. Methyleneblue, crystal violet.

Analysis of medicinal:

2. Complete pharmacopoeial assay of acetyl salicylic acid. (I.P.).
3. Sorensen formol titrations eg. Glycine.
4. Nonaqueous titrations eg. glycine, sodium benzoate, pyridoxine HCl, mebendazole, diazepam tablets, sulphamethoxazole, etc.

Estimation of organic compounds in drug formulations:

5. Benzoic acid and salicylic acid, Aspirin and caffeine, Dextrose and saline injection, Chloramphenicol palmitate suspension, Paracetamol.

Analysis of food products:

6. Iodine value of oils and fats.
7. Fe, Ca, and P in milk powder, Proteins in milk and wheat flour, Lactose in milk by Cole's ferricyanide method.
8. Analysis of alcoholic beverages.

Analysis of detergents:

9. Moisture content, Oxygen releasing compounds, Alkalinity, Tripolyphosphate, Active detergent material (anionic, cationic, non -ionic, amphoteric detergents).

Biochemical analysis: Determination of the following in serum/blood.

10. Uric acid, Sugar, Cholesterol.

Electroanalytical methods:

11. Determination of mixture of acids eg. HCl and phosphoric acid potentiometrically using glass electrode.
12. Determination of organic amines by potentiometric titration in glacial acetic acid.
13. Determination of reversibility of a redox system and area of an electrode by cyclic voltammetry.

LIST OF REFERENCES/BOOKS FOR PRACTICAL:

1. Vogel's textbook of Quantitative Inorganic analysis, 5th ED. ELBS (1991).
2. Quantitative Organic Analysis, Part III, A. I. Vogel, 2nd Ed. CBS (1987).
3. Colorimetric Analytical Methods, 9th Ed. L. C. Thomas and G. J. Chamberlin, The Tintometer Salisbury, England (1980).
4. Spectrometric Identification of Organic compounds, T. C. Morrili, R. H. Silverstein and G.C. Bossler, Wiley (1981).
5. Indian Pharmacopeia 2010, Vol. I, II, III and Addendum 2012, 6th Ed. The Indian Pharmacopoeia Commission, Ghaziabad, 2010.
6. British Pharmacopeia.
7. Chemical Analysis of Food and Food Products, H. B. Jacob, Van Nostrand Reinhold (1958).
8. Encyclopedia of Industrial Chemical Analysis, Eds. F. D. Snell and L. S. Etter, Interscience, A series of Volumes.
9. Official Methods of Analysis of the Association of Official Analytical Chemists (AOAC), 14th Ed., (1984).
10. Analysis of Foods and Beverages. Ed. George Charalambous, Academic Press (1978).
11. Standard Methods for Analysis of Oils, Fats and derivatives, 7th Ed., C. Faquot and A Hautfenne, Blackwell Scientific (1987).
12. Manual of food quality central, food analysis quality, Adulteration and tests of identity, a series of volumes, F.A.O. Rome (1986).
13. Food Analysis, A.G. Woodman. McGraw Hill (1941).

14. Chemical Analysis of food and food products, H.B. Jacob, Van Westrand Reinhold (1958).
15. Introduction of Food Science and Technology, food science and technology series, G.F. Stewart and M.A. Amerine, Academic Press.
16. The Chemical Analysis of food, Pearson
17. Gas Chromatography in food Analysis, G.D. Dickes and P.V. Nickel, Butter Worths.
18. Analytical Biochemistry, D.J. Holme and H. Peck, Longman (1983).
19. Bioanalytical Chemistry, S. R. Mikkelsen and E. Corton, John Wiley and sons, 2004.
20. Immunoassay – a practical guide Eds. D.W. Chan and M.T. Perlstein. Academic Press (1987).
21. Hawk's Physiological Chemistry, Mc Graw Hill.

CHEM 347: ANALYTICAL CHEMISTRY PRACTICAL IV

Minerals, ores, alloy, spectrometry, water, soil, fertilizer and column Chromatography:

Ores & Alloy:

1. Bauxite.
Al (gravimetric), Fe (volumetric), Ti (colorimetric).
2. Ilmenite.
Ti (gravimetric/volumetric), Fe (colorimetric).
3. Steels and stainless steels.
Ni (homogeneous precipitation), Cr (volumetric), Mn (spectrophotometric).

Spectrophotometry & AAS:

4. Determination of copper and bismuth of a mixture using EDTA spectrophotometrically.
5. Determination of copper by extractive photometry using diethyldithiocarbamate.
6. Determination of tin and zinc in canned food by Atomic Absorption Spectroscopy.

Determination of Water Quality Parameters:

Soil & fertilizer Analysis:

8. NPK ratio, Determination of micronutrients, Cation exchange capacity.

Column chromatography:

9. Separation of cadmium and zinc on an anion exchanger.
10. Analysis of mixture of alcohols by GC (ethanol, n- propanol, n-butanol, n- pentanol and t-butanol.).
11. Separation and estimation of a mixture of acetophnone, benzene and toluene by HPLC using C₁₈ column and acetonitrile + water (60:40) mobile phase. Determination of number of theoretical plates.

Texts/ References:

1. Vogel's Textbook of Quantitative Chemical Analysis, 3rd Edition.
2. Vogel's Textbook of Quantitative Chemical Analysis, 5rd Edition.
3. Standard methods of Chemical Analysis, Vol. 2, (Part A& B), 5th ed, F. J. Welcher, Von Nostrand& Robert E. Krieger Publishing Co. New York, (1975).
4. Official Methods of Analysis of the Association of Official Analytical Chemists (AOAC), 14th Ed., (1984).

SEMESTER-IV: PHYSICAL CHEMISTRY

Course Code	Title of the Course	No. of Credits	No. of hours per SEMESTER	Examination		Total Marks
				Continuous Evaluation Marks	End-Sem Marks	
CHEM 411	Atomic Structure, Group Theory & Chemical Bonding Unit-I Approximate Methods	4	60	40	60	100
CHEM 412	Electrochemistry-II	4	60	40	60	100
CHEM 413	Physical Aspects of Polymer, Photo-Physical & Photo-Chemical Processes	4	60	40	60	100
CHEM 414 OC-I	Intellectual Property Rights & Chemoinformatics	4	60	40	60	100
CHEM 415 OC-II	Research Methodology	4	60	40	60	100
CHEM 416	Research Project	8	*	80	120	200

No. of CREDITS: 24 TOTAL MARKS: 600

Students will have to select one of the optional courses i.e. CHEM 414 OC-I or CHEM 415 OC-II

***Practical component involves 16 hr per week of laboratory work for 15 weeks.**

SEMESTER-IV: PHYSICAL CHEMISTRY

CHEM 411: ATOMIC STRUCTURE, GROUP THEORY & CHEMICAL BONDING

Unit-I-APPROXIMATE METHODS [15L]

Variation method (linear and non-linear), Non-degenerate first order perturbation theory, Application to helium atom-ground state, Hückel molecular orbital method: conjugated π systems, Dissociation energy and aromaticity, π -electron densities and bond orders, Theory of electrocyclic reactions –Woodward's-Hoffmann rule, Introduction to extended Hückel molecular orbital method

Unit-II MULTI-ELECTRONIC ATOMS & THEORY OF ANGULAR MOMENTUM [15L]

Anti-symmetry and Pauli principle, Slater determinants, Slater type orbitals, Basis sets, Russell-Saunders coupling, Term symbols, Hund's rules, Normal and anomalous Zeeman effect, Paschen Back effect

Unit-III GROUP THEORY [15L]

Symmetry elements and symmetry operations, Symmetry point groups, Identification of point group of molecules, Representation of groups, Matrix representation of operations, Characters and character tables, Reducible and irreducible representations, Statement of the Great Orthogonality theorem and its consequences, Symmetry adapted linear combination

Unit-IV DIATOMIC & POLYATOMIC MOLECULES [15L]

Diatomic molecules:

Born-Oppenheimer approximation, Valence bond theory of hydrogen molecule, Molecular orbital theory of hydrogen molecule ion, Molecular orbitals of homonuclear and heteronuclear diatomic molecules, Bond order, Term symbols.

Polyatomic molecules: Hartee-Fock SCF method and configuration interaction, Walsh diagrams.

Reference books:

18. D. A. McQuarrie and J. D. Simon, *Physical Chemistry - a molecular approach*, Viva Books Private Limited, New Delhi, 1998.
19. D. A. McQuarrie, *Quantum Chemistry*, Viva Books Private Limited, New Delhi, first Indian ed., 2003.
20. R. K. Prasad, *Quantum Chemistry*, 3rd Ed., New Age International Publishers, 2006.
21. Ira N. Levine, *Quantum Chemistry*, 5th Ed., Pearson Education (Singapore) Pte. Ltd., Indian Branch, New Delhi, 2000.
22. James E. House, *Fundamentals of Quantum Chemistry*, Second Ed., Academic Press, 2005.
23. Robert L. Carter, *Molecular Symmetry and Group Theory*, John Wiley and Sons (Asia) Pte. Ltd., 2004.

24. T. A. Littlefield and N. Thorley, *Atomic and Nuclear Physics – An Introduction*, Van Nostrand, 1979.

List of Books for further reading:

1. John P. Lowe, *Quantum Chemistry*, 3rd ed., Academic Press, New York, 2006.
2. R. Anantharaman, *Fundamentals of Quantum Chemistry*, McMillan India Limited, 2001.
3. Mahendra R. Awode, *Quantum Chemistry*, S. Chand and Co. Ltd., New Delhi, 2002.
4. David O. Hayward, *Quantum Mechanics for Chemists*, Royal Society for Chemistry, 2002.
5. Jack Simons, *An Introduction to Theoretical Chemistry*, Cambridge University Press, 2003.
6. Victor M. S. Gil, *Orbitals in Chemistry, A Modern Guide to Students*, Cambridge University Press, 2000.
7. A. K. Chandra, *Introduction to Quantum Chemistry*, 4th Ed., Tata-McGraw-Hill, 1994.
8. S. N. Datta, *Lectures on Chemical Bonding and Quantum Chemistry*, Prism Books Pvt. Ltd., 1998.
9. R. McWeeny, *Coulson's Valence*, 3rd Ed., Oxford University Press, 1979.
10. J. N. Murrell, S. F. A. Kettle and J. M. Tedder, *The Chemical Bond*, Wiley, 1985.
11. F. A. Cotton, *Chemical Applications of Group Theory*, 3rd Ed., John Wiley and Sons (Asia) Pte. Ltd., 1999.
12. D. C. Harris and M. D. Bertolucci, *Symmetry and Spectroscopy*, Oxford University.

CHEM 412: ELECTROCHEMISTRY-II

Principles, Instrumentation and applications of the following:

Unit I POLAROGRAPHY

[15L]

Necessity and development of new voltammetric techniques and their comparison with classical DC polarography, Current sampled (TAST) polarography, Pulse (normal, differential and differential double pulse) Polarography,

Unit II VOLTAMMETRY

AC and square wave, linear sweep voltammetry and cyclic voltammetry, criteria of reversibility of electrochemical reactions, Quasi reversible and irreversible processes, stripping voltammetry, adsorptive stripping voltammetry, voltammetry with ultra-micro electrodes, Chemically modified electrodes, Molecularly Imprinted Polymers (MIP), Applications of electrochemical methods in organic synthesis.

Unit III CHRONOTECHNIQUES & SENSORS

[15L]

Chronopotentiometry, applications of chronopotentiometry, chronoamperometry and chronocoulometry.

Electrochemical sensors-potentiometric sensors, amperometric sensors and conductivity measurement; Ion selective field effect transistors -Principle, applications and advantages; Biosensors-Bio catalytic membrane electrodes, enzyme based glucose biosensors; Analysis based on multilayer films-General Principle, film structures; Disposable multilayer pIon systems-General principle, performance and applications; Screen printed electrodes. Quartz Crystal Microbalance: Principles and Applications.

Unit IV ELECTROPHORESIS

[15L]

Zone electrophoresis, factors affecting migration rates, supporting media (gel, paper, cellulose acetate, starch, polyacrylamide, agarose, sephedax, and thin layers).

Techniques of electrophoresis: low and high voltage, SDS-PAGE, isoelectric focusing; continuous and discontinuous electrophoresis, Capillary electrophoresis, electro osmotic flow; Techniques of capillary electrophoresis: zone, gel, isoelectric focusing, isotechophoresis and micellar electrokinetic capillary chromatography, detection and applications.

Reference books:

1. D. A. Skoog, F. J. Holler, and T. A. Nieman, *Principles of Instrumental Analysis*, 5th ed., Philadelphia: Saunders College Publishing, 1998.
2. D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch, *Fundamentals of Analytical Chemistry*, 8th ed., Philadelphia: Saunders College Publishing, 2004.
3. A. J. Bard and L. R. Faulkner, *Electrochemical Methods*, Wiley, New York, 1980.
4. A. M. Bond, *Modern Polarographic Methods in Analytical Chemistry*, Marcel Dekker, New York, 1980.
5. J. J. Lingane, *Electroanalytical Chemistry*, 2nd ed.
6. A. Braithwaite and F. J. Smith, *Chromatographic Methods*, 5th ed., Kluwer Academic Publisher, 1999.
7. F. W. Fifield and D. Kealey, 5th ed., Blackwell science Ltd. 2000.
8. Andrew G. Ewing, Ross A. Wallingford, and Teresa M. Olefirowicz, *Analytical Chemistry*, Vol. 61 No. 4.

CHEM 413: PHYSICAL ASPECTS OF POLYMER, PHOTO-PHYSICAL & PHOTO-CHEMICAL PROCESSES

Unit I **POLYMER SCIENCE-I** **[15I]**

Introduction:

Polymer science, Classification of Polymers, Nomenclature of polymers, Isomerism in Polymer chains, History of Polymers, Intermolecular forces in Polymers, Conformations in polymer chains.

Molecular weight of polymers:

Solubility, Average molecular weight values, Fractionation of polydisperse systems, Light scattering, GPC, Collegative molecular weights : Osmometry, End group analysis, Other techniques : Ultracentrifugation, Mass spectrometry, Viscometry.

The Synthesis of Polymers:

Chain growth (Addition) polymerization: Mechanism, and kinetics of free radical, cationic and anionic polymerization, Chain transfer reactions, Mayo equation, Thermodynamic aspects of polymerization

Copolymerization: Kinetics of copolymerization, monomer reactivity ratios, determination of monomer reactivity ratios, The Q-e scheme, block copolymers, graft copolymers, dendrites

Unit II **POLYMER SCIENCE-II** **[15L]**

Techniques of polymerization (Phase systems in polymerisation): Bulk

polymerization, Solution polymerization, Precipitation polymerization, Suspension polymerization, Emulsion polymerization

Step-growth polymerization (Polycondensation): Molecular weight in a step-growth polymerization, Mechanism of polycondensation, Kinetics of polycondensation.

Polymer reactions, degradation and additives: Polymer analog reactions and Cross-linking reactions.

Polymer degradation and stability: Thermal degradation, Oxidative and UV stability, Chemical and hydrolytic stability, Radiation effect

Polymer additives: Plasticizers, Stabilizers (Heat & UV), Flame retardants, Colorants, Curing agents and other polymer additives

Glass transition temperature: Glass transition temperature, Factors influencing the glass transition temperature, Glass transition temperature and molecular weight, Glass transition temperature and melting point, Importance of glass transition temperature.

Unit III **PHOTOCHEMISTRY-I**

[15L]

Mechanism of Absorption and Emission processes:

Electric dipole transition, Einstein's treatment of absorption and emission phenomena, Time-dependent Schrodinger equation, Time-dependent perturbation theory, correlation with experimental quantities, Intensity of electronic transitions, rules governing transition between two energy states

Physical Properties of Electronically excited molecules:

Nature of changes on electronic excitation, Electronic, vibrational and rotational energies, potential energy diagram, Frank-Condon principle, Emission spectra, Environmental effect on absorption and emission spectra, properties of excited states, excited state acidity constants, dipole moments and redox properties. Types of transitions, fluorescence emission, e-type and p-type delayed fluorescence, phosphorescence emission.

Unit IV **PHOTOCHEMISTRY-II**

[15L]

Photo-physical Kinetics:

Photokinetic scheme for determination of quantum yields, Kinetics of self and collisional quenching and Stern- Volmer equation and deviations from Stern Volmer equation, Concentration dependence of quenching and excimer formation, Quenching by added substances: charge transfer mechanism and energy transfer mechanism.

Photo-chemical reactions:

Types of photo-chemical reactions, Selection rules, Kinetics of Photo-chemical reactions. Photochemical reactions of ketones, olefins conjugated olefins and aromatic compounds. Woodward-Hoffman rule of electro-cyclic reactions.

Applications of Photochemistry:

Importance of photochemistry, mutagenic effect of radiation, photosynthesis, mechanism of vision, photo electrochemistry, prospects of solar energy conversion and storage, organic solar cells.

Reference books:

1. P. Bahadur and N. V. Sastry, *Principles of Polymer Science*, second edition, Narosa Publishing House, 2005.
2. C. E. Carraher, Jr., *Carraher's Polymer Chemistry*, 8th edition, CRC Press, New York, 2010.
3. Joel R. Fried, *Polymer Science and Technology*, Prentice-Hall of India Pvt. Ltd., 2000.
4. V. R. Gowariker, H. V. Viswanathan and J. Sreedhar, *Polymer Science*. New Age International Pvt. Ltd., New Delhi, 1990.
5. F. W. Billmeyer Jr., *Text Book of Polymer Science*, 3rd edition, John Wiley and Sons, 1984.
6. K.K. Rohatgi-Mukherjee, *Fundamentals of Photochemistry*, New Age International Publishers, Revised Edition (2003).
7. C.H.DePuy and O.L.Chapman, *Molecular reactions and photochemistry*, Prentice hall of India PVT.LTD. 1988.

Books for further reading:

1. J. M. G. Cowie, *Polymers: Chemistry and Physics of Modern Materials*, 2nd ed. (first Indian Reprint 2004), Replika Press Pvt. Ltd.
2. G. S. Misra, *Introductory Polymer Chemistry*, New Age International (P) Limited, Publishers, 1993.
3. L. H. Sperling, *Introduction to Physical Polymer Science*. 2nd Edition, John Wiley and Sons. Inc.
4. Hans- Georg Elias, *An Introduction to polymer Science*, VCH 1997.
5. Charles E. Seymour, Jr., *Seymour/Carraher's Polymer Chemistry*, 6th ed., Marcel Dekker, Inc., 2003.
6. A. Ravve, *Principles of Polymer Science*, 2nd ed., Kluwer Academic/Plenum Publishers, New York, 2000.

CHEM 416: RESEARCH PROJECT

SEMESTER-IV: INORGANIC CHEMISTRY

Course Code	Title of the Course	No. of Credits	No. of hours per SEMESTER	Examination		Total Marks
				Continuous Evaluation	End-Sem	
CHEM 421	Solid State Chemistry - II	4	60	40	60	100
CHEM 422	Organometallic Chemistry and Catalysis	4	60	40	60	100
CHEM 423	Instrumental Methods, Spectroscopy and Group Theory	4	60	40	60	100
CHEM 424 OC-I	Intellectual Property Rights & Chemoinformatics	4	60	40	60	100
CHEM 425 OC-II	Research Methodology	4	60	40	60	100
CHEM 426	Research Project	8	*	80	120	200

No. of CREDITS: 24 TOTAL MARKS: 600

Students will have to select one of the optional courses i.e. CHEM 424 OC-I or CHEM 425 OC-II

***Practical component involves 16 hr per week of laboratory work for 15 weeks**

SEMESTER-IV: INORGANIC CHEMISTRY

CHEM 421: SOLID-STATE CHEMISTRY-II

Unit-I: ELECTRICAL PROPERTIES OF SOLIDS:

[15L]

(i) Ionic conductivity and solid electrolytes:

Mechanism of conduction in solid electrolytes, e.g. hopping conduction; fast ion conductors, e.g. silver ion conductors, oxygen ion conductors, sodium ion conductors; applications of solid electrolytes, e.g. electrochemical cells, batteries, sensors, fuel cells. (ii)

Electrical Properties:

Band structures of metals, insulators, semi-conductors and inorganic solids; Applications of semiconductors (diodes, transistors, etc.)

Other electrical properties: Thermocouples and their applications, Thomson, Peltier and Seebeck effects; Dielectric, piezoelectric, pyroelectric and ferroelectric materials; their inter-relationship and applications.

Unit-II: MAGNETIC PROPERTIES OF SOLIDS:

[15L]

Behaviour of substances in magnetic field, mechanism of ferromagnetic and antiferromagnetic ordering, superexchange, Hysteresis, Hard and soft magnets, Structures and magnetic properties of metals and alloys, transition metal oxides, spinels, garnets, ilmenites, perovskite and magneto-plumbites, Applications of magnetic materials.

Spin glasses: Formation and characteristics.

Unit-III:

[15L]

(a) Optical Properties of Solids:

Luminescence and phosphor materials: Configurational coordinate model, Anti-Stokes phosphor, Lasers: Ruby laser, Neodymium laser. Absorption and emission of radiation in semiconductor: light emitting diodes, gallium arsenide laser, blue lasers; optical fibers.

(b) Thermal properties of solids:

Introduction, heat capacity and its temperature dependence, thermal expansion of metals, ceramics and polymers, thermal conductivity, mechanism of heat conduction metals, ceramics and polymers; thermal stresses.

Unit-IV: ADVANCES IN NANOMATERIALS

[15L]

(a) Introduction to nanotechnology:

General preparative methods for various nanomaterials, functionalization of nanoparticles for various applications (capping), generic challenges in nanomaterial synthesis.

(b) Special nanomaterials; Carbon nanotubes: Types, synthesis, properties, applications; Quantum dots: properties and applications. Aerogels: types, properties and applications.

(c) Applications of nanomaterials in consumer goods and biomedical fields.

(d) Environmental aspects of nanotechnology.

CHEM 422: ORGANOMETALLIC CHEMISTRY & CATALYSIS

Unit-I: ORGANOMETALLIC CHEMISTRY OF MAIN GROUP ELEMENTS

[15L]

Recapitulation of Organometallic compounds. General properties, stability of organometallic compounds, Preparation methods for s- and p-block elements organometallics. Trends in group 1-2 and 13-16 organometallics.

Unit-II:

[15L]

(a) Organometallic chemistry of f-block elements:

Neutral binary σ -organyls, agostic interactions, alkynyl compounds, η^5 , η^6 , η^7 and η^8 compounds.

(b) Metal-metal bonding and metal atom clusters:

Electron count and structures of clusters, synthesis, reactions, isolobal analogy and structures, Wade's rule (applications to boranes, carboranes and organometallic compounds).

Unit-III: [15L]

(a) Introduction to catalysis and organometallics as catalysts in organic reactions involving hydrogen:

Hydrogenation, asymmetric hydrogenation, hydrosilylation, hydroboration and hydroamination reactions,

(b) Organometallics as catalysts in organic reactions involving carbon monoxide:

Hydroformylation, carbonylation, Water-Gas shift reaction, Fischer-tropsch, alcohol carbonylation, Wacker process, aminocarbonylation reactions.

Unit-IV: [15L]

(a) Organometallics as catalysts in organic reactions involving unsaturated hydrocarbons:

Olefin oligomerization (SHOP process, ethene trimerization, propene dimerization and cyclotrimerization of butadiene), alkene isomerization and alkene/alkyne metathesis.

(b) Organometallics in C-C bond formations reactions:

Heck, Suzuki, Sonogashira, Stille reactions and Reppe Synthesis.

CHEM 423: INSTRUMENTAL METHODS, SPECTROSCOPY & GROUP THEORY

Unit-I [15L]

(a) Infrared spectroscopy:

Introduction to basic principles, instrumentation, factors affecting the character of vibrations, IR absorption bands of metal - donor atom, effect of complex formations on the IR spectrum of ligands. Application of IR spectroscopy to inorganic molecules.

(b) Nuclear Magnetic Resonance:

Introduction to basic principles and instrumentation, NMR parameters, Relaxation process. Use of ^1H , ^{19}F , ^{31}P , ^{11}B NMR spectra in structural elucidation of inorganic compounds.

Unit-II: MICROSCOPY FOR SURFACE CHEMISTRY [15L]

Introduction to surface characterization, problems associated with surface analysis, distinction of surface species, sputter etching, depth profile and chemical imaging. Principle, instrumentation and applications of following techniques: Auger emission spectroscopy (AES), electron spectroscopy for chemical analysis (ESCA), scanning electron microscopy (SEM), transmission electron microscopy (TEM) and atomic force microscopy (AFM).

Unit-III: THERMAL & OPTICAL METHODS OF ANALYSIS [15L]

(a) Introduction to principles and instrumentation of thermoanalytical techniques TGA, DTA, DSC, Applications of thermal techniques in materials science and industry, Determination of thermodynamic parameters for the reaction employing thermoanalytical measurements.

(b) Circular dichroism (CD) and optical rotatory dispersion (ORD):

Introduction, principle, Cotton effect, Faraday and Kerr effects, instrumentation, and applications in determining absolute configuration of metal complexes.

Unit-IV: APPLICATIONS OF GROUP THEORY [15L]

Introduction to basic concepts of symmetry, Matrix representation of symmetry operations, reducible and irreducible representations and great orthogonality theorem.

Construction of character tables for point groups C_{2v} , C_{3v} and C_{2h} , Mulliken's notations for irreducible representations, structure of character tables, determination of symmetry species for translations and rotations, reduction of reducible representations using reduction formula.

Applications of group theory in: (i) infrared and Raman spectroscopy, (ii) construction of Molecular orbital diagram (tetrahedral AB_4 and octahedral AB_6 molecule involving both sigma and pi-bonding) (iii) Ligand Field Theory: Splitting of levels and terms in a chemical environment; Construction of energy level diagrams; Methods of descending Symmetry; Correlation diagrams for d^2 ions in octahedral and tetrahedral ligand field.

Reference books:

CHEM 421:

Unit-I:

1. A. R. West, *Solid state chemistry and its chemical applications*, John Wiley & Sons, (1984).
2. Lesley E. Smart and Elaine A. Moore, *Solid state chemistry – An introduction*, 3rd Ed., Taylor and Francis, (2005).
3. R. C. Ropp Warren, *Solid State Chemistry*, Elsevier Science B.V. (2003).

Unit-II:

1. A. R. West, *Solid state chemistry and its chemical applications*, John Wiley & Sons, (1984).
2. Lesley E. Smart and Elaine A. Moore, *Solid state chemistry – An introduction*, 3rd Ed., Taylor and Francis, (2005).

Unit-III:

1. A. R. West, *Solid state chemistry and its chemical applications*, John Wiley & Sons, (1984).
2. W. D. Callister, Jr., (adapted by R. Balasubramaniam), *Callister's Materials science and engineering*, Wiley-India (2010).

Unit-IV:

1. Sulabha K. Kulkarni, *Nanotechnology: Principles and practices*, Capital publishing company (2007)
2. Lesley E. Smart and Elaine A. Moore, *Solid state chemistry – An introduction*, 3rd Ed., Taylor and Francis, (2005).
3. M. Weller, T. Overton, J. Rourke and F. Armstrong, *Inorganic chemistry*, 6th edition, Oxford University Press (2015).

CHEM 422:

Unit-I-IV:

1. Jahn Hartwig, *Organotransition chemistry-From bonding to catalysis*, University science books, California (2010).
2. Christoph Elschenbroich, *Organometallics*, 3rd edition, Wiley-VCH (2005).

3. R. C. Mehrotra and A. Singh, *Organometallic chemistry- A unified approach*, 2nd edition, New Age International (P) Ltd. (2000).
4. R. H. Crabtree, *The organometallic chemistry of the transition metals*, 5th edition, John Wiley & Sons (2009).
5. D. F. Shriver and P. W. Atkins, *Inorganic chemistry*, 3rd edition, Oxford University Press (1999).
6. Gary O. Spessard and Gary L. Miessler, *Organometallic Chemistry*, 3rd edn., Oxford University Press (2015).

CHEM 423:

Unit-I:

1. R. S. Drago, *Physical methods for Chemists*, 2nd edition, Saunders College publishing (1992).
2. R. S. Drago, *Physical methods in Inorganic chemistry*, Affiliated East-West Press Pvt. Ltd; New Delhi
3. Fmiza Hammer, *Inorganic spectroscopy and related topics*, Sarup & Sons (2008).
4. D. N. Sathyanarayana, *Introduction to magnetic resonance spectroscopy ESR, NMR, NQR*, I. K. Intenational publishing house pvt. Ltd. (2009).
5. K. Burger, *Coordination chemistry: Experimental methods*, London Butterworths, (1973).
6. C. E. Housecroft and A. G. Sharpe, *Inorganic Chemistry*, Pearson Education Ltd. 2nd Edition (2005).

Unit-II:

1. D. A. Skoog and F. J. Holler and T. A. Nieman, *Principles of instrumental analysis*, 5th ed., Harcourt Asia PTE Ltd. (1998).
2. R. A. Scott and C. M. Lukehart, *Applications of physical methods to inorganic and bioinorganic chemistry*, John Wiley & Sons Ltd. (2007).
3. Sulabha K. Kulkarni, *Nanotechnology: Principles and practices*, Capital publishing company (2007).

Unit-III:

1. W. W. Wendlandt, *Thermal analysis*, Interscience (1985).
2. P. D. Garn, *Thermoanalytical methods of investigation*, Academic press, N. Y. (1963).
3. A. Blazek, *Thermal analysis*, Van Norstrand Reinhold Co., London (1973).
4. T. Daniel, *Thermal analysis*, Kogan page Ltd., London (1973).
5. C. J. Keattch and D. Dollimore, *An introduction to thermal analysis*, Heyden, London (1975).
6. M. D. Judd and M. I. Pope, *Differential thermal analysis*, Heydon, London (1977).
7. G. W. H. Hohne, W. F. Hemminger and H. Flammersheim, *Differential scanning calorimetry-An introduction for practioners*, Springer-verlag, Berlin (1996).
8. K. Burger, *Coordination chemistry: Experimental methods*, London Butterworths, (1973).
9. G. W. H. Hohne, W. F. Hemminger and H. Flammersheim, *Differential scanning calorimetry-An introduction for practioners*, Springer-verlag, Berlin Heidelberg (2003).
10. R. A. Scott and C. M. Lukehart, *Applications of physical methods to inorganic and bioinorganic chemistry*, John Wiley & Sons Ltd. (2007).

11. D. A. Skoog and F. J. Holler and S. R. Crouch, Instrumental analysis, 5th ed., Harcourt Asia PTE Ltd. (1998).

Unit-IV:

1. Gary Wulfsberg, Inorganic chemistry, Viva Books Pvt. Ltd., (2002).
2. J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, *Inorganic chemistry- Principles of structure and reactivity*, 4th edition, Pearson (2006).
3. D. F. Shriver and P. W. Atkins, *Inorganic chemistry*, 3rd edition, Oxford University Press (1999).
4. R. L. Carter, *Molecular symmetry and group theory*, John Wiley & Sons, New York, (1998).
5. S. F. A. Kettle, *Symmetry and structure-Readable Group Theory for Chemists*, 3rd Ed., John Wiley & Sons, Inc. (200&0).
6. K. V. Reddy, *Symmetry and Spectroscopy of molecules*, New Age International (P) Ltd. 2nd Edition, (2009).
7. A. S. Kunju and G. Krishnan, *Group theory and its application in chemistry*, PHL Learning Pvt. Ltd., (2010).
8. F. A. Cotton, *Chemical applications of group theory*, Wiley Eastern Ltd., (1989).

CHEM 426: RESEARCH PROJECT

SEMESTER-IV: ORGANIC CHEMISTRY

Course Code	Title of the Course	No. of Credits	No. of hours per SEMESTER			Total Marks
				Continuous Evaluation Marks	End-Sem Marks	
CHEM 431	Stereochemistry, Asymmetric Synthesis, Organic Electronic and Photonic materials	4	60	40	60	100
CHEM 432	Advanced Synthetic Organic chemistry	4	60	40	60	100
CHEM 433	Natural Products Chemistry	4	60	40	60	100
CHEM 434 OC-I	Intellectual Property Rights & Chemoinformatics	4	60	40	60	100
CHEM 435 OC-II	Research Methodology	4	60	40	60	100
CHEM 436	Research Project	8	*	80	120	200

No. of CREDITS: 24 TOTAL MARKS: 600

Students will have to select one of the optional courses i.e. CHEM 434 OC-I or CHEM 435 OC-II

***Practical component involves 16 hr per week of laboratory work for 15 weeks**

SEMESTER- IV: ORGANIC CHEMISTRY

CHEM 431: STEREOCHEMISTRY, ASYMMETRIC SYNTHESIS, THEORETICALLY FASCINATING MOLECULES, ORGANIC ELECTRONIC AND PHOTONIC MATERIALS

Unit-I STEREOCHEMISTRY [15L]

- 1.1. Racemates and methods of resolution of racemates. [3L]
- 1.2. Chemical and Instrumental methods of determining configurations. [4L]
- 1.3. Conformation and reactivity in cyclic compounds with more emphasis on cyclohexane derivatives, Reactions involving steric factors and stereoelectronic factors, Addition reactions, substitution reactions, elimination reactions, rearrangement reactions, I-strain concept. [4L]
- 1.4. Determination of enantiomer and diastereomer composition.
- (a) Chiroptical methods and their limitations [Horeau effect]
- (b) **Methods based NMR:**
Use of Chiral Derivatizing Agents, CDA, Chiral Solvating Agents, CSA, and Chiral Shift Reagents, CSR.;
- (c) Chromatographic methods, use of chiral stationary phase (chiral columns) [4L]

Unit-II ASYMMETRIC SYNTHESIS [15L]

Principles of asymmetric synthesis, Cram's rule, Sharpless epoxidation, asymmetric dihydroxylation, asymmetric aminohydroxylations, asymmetric Diels-Alder reactions, chiral borane reagents, asymmetric reductions of prochiral carbonyl compounds and olefins. Use of chiral auxiliaries in Diastereoselective reductions. Synthesis of alpha amino acids (Corey's Diastereoselective hydrogenation of cyclic hydrazones); Synthesis of L-DOPA [Knowles's Monsanto process], asymmetric aldol and related reactions.

Use of Chiral BINOLs, BINAPs, and chiral oxazolines and oxazolidines in asymmetric transformations.

Unit-III THEORETICALLY FASCINATING MOLECULES [15L]

- 3.1. Structures, synthesis and properties of cyclophanes, calixarenes, C-60, rotaxanes [5L]
- 3.2. Design, operating photophysical principles, synthesis of selected chemo- and fluorescence based metal ion sensors derived from crown ethers and macrocyclic systems, and chemo- and fluorophore chelators. [8L]
- 3.3. **The Host Guest binding phenomena:**

Assessment by UV/VIS or Fluorescence methods; NMR methods. The Benesi-Hildebrand Equation, Stern Volmer relationships [2L]

Unit-IV ORGANIC, ELECTRONIC & PHOTONIC MOLECULES [15L]

Organic nonlinear chromophores, Conducting polymers, Dye sensitized organic photovoltaic materials, Organic Magnetic materials, Organic light emitting diodes. General examples of organic conjugated chromophores and polymers, synthesis and various applications.

CHEM 432: ADVANCED SYNTHETIC ORGANIC CHEMISTRY

Unit-I DOMINO REACTION & CLICK CHEMISTRY

[15L]

- 1.1. Multi-component reactions: i) Strecker reaction ii) Hantzsch dihydropyridine synthesis iii) Biginelli condensation iv) Passerni 3- component condensation v) Ugi 4- component condensation iv) Domino Knoevenagel-hetero-Diels-Alder reaction.
- 1.2. Domino Reactions/Tandem Reaction/Cascade Reactions: Definition and Classification
Cascade processes: concept, examples of cationic, anionic and radical initiated cascade reactions.
- 1.3. Click Chemistry reactions

Unit-II POLYMER SUPPORTED REAGENTS & ELECTROORGANIC SYNTHESIS

[15L]

- 2.1. Polymer supported reagents for acid base catalysis,
- 2.3. Introduction: Electrode potential, cell parameters, electrolyte, working electrode, choice of solvents, supporting electrolytes.
- 2.4. Cathodic reductions: alkyl halides, aldehydes/ketones, nitro compounds, olefin, arenes, Electrodimerizations.
- 2.5. Anodic oxidations,: Kolbe type reactions, oxidation of arylalkanes .

Unit-III NON-CLASSICAL METHODS OF ORGANIC SYNTHESIS

[15L]

Principles and applications of the following:

- 3.1.1) Phase transfer catalysis, crown ethers and cryptands, concepts, synthesis and applications 2) Micelles, structures, properties and reactions 3) Ionic liquids 4) cyclodextrin, structure and functions 5) ultrasound in organic synthesis 6) Zeolites, structures, properties and catalysis and 7) Organocatalysis 7) Microwave in organic synthesis 8) Solid phase synthesis

Unit-IV DESIGNING ORGANIC SYNTHESIS

[15L]

4.1. Umpolung:

Concept of umpolung, generation of acyl anion equivalent-1,3-dithiane from carbonyl compounds, use of methylthio-methylsulfoxide, via cyanide ion and cyanohydrin ethers, nitro compounds and metallated vinyl ethers

4.2. Methodology in organic synthesis:

Functional group interconversions, general methods of 4 -7 membered ring formation, Disconnection approach and Retrosynthetic analysis, ideas of synthones and retrones, Examples of acyclic saturated and unsaturated systems, monocyclic and bicyclic compounds.

4.3. Target oriented and methods oriented synthesis: Strategies and tactics.

4.4. Protection-deprotection of functional groups:

carbonyl, hydroxyl, amino, carboxyl, with examples illustrating the applications of each.

CHEM 433: NATURAL PRODUCTS CHEMISTRY

Unit-I NATURAL PRODUCTS CHEMISTRY-I

[15L]

1.1.Steroids:

Occurrence, structures, classification biological role, important structural and stereochemical features of the following types of steroids- Estrogens, gestrogens, androgens, corticosteroids, sterols, bile acids, calciferol, sapogenins and steroidal alkaloids. **[5L]**

1.2.Synthesis of 16-DPA from cholesterol and plant sapogenin. **[3L]**

1.3. Synthesis of commercially important steroids from 16-DPA. **[4L]**

1.4.Synthesis of cinerolone, Jasmolone, allethrolone, pyrethrolone, exaltone and muscone. **[3L]**

Unit-II NATURAL PRODUCTS CHEMISTRY-II

[15L]

2.1.Insect pheromones:

Structural features and importance .Synthesis of bombycol, gossyplure, disparlure, brevicomin and grandisol **[5L]**

2.2.Insect growth regulators:

General idea, constitution of JH, structures of JH₂ and JH₃ **[2L]**

2.3.Plant growth regulators:

Structural features and applications of aryl acetic acids, gibberelic acids, brassinolides and triacontanol, Synthesis of triacontanol. **[2L]**

2.4.Antibiotics:

Classification on the basis of activity and structure determination of penicillin-G, Cephalosporin-C and terramycin, Synthesis of penicillin-G, phenoxymethyl penicillin and Semi-synthetic cephalosporins. **[6L]**

Unit-III NATURAL PRODUCTS CHEMISTRY-III

[15L]

3.1.Carbohydrates

3.2.Types of naturally occurring sugars:

Deoxy sugars, amino sugars, branched sugars. Structure determination of lactose, inositol and amino sugars, Constitution and applications of chitin. **[6L]**

3.3.Natural pigments:

[4L]

General structural features, occurrence, isolation, biological importance and applications of- carotenoids, anthocyanins, flavones, xanthenes, quinones, pterins and porphyrins, Structure determination and synthesis of β -carotene and ubiquinone.

3.4.Prostaglandins:

[3L]

Classification, General structure and biological importance.

Structure determination and synthesis of PGE₁ and PGF_{1 α}

3.5.Lipids:

[2L]

Structure and role of carbolipids, phospholipids and sphingolipids.

Unit-IV NATURAL PRODUCTS CHEMISTRY-IV

[15L]

4.1.Vitamins:

[5L]

Classification, sources and biological importance, Synthesis of B₁, B₂, B₆, D, E, K and compounds with vitamin-K activity.

4.2. Multi-step synthesis of natural products:

[10L]

Synthesis of the following natural products with special reference to reagents used, stereochemistry and functional group transformations-Reserpine, Longifoline, Griseofulvin, Estrone, β - Vetivone, 4-Demethoxy daunomycin, caryophyllin, etc.

References Books:

1. Organic Chemistry, J. Claydens, N. Greeves, S. Warren and P. Wothers, Oxford University Press.
2. Advanced Organic Chemistry, F.A. Carey and R.J. Sundberg, Part A and B, Plenum Press.
3. Stereochemistry: Conformation and mechanism, P.S. Kalsi, New Age International, New Delhi.
4. Stereochemistry of carbon compounds, E.L. Eliel, S.H. Wilen and L.N. Manden, Wiley.
5. Stereochemistry of Organic Compounds- Principles and Applications, D. Nasipuri. New International Publishers Ltd.
6. March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure, Michael B. Smith, Jerry March, Wiley.
7. Advanced Organic Chemistry: Reactions and mechanism, B. Miller and R. Prasad, Pearson Education.
8. Advanced Organic Chemistry: Reaction mechanisms, R. Bruckner, Academic Press.
9. Understanding Organic Reaction Mechanisms, Adams Jacobs, Cambridge University Press.
10. Writing Reaction Mechanism in organic chemistry, A. Miller, P.H. Solomons, Academic Press.
11. Principles of Organic Synthesis, R.O.C. Norman and J.M. Coxon, Nelson Thornes.
12. Advanced Organic Chemistry: Reactions and mechanism, L.G. Wade, Jr., Maya Shankar Singh, Pearson Education.
13. Introduction to Spectroscopy, Donald L. Pavia, Gary M. Lampman, George S. Kriz, Thomson Brooks.
14. Spectrometric Identification of Organic Compounds, R. Silverstein, G.C. Bassler and T.C. Morrill, John Wiley and Sons.
15. Organic Spectroscopy, William Kemp, W.H. Freeman & Company.
16. Organic Spectroscopy-Principles and Applications-Jagmohan, Narosa Publication.
17. Organic Spectroscopy, V.R. Dani, Tata McGraw Hill Publishing Co.
18. Spectroscopy of Organic Compounds, P.S. Kalsi, New Age International Ltd.
19. Mechanism in Organic Chemistry, Peter sykes, 6th edition onwards.
20. Physical Organic Chemistry, Neil Isaacs
21. Modern Physical Organic Chemistry, Eric V. Anslyn and Dennis A. Dougherty
22. Stereochemistry: A Three-Dimensional Insight by Anil V. Karnik and Mohammed Hasan.

CHEM 436: RESEARCH PROJECT

SEMESTER-IV: ANALYTICAL CHEMISTRY

Course Code	Title of the Course	No. of Credits	No. of hours per SEMESTER			Total Marks
				Continuous Evaluation	End-Sem	
CHEM 441	Quality In Analytical Chemistry and Pharmaceutical Analysis	4	60	40	60	100
CHEM 442	Advanced Instrumental Techniques and nanotechnology	4	60	40	60	100
CHEM 443	Analysis of Ores, Food, Agro / Agriculture	4	60	40	60	100
CHEM 444 OC-I	Intellectual Property Rights & Chemoinformatics	4	60	40	60	100
CHEM 445 OC-II	Research Methodology	4	60	40	60	100
CHEM 446	Research Project	4	*	80	120	200

No. of CREDITS: 24 TOTAL MARKS: 600

Students will have to select one of the optional courses i.e. CHEM 444 OC-I or CHEM 445 OC-II

***Practical component involves 16 hr per week of laboratory work for 15 weeks**

SEMESTER IV:ANALYTICAL CHEMISTRY
CHEM 441: QUALITY IN ANALYTICAL CHEMISTRY AND PHARMACEUTICAL
ANALYSIS

UNIT I:

[15L]

Quality in Analytical Chemistry:

- 1.1 The need for reliable results: Social and economic impact of wrong analysis, concept of quality, customer requirement, purpose of analysis.
- 1.2 Principle of quality assurance quality control: Quality management system, quality assurance and quality control, different standards and their main features, best practice.
- 1.3 Sampling: Definition, types of samples, sampling plan, sub-sampling, sample registration and storage, acceptance sampling- inspection by attributes.
- 1.4 Preparation for analysis: Method selection, Sources of methods, Factors to consider in choosing a method, performance criteria for methods to determine analytes by selected techniques, reasons for incorrect analytical results, method validation.
- 1.5 Making Measurements: Good laboratory practice, calibration of measurement, chemical standards and reference materials, quality control, environment, equipment, chemicals, consumables, maintenance and calibration of equipments.

UNIT II:

[15L]

- 2.1 Data treatment: Control charts, measurement uncertainty: Definition and evaluation of uncertainty; putting uncertainty to use.
- 2.2 Documentation and its management: Quality manual, record management and reporting results.
- 2.3 Managing quality: Management system, Standards available for laboratories, audit, review, responsibilities of laboratory staff for quality.
- 2.4 **Signals and Noise:**
Signal to noise ratio, sources of noise in instrumental analysis, signal to noise enhancement, hardware devices and software methods for noise reduction.

UNIT III:

[15L]

Pharmaceutical Analysis I:

- 3.1 General idea regarding pharmaceutical industry, definition and classification of drugs, introduction to pharmaceutical formulations, classification of dosage forms.
- 3.2 Sources of impurities in pharmaceutical chemicals and raw materials.
- 3.3 Standardization of finished products and their characteristics, official methods of control, use of pharmacopoeia.
- 3.4 Analysis of compounds based on functional groups (eg. Aspirin, paracetamol, ascorbic acid, vitamin-A), classical and instrumental methods

of drug analysis, proximate assays, assays of enzyme containing substances, biological and microbiological assays and tests.

UNIT IV:

[15L]

Pharmaceutical Analysis II:

- 4.1 Limit tests, solubility tests, disintegration tests, stability studies, impurity profile of drugs, bioequivalence and bioavailability studies.
- 4.2 Pharmaceutical legislation: Introduction to drug acts, drug rules (schedules), FDA and ISO standards, ISO 9000 and its requirements, introduction to GMP.
- 4.3 Introduction to drug development.

Text/ References:

1. Quality assurance in Analytical Chemistry, Elizabeth Prichard and Vicki Barwick, LGC, Teddington, UK, 2007.
2. Quality Assurance in Analytical Chemistry W. Funk, V. Dammann, G. Donnevert VCH Weinheim (1995).
3. Principles of Instrumental Analysis, D.A. Skoog, F.J. Holler, and J.A. Nieman 5th Edition (1998).
4. Good Laboratory practice, Eds. W.Y. Garner, M.S. Barge and J.P. Ussary, ACS Professional Reference Book (1992).
5. Quantitative Organic Analysis Via functional groups, 3rd Ed. S. Sigia. John Wiley, N.Y. (1972).
6. Pharmaceutical Drug Analysis (Methodology-Theory-Instrumentation Pharmaceutical assays-Cognate Assays), AshutoshKar, New Age Int. Pvt. Ltd. New Delhi (2010).
7. Indian Pharmacopeia 2010, Vol. I, II, III and Addendum 2012, 6th Ed. The Indian Pharmacopoeia Commission, Ghaziabad, 2010.
8. British Pharmacopeia.
9. Pharmaceutical Analysis, T. Higuchi and E. Brochmann- Hanssen, Interscience (1961).
10. The quantitative analysis of drugs, D.C. Garratt, Chapman and Hall (1964).
11. Pharmaceutical Analysis, A.H. Beckett and J.B. Stenlake, Chapman and Hall.
12. Methods of Drug Analysis, B.F. Granbowshi, Lea and Feniger.
13. Analysis of Drugs and Chemicals, N. Evers, W. Smith and C. Griffin.
14. Hawk's Physiological Chemistry, Mc Graw Hill.
15. ICH Guidelines

SEMESTER IV:ANALYTICAL CHEMISTRY

CHEM 442: ADVANCED INSTRUMENTAL TECHNIQUES AND NANOTECHNOLOGY

Unit I:

[15L]

Principles, instrumentation and applications of followings:

- 1.1 Electron spectroscopy: AUGER &XPS (ESCA)
- 1.2 Electron microprobe method.
- 1.3 Reflectance spectroscopy

1.4 Photoacoustic spectroscopy

Unit II: [15L]

Principles, instrumentation and applications of followings:

- 2.1 Electron microscopy: Scanning electron microscopy, Scanning probe microscopes: The Scanning Tunneling Microscope, Atomic force Microscope.
- 2.2 Chemiluminescence method.
- 2.3 Polarimetry: ORD, CD.

Unit III: [15L]

Hyphenated Techniques:

- 3.1 Introduction, need for hyphenation, possible hyphenation, Interfacing devices and applications of the following: GC-IR, ICP-MS, Spectroelectrochemistry and radio-chromatography.
Application of GC-MS, MS-MS, to Agrochemicals, fine chemicals and Petrochemicals
Application of HPLC-MS and MS-MS to pharmaceuticals and bio molecules

Unit IV: [15L]

Nanotechnology: Introduction and Applications of Nanomaterials

- 4.1 Types of nanomaterials, Classification, General preparative methods for various nanomaterials.
- 4.2 Some important properties on nanomaterials: optical, magnetic properties, Structural and chemical properties.
- 4.3 Some special nanomaterials: Carbon nanotubes and quantum dots, Preparation and applications.
- 4.4 Applications of nanomaterials in electronics, energy, automobiles, sports and toys, textile, cosmetics, medicine, space and defense.
- 4.5 Analytical techniques for characterization of nanomaterials.

Reference Books:

- 1. **Hofmann**, Siegfried, Auger- and X-Ray Photoelectron Spectroscopy in Materials Science Springer-Verlag Berlin Heidelberg.
- 2. S. J. B. Reed, I. M. Romanenko, D. S. Woolum, P. Trocellier, Microprobe Analysis.
- 3. **Kuo**, John, Electron Microscopy: Methods and Protocols, Humana Press.
- 4. [Gustav Kortüm](#), Reflectance Spectroscopy: Principles, Methods, Springer; Softcover reprint of the original 1st ed. 1969 edition (January 1, 1969).
- 5. [John W. Birks](#) Chemiluminescence and Photochemical Reaction Detection in Chromatography, Wiley-VCH; (July 26, 1989)
- 6. Lihong V. Wang, Photoacoustic Imaging and Spectroscopy, CRC press.
- 7. Douglas A. Skoog; F. James Holler; Stanley R. Crouch; Principles of Instrumental Analysis 6th Edition.
- 8. Handbook of GC/MS Fundamentals and Applications, H. J. Hubschmann, Weinheim, Germany, Wiley VCH, 2001
- 9. Modern practice of Gas Chromatography, R. L. Grab and E. F. Berry, 4th Edition, Wiley Interscience, New York, 2004.

10. LC/MS: A Practical User Guide, W. C. McMaster, Hooken, Wiley, New Jersey, 2005.
11. Technologies and Applications of Tandem Mass Spectrometry, K. L. Busch, G. L. Glish and S. A. McLuckey, New York, VCH, 1998.
12. Inductively coupled Mass Spectrometry, A. Montaser (Ed), Wiley VCH, Chinchester, 1998, New York.
13. Nanotechnology: Principles and Practices, J. K. Kulkarni, Capital Publishing Co., 2007

SEMESTER IV:ANALYTICAL CHEMISTRY

CHEM 443: ANALYSIS OF ORES, FOOD, AGRO /ARICULTURE

Unit I: Analysis of Minerals, Ores and alloys [15L]

- 1.1 Analytical treatment of minerals and ores: Sampling, analytical treatment, dissolution of ores. Biomining.
- 1.2 Analyses of ores: bauxite and monazite.
- 1.3 Analysis of alloys: steel and stainless steel and copper based alloys.

Unit II: Soil and Fertiliser Analysis [15L]

- 2.1 Soil health card scheme. Sampling and preparation of soil samples for analysis, solid texture estimation. pH, electrical conductance, macro and micro nutrients, organic carbon, CaCO_3 (free lime), cation exchange capacity, gypsum requirements, micro and macro nutrients in soil. Soil miro-organisms and their functions.
- 2.2 Different types of synthetic fertilizers and introduction to organic fertilizers and their analysis and interaction with different components of soil.
- 2.3 Degradation of different insecticides, fungicides and weedicides in soil.

Unit III: Food Quality Concepts [15L]

- 3.1 General idea regarding moisture content, ash, fibre, proteins, carbohydrates, lipids and fats in food analysis.
- 3.2 Food standards – their importance and limitations. Food preservatives, adulterants and contaminants.
- 3.3 Analysis-
Additives: flavours and colour.
- 3.4 Contaminant: heavy metals and pesticide residues

Unit IV: Food Analysis &Pesticide Analysis [15L])

- 4.1 Processing and quality control requirements of milk and milk products (butter, cheese, ice cream), carbonated and alcoholic beverages.
- 4.2 Analysis of dairy products, oils, fruits and vegetables.
- 4.3 Pesticide Analysis-
Pesticide formulation– Application test.
- 4.4 Pesticideresidue analysis in water, beverages, food products and soil by GC/HPLC/GC-MS.

Texts/ references:

1. Standard methods of Chemical Analysis, Vol. 2, (Part A& B), 5th ed, F. J. Welcher, Von Nostrand& Robert E. Krieger Publishing Co. New York, (1975).

2. Quantitative Organic Analysis, Part III, 2nd Ed., A. I. Vogel, CBS, (1987).
3. Chemical Analysis of Food and Food Products, H. B. Jacob, Van Nostrand Reinhold, (1958).
4. Official Methods of Analysis of the Association of Official Analytical Chemists (AOAC), 14th Ed., (1984).

OPTIONAL COURSES

OPTIONAL PAPER-I

CHEM 414-OC-I / CHEM 424- OC-I/ CHEM 434- OC-I / CHEM 444-OC-I

INTELLECTUAL PROPERTY RIGHTS & CHEMOINFORMATICS

Unit-I [15L]

Introduction to Intellectual Property: [2L]

Historical Perspective, Different types of IP, Importance of protecting IP.

Patents: [5L]

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

Industrial Designs: [2L]

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

Layout design of integrated circuits: [2L]

Circuit boards, Integrated Chips Importance for electronic industry.

Copyrights: [2L]

Introduction, How to obtain, Differences from Patents.

Trade Marks: [2L]

Introduction, How to obtain, Different types of marks-Collective marks, certification marks, service marks, Trade names, etc.

Unit-II [15L]

Geographical Indications: [2L]

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

Trade Secrets: [2L]

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

IP Infringement issue and enforcement: [5L]

Role of Judiciary, Role of law enforcement agencies-Police, Customs, etc.

Economic Value of Intellectual Property:

Intangible assets and their valuation, Intellectual Property in the Indian Context- Various Laws in India Licensing and technology transfer.

Different International agreements: [6L]

(a) World Trade Organization (WTO):

- (i) General Agreement on Tariffs & Trade (GATT), Trade Related Intellectual Property Rights (TRIPS) agreement
- (ii) General Agreement on Trade related Services (GATS)
Madrid Protocol

(iii) Berne Convention

(iv) Budapest Treaty

(b) Paris Convention

WIPO and TRIPS, IPR and Plant Breeders Rights, IPR and Biodiversity

Unit-III

[15L]

Introduction to Cheminformatics:

[5L]

History and evolution of cheminformatics, Use of cheminformatics, Prospects of cheminformatics, Molecular Modeling and Structure elucidation.

Representation of molecules and chemical reactions:

[5L]

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

Searching chemical structures:

[5L]

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

Unit-IV

[15L]

Applications:

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

Reference books:

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

OPTIONAL PAPER-II

CHEM 415-OC-II / CHEM 425- OC-II / CHEM 435- OC-II / CHEM 445-OC-II

RESEARCH METHODOLOGY

Unit-I LITERATURE SURVEY[15L]

Print:

[5L]

Primary, Secondary, Tertiary sources,

Journals:

Journal abbreviations, abstracts, current titles, reviews, monographs, dictionaries, text-books, current contents, Introduction to Chemical Abstracts and Beilstein, SubjectIndex, Substance Index, Author Index, Formula Index, and other Indices with examples.

Digital:

[5L]

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

Information Technology and Library Resources:

[5L]

The Internet and World Wide Web, Internet resources for chemistry, Finding and citing published information.

Unit-II DATA ANALYSIS

[15L]

The Investigative Approach:

Making and recording Measurements, SI Unit-s and their use, Scientific methods and design of experiments.

Analysis and Presentation of data:

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

Unit-III METHODS OF SCIENTIFIC RESEARCH & WRITING SCIENTIFIC PAPERS [15L]

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

Writing scientific papers:

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

Unit IV: CHEMICAL SAFETY & ETHICAL HANDLING OF CHEMICALS [15L]

Safe working procedure and protective environment, protective apparel, emergency procedure, and first aid, laboratory ventilation, safe storage and use of hazardous chemicals, procedure for

working with substances that pose hazards, flammable or explosive hazards, procedures for working with gases at pressures above or below atmospheric- safe storage and disposal of waste chemicals, recovery, recycling and reuse of laboratory chemicals, procedure for laboratory disposal of explosives, identification, verification and segregation of laboratory waste, disposal of chemicals in the sanitary sewer system, incineration and transportation of hazardous chemicals.

Reference books:

1. Dean, J. R., Jones, A. M., Holmes, D., Reed, R., Weyers, J., & Jones, A., (2011), *Practical skills in chemistry*, 2nd Ed., Prentice Hall, Harlow.
2. Hibbert, D. B., & Gooding, J. J., (2006), *Data analysis for chemistry*, Oxford University Press.
3. Topping, J., (1984), *Errors of observation and their treatment*, 4th Ed. Chapman Hll, London.
4. Harris, D. C., (2007), *Quantitaive chemical analysis*, 6th Ed., Freeman Chapters 3-5
5. Levie, R. de., (2001), *How to use Excel in analytical chemistry and in general scientific data analysis*, Cambridge Univ Press 487 pages.
6. Chemical safety matters-IUPAC-IPCS, Cambridge University Press, 1992.
7. OSU safet manual 1.01

CHEM 446: RESEARCH PROJECT

9. **Fees for M. Sc. (Choice Based Credit System) course*:**

(*fee structure is likely to undergo revision from the academic year 2023-24)

Sr. No	Fee Details	For Open category students	Reserved Category students
	Fees Head Description	Amount in Rs.	Amount in Rs.
1	Application Form & Prospectus Fee	100.00	100.00
2	Caution Money Deposit	800.00	800.00
3	Computer & Internet	500.00	-
4	Development Fee	500.00	-
5	Group Insurance Fee	40.00	40.00
6	Identity Card	50.00	50.00
7	Library Fee	1,000.00	-
8	Gymkhana	200.00	-
9	Magazine	100.00	-
10	Student Welfare Fund Contribution	50.00	50.00
11	E-Suvidha Fee	50.00	50.00
12	Disaster Relief Fund	10.00	10.00
13	P.G. Registration Fee	850.00	850.00
14	P.G. Registration Form Fee	25.00	25.00
15	Tution Fee	1,000.00	-
16	Admission Processing Fee	200.00	200.00
17	Utility	250.00	-
18	Other Fees/ Extracurricular Activity	250.00	-
19	Sports Activity Fund, University Sport & Cultural Activity	30.00	-
20	Eligibility Cum Enrolment Fee	-	-
21	Sports Contribution	-	-
22	National Sevice Scheme	-	-
23	Vise Chancellor's Fund Contribution	20.00	20.00
24	E-Charges	20.00	-
24	Railway Consession	-	-
25	Laboratory Fees	6,000.00	-
	Total	12,045.00	2,195.00

* Note:- (Sr.No.20) Eligibility fees is valid for only other University students. It is 400 for Within Maharashtra University Student and 500 For Outside of Maharashtra University Students, this Fees is Same For all Category.

Fees for Ph. D. course:

(*fee structure is likely to undergo revision from the academic year 2023-24)

Open category

No.	Account Head	Fee (Rs.)
1.	Tuition fee	4000/-
2.	Other fees / Extracurricular activities	250/-
3.	Admission Processing Fee	200/-
4.	Laboratory fee	12000/-
5.	Library fee	1000/-
6.	Gymkhana fee	200/-
7.	Vice-Chancellor's fund	20/-
8.	Magazine	100/-
9.	Identity card fee	50/-
10.	Group insurance	40/-
11.	Student welfare	50/-
12.	University sports and cultural activities	30/-
13.	Development fee	500/-
14.	Utility	250/-
15.	Computer/Internet	500/-
16.	e-Suvidha	50/-
17.	e-Charges	20/-
18.	Disaster Relief fund	10/-
19.	Railway concession (wherever applicable)	20/-
20.	Caution money, Library and Laboratory deposit	800/-
21.	Registration fee	1000/-
22.	Registration form	25/-
	Total	21,115/-

Office timings

The office working hours for students and visitors are from Monday to Saturday between 11.00 a.m. and 4.00 p.m. with half an hour recess between 1.00 p.m. and 1.30 p.m. The office will remain closed on all Sundays, Bank holidays and on second and fourth Saturdays.

11. IMPORTANT CIRCULARS

UNIVERSITY OF MUMBAI

No. Th / 69 of 2001

CIRCULAR

A reference is invited to this office circular No. Th/412 of 2000, dated 30th November, 2000, of the Directors/Heads of the various University Departments, Principals of the affiliated Colleges and Heads of the recognized Institutions are hereby informed that the following procedure has been prescribed by the University for approving the topic of the thesis/dissertation for admission to the Master's Degree (By Research) and Ph.D. Degree course in various subjects of this University as per the provisions of Section 36 (A) of the Maharashtra Universities Act, 1994.

1. A student seeking admission to the Master's Degree (By Research) and Ph.D. Degree course in various subjects of this University is required to submit prescribed application provided by this office duly forwarded through the guiding teacher and the Head/Director/Principal of the Department/Institution/College where he/she intends to seek admission.
2. The application with payment of prescribed fee along with 15 copies of the outline of the topic of thesis/dissertation signed by the student and his/her guiding teacher be submitted to the Thesis Section of the University.
3. Admission and subsequent registration for the said degree courses will be granted only to such student whose topic of the thesis/dissertation has been approved by the Research and Recognition Committee of the each Board/Ad-hoc Board/Ad-hoc Committee for the course which he/she has applied.
4. In case to topic of the thesis/dissertation is not approved by the said committee, the student can apply again a fresh with the payment of prescribed fee. In any circumstances, the fee once paid will not be refunded to the student.

The cost of the blank application is Rs. 25/- (Rupees Twenty Five Only) and fee prescribed for the procedure to approve topic of thesis/dissertation for the said course is Rs. 200/- (Rupees Two Hundred only).

The rules relating to the Ph.D. degree are as under:-

These rules are applicable to the students, who have registered after 5th July, 1999.

- R. 20** Candidate for research degree be permitted to submit to the University through guiding teacher and Head/Principal/Director of the Department/College/Institute, the title of the problem of their research not later than one year from the date of the registration as Post-graduate student. If however, the candidate fails to submit the title of the problem of his/her research within one year from the date of registration, the period of delay will be taken into account while fixing the date of submission of synopsis e.g. if the delay is of the period of one month the date of submission of synopsis will be extended by a minimum period of one month.
- R. 21** Candidates for research degree be permitted to change the problem of their thesis on applying thereto the guiding teacher and Head/Principal/Director, of Department/College/Institute, but such candidate will have to keep all the terms fresh for the new problem from the day they change the problem.
- R. 22** Candidate for research degree be permitted to submit the exact title with the slight changes in the title as submitted at the time of the registration of the problem of their

thesis on applying through the guiding teacher and Head/Principal/Director, of the Department/College/Institute, six months prior to the submission of the synopsis, provided that the guiding teacher offers his/her remarks that the candidate has made a slight change or changes in the title of the problems but problem of research remains substantially the same.

Change of Guide:

R. 23 Candidates for research degree changing their guiding teacher shall apply to the Registrar for permission to do so, through both the old new teachers. Whenever a teacher ceases to be recognized teacher, he shall inform the students registered under him that they have to continue their work under some other recognized teacher.

Rule regarding the submission of the thesis after the submission of the synopsis

R. 24 A research student, who has submitted a synopsis. A research student failing to submit his thesis within prescribed limit of six months of the date of submission of his synopsis, shall pay a fresh fee for admission to the examination.

As per circular No. Th./ 48611 of 1997, 1st Aug. 1997 students should submit the following document at the time of submission of registration form, synopsis submission form and thesis submission form.

A) At the time of submission for Registration form for research degree:

- 1) Registration form duly completed by the student the Department/College/Institutions in all branches.
- 2) Certified Xerox copy of the Statement of Marks.
- 3) Certified Xerox copy of the Degree Certificate.
- 4) Certified Xerox copy of the Provisional Statement Eligibility, (if the student is from another University).
- 5) Certified Xerox copy of the Marriage Certificate.
- 6) In case of foreign students certified copy of passport/student visa, NOC from concerned policy and Government Authorities.
- 7) Challan Form duly signed by the Director/Principal/Head of the Department/College/Institutions.
- 8) Work Experience Certificate issued by the employer. (In case of the students those who intend to join Ph.D. in Management Studies.)

B) At the time of submitting synopsis of a research degree:

1. Synopsis submission form duly completed by the student and the Department/College/Institution in all respects.
2. Certified Xerox copy of the statement of marks of M. Sc. Part I/M. Sc. Part II examination of the University.
3. Certified Xerox copy of the Passing/Degree Certificate.
4. Certified Xerox copy of the Confirmation of Provisional Eligibility Certificate, (if the student is from another University).
5. Challan Form duly signed by the Director/Principal/Head of the Department/College/Institution.

C) At the time of submission of Thesis:

1. Thesis submission form duly completed by the student and the Department/College/Institution in all respect.
2. Three copies of the thesis.
3. Account clearance Certificate Filled and Certified by the Deputy Accountant of the respective campus.

The format of the front-page of the synopsis other than Biochemistry.

Title of the thesis.

Name of the Research Student.

Name of the Research Supervisor/Guiding Teacher.

Place of Research Work.

Registration Number.

Date of synopsis Submission.

Signature of the Candidate

Signature of the Research Guide with full Name.

Sd/-
for Registrar

Mumbai - 400 032.

Proforma – A

(Undertaking to be given by candidate who is unable to produce original certificates at the time of his / her admission round, as admission is already taken elsewhere)

UNDERTAKING

Ihave secured admission to M. Sc. (Choice-Based Credit System) (Four-SEMESTER- Course) at the Department of Chemistry, University of Mumbai on

I have not produced the following original documents at the time of my admission as I have already secured admission for.....Course at College/Institute.

(Please put X against 'not submitted' document)

1. Original Mark sheet of the T. Y. B. Sc. Examination.
2.
3.

I have produced the photocopies of the above documents, attested by the Head of the Institution (along with the certification) where my original documents are retained on account of my admission to that college/institute.

I hereby undertake to submit the original documents as mentioned above on or before (within **three** working days).....at Department of Chemistry, University of Mumbai.

I am aware of the fact that failure on my part to submit the original documents in given time results in cancellation of my admission without any refund of tuition fees as per the provisions of the admission rule.

Date :

(Name of candidate with signature)

Place :

Merit No.

Proforma- B

(Specimen Application form for cancellation of admission)

(To be submitted in duplicate)

Date:.....

To

The Head,
Department of Chemistry
University of Mumbai

Respected Sir,

Full name of Candidate:.....

Branch:.....Date of Admission

Merit Number:.....

Amount of fees paid: Rs.

Fee Receipt Number and Date:..... (Attach Photocopy)

I request you to kindly return my original documents.

.....

Signature of candidate

Received the Original Mark Sheet of the T. Y. B. Sc. examination from the Admission Authority.

Signature of the candidate

Proforma- C

(Specimen Application form for refund of fees on cancellation of admission)

(To be submitted in duplicate)

Date:.....

To

The Registrar,
University of Mumbai

Sir,

I have cancelled my admission to the M. Sc. (Choice-Based Credit System) (Four-SEMESTER-Course). My details are as given below:

Full name of candidate:.....

Branch:.....Date of Admission

Merit Number:.....

Amount of fees paid: Rs.

Fee Challan Number and Date:..... (Attach Photocopy)

I request you to kindly refund the fees paid as per the rules.

Signature of candidate

For Office use only: Full address of the candidate :	Amount Paid, Rs.
	Amount Deducted, Rs.
	Amount Refunded, Rs.
Tel./Mobile No.:	Cheque No. & date
E mail:	Bank particulars

12. STATEMENT SHOWING THE NUMBER OF SEATS AVAILABLE FOR STUDENTS OF DIFFERENT CATEGORIES FOR ADMISSION TO M. Sc. DEGREE COURSE IN DIFFERENT BRANCHES OF CHEMISTRY FOR THE YEAR 2023-2024

Branch	Total Seats	Number of Seats for Reserved Category Students									Reserved Category 62%	General Category 38%
		SC 13%	ST 7%	DT(A) (VJ) 3%	NT(B) 2.5%	NT(C) 3.5%	NT(D) 2%	OBC 19%	SBC 2%	EWS 10%		
Organic	20	2	1	-	1	1	1	3 + 1*	-	2	12	7 + 1 ^Φ
Analytical	20	3	2	1	-	1	-	3	1	2	13	6 + 1 [@]
Inorganic	20	3	2	-	-	1	-	4	-	1 + 1 [@]	12	7 + 1 [#]
Physical	20	2	1	1	1	-	1	3 + 1 [#]	1	2	13	6 + 1*
Total	80	10	6	2	2	3	2	15	2	8	50	30

Seats are reserved as per Government of Maharashtra's directives

1% seats are reserved for Orphan students (marked by ^Φ)

3% seats are reserved for Other University students (marked by *)

3% seats are reserved for Physically Handicapped students (marked by [#])

3% seats are reserved for the following category students (marked by [@])

1. Wards of the Central / State Govt. employees / officers who have been transferred
2. Wards of the present / past defence personnel
3. Students obtaining dexterity at National / State level Sports/ Cultural activities
4. Widow / Deserted female students
5. Wards of the Freedom Fighters

