

# 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

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**2022-2023**

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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

<b>PAPERS PUBLISHED:</b>	66	<b>Ph. D STUDENTS UNDER GUIDANCE:</b>	03
<b>M.Sc (BY RESEARCH) STUDENTS GUIDED:</b>	05	<b>RESEARCH PROJECTS:</b>	03
<b>Ph. D STUDENTS GUIDED:</b>	10	<b>Patents</b>	Granted-02 Published-01
<b>POSTDOC.</b>	02	<b>BOOK CHAPTER</b>	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 ( $\text{CuFeS}_2$ ) 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  $\text{TiO}_2$  nanoparticles and  $\text{CdS@TiO}_2$  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  $\text{NiFeS}_2$  nanocomposite and its use as a high performance supercapacitor material.

- A. Ansari, R. A. Badhe, S. S. Garje, *Mater. Lett.*, 281 (2020) 128636.
- 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.
  - 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.
  - Synthesis of bare and surface modified TiO<sub>2</sub> 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.
  - 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.
  - 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.
  - 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.
  - Preparation of ternary metal chalcogenide (M<sub>1-x</sub>Fe<sub>x</sub>S, 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

<b>PAPERS PUBLISHED:</b>	<b>35</b>	<b>Ph. D STUDENTS GUIDED:</b>	<b>03</b>
<b>M.Sc (BY RESEARCH) STUDENTS GUIDED:</b>	<b>03</b>	<b>RESEARCH PROJECTS COMPLETED:</b>	<b>01</b>

• **RESEARCH INTERESTS:** Solvent Extraction, Solid phase Extraction, Environmental Analysis.

**KEY PUBLICATIONS:**

- 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.
- 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. Rajesh M. Kamble



• DESIGNATION: Professor

<b>PAPERS PUBLISHED:</b>	<b>41</b>	<b>Ph. D STUDENTS UNDER GUIDANCE:</b>	<b>05</b>
<b>M.Sc (BY RESEARCH) STUDENTS GUIDED:</b>	<b>01</b>	<b>RESEARCH PROJECTS:</b>	<b>03</b>
<b>Ph. D STUDENTS GUIDED:</b>	<b>04</b>	<b>CONSULTANCY PROJECTS (IN PROGRESS)</b>	<b>Nil</b>

- **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.

#### KEY PUBLICATIONS:

1. 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)
2. 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>)
3. Synthesis, optical, electrochemical and theoretical studies of 2,3-Di(pyridin-2-yl)quinoxaline amine derivatives as blue-orange emitters for organic electronics. Suraj S. Mahadik, Dinesh R. Garud, Rahul V. Pinjari, Rajesh M. Kamble, Journal of Molecular Structure, 2022, 1248, 131541 (<https://doi.org/10.1016/j.molstruc.2021.131541>)
4. 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>)
5. 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>)
6. 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>)
7. 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)
8. Impact of Donor Substituent on Optoelectrochemical properties of 6*H*-indolo[2,3-*b*]quinoxaline Amine Derivatives. Pooja S. Singh, Purav M. Badani and Rajesh M. Kamble, New J. Chem., 2019, 43, 19379–19396 (DOI: 10.1039/c9nj05558d)
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>)
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)

[4] NAME: Dr. Vishwanath R. Patil



• DESIGNATION: Professor

<b>PAPERS PUBLISHED:</b>	<b>65</b>	<b>Ph. D STUDENTS GUIDED:</b>	<b>14</b>
<b>PATENTS:</b>	<b>33</b>	<b>Ph. D STUDENTS UNDER GUIDANCE:</b>	<b>06</b>
<b>M.Sc (BY RESEARCH) STUDENTS GUIDED:</b>	<b>04</b>	<b>RESEARCH PROJECTS COMPLETED:</b>	<b>04</b>

• KEY AWARDS/HONORS:

- Prof. B. C. Haldar Memorial Research Award
- Best Researcher & Academician Award (Bionano Frontier & University of Mauritius)
- Fellow of Maharashtra Science Academy

• RESEARCH INTERESTS: Light emitting polymers, Water soluble polymers, biosynthesis of nanoparticles, Polymer nano composites.

• KEY PUBLICATIONS:

1. Click Gold Quantum Dots Biosynthesis with Conjugation of Quercetin for Adenocarcinoma Exertion, Amol V. Pansare, Priyanka V. Pansare, Amol A. Shedge, 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).
2. Deciphering the sensing of  $\alpha$ -amyrin 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).
3. 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).
4. 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).
  5. 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.
  6. 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).
  7. Enantioselective high performance new solid contact ion-selective electrode potentiometric sensor based on sulphated  $\gamma$ -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).
  8. Benzo Crown Ether Functionalized Conjugated Polyfluorenes with Anthracene Fragment for Sustainable Light Emitting Device Technology, Meenakshi M. Rananaware, Vaijayanti D. Ghase, Vishwanath R. Patil, Polymer Bulletin, <https://doi.org/10.1007/s00289-021-03617-w>, ISSN:0170-0839 (print) 1436-2449 (web),2020, (Impact factor-2.014).
  9. Development and Validation of a Stability-indicating RP-HPLC Method for the Simultaneous Determination of Telmisartan and its Related Substances in Telmisartan Bulk Drug Substance, Jayram V. Gholave , Nayan S. Gadhari, Suyog S. Patil , Sharad S. Upadyay, Vishwanath R. Patil, Kiran F. Shelke, Analytical Chemistry Letters (Taylers & Fransis) 10(5), 577-589, 2020, <https://doi.org/10.1080/22297928.2020.1850348>, ISSN: 2229-7928 (Print), (Impact factor-1.727).
  10. Progress in the Synthesis of Oxindole-Naphthoquinone Molecular Hybrid Scaffolds: A Concise Review, Ganesh A. Thakur, Rupashri K. Kadu, Vishwanath R. Patil, Pramod B. Thakur, Chemistry Select, <https://doi.org/10.1002/slct.202002961>. ISSN 2365-6549 (Online), (Impact Factor: 1.811).

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



• DESIGNATION: Associate Professor

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

• **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 NO<sub>2</sub> 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  $\alpha$ -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 physicomechanical 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 physicomechanical 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  $\alpha$ -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.

[6] NAME: Dr. Suresh Damodar Pawar



• DESIGNATION: Associate Professor

<b>PAPERS PUBLISHED:</b>	<b>29</b>	<b>Ph. D STUDENTS UNDER GUIDANCE:</b>	<b>06</b>
<b>M.Sc (BY RESEARCH) STUDENTS GUIDED:</b>	<b>01</b>	<b>RESEARCH PROJECTS:</b>	<b>03 (Minor)</b>
<b>Ph. D. STUDENTS GUIDED:</b>	<b>02</b>	<b>CONSULTANCY PROJECTS (IN PROGRESS)</b>	<b>-</b>

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

#### Key Publications

- Design, synthesis and biological evaluation of furan based  $\alpha$ -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.
- 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.
- 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.
- 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.
- 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.
  - 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.
  - Extraction studies of Uranium(VI) from sodium perchlorate medium, R. R. lakhan and S. D. Pawar\*, **Asian Journal of Chemistry**, 28(3), 2016, 687-690.
  - Extraction studies of Thorium(IV) from sodium perchlorate medium, R. R. Lakhan and S. D. Pawar\*, **Research Journal of Chemistry and Environment**, 19(7), 2015, 27-31.
  - Extraction studies of Zn(II) from salicylate medium using Cyanex-923 extractant in toluene, S. U. Gaikwad and S. D. Pawar\*, **Journal of the Indian Chemical Society**, 92, 2015, 65-69.
  - Extraction and Separation Study of Mo(VI) and W(VI) using organophosphorous extractant, D. V. Chavan and S. D. Pawar\*, **International Letters of Chemistry, Physics and Astronomy**, 48, 2015, 87-94.

[7] NAME: Dr. S. Sachar



- **DESIGNATION:** Assistant Professor

<b>PAPERS PUBLISHED:</b>	<b>26</b>	<b>Ph. D STUDENTS UNDER GUIDANCE:</b>	<b>3</b>
<b>M.Sc (BY RESEARCH) STUDENTS GUIDED:</b>	<b>-</b>	<b>RESEARCH PROJECTS:</b>	<b>1</b>
<b>Ph. D STUDENTS GUIDED:</b>	<b>2</b>	<b>CONSULTANCY PROJECTS (IN PROGRESS)</b>	<b>-</b>

- **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. 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.
2. 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.
3. A chronological overview of analytical techniques in forensic identification of printing toners, Anjali Tomar, Reeta R. Gupta, S. K. Mehta, Shilpee Sachar, Shweta Sharma, *TrAC Trends in Analytical Chemistry*, 144 (2021) 116450.
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

<b>PAPERS PUBLISHED:</b>	<b>30</b>	<b>Ph. D STUDENTS UNDER GUIDANCE:</b>	<b>02</b>
<b>M.Sc (BY RESEARCH) STUDENTS GUIDED:</b>	<b>--</b>	<b>RESEARCH PROJECTS:</b>	<b>01</b>
<b>Ph. D STUDENTS GUIDED:</b>	<b>01</b>	<b>CONSULTANCY PROJECTS</b>	<b>01</b>

• **KEY AWARDS/HONORS:**

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

- **RESEARCH INTERESTS:** Theoretical Chemistry, Computational Organic 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. Theoretical kinetic analysis and molecular dynamic simulations for exploring the dissociation pathways of CF<sub>3</sub>OH. N Gulvi, P Maliekal, M Mapari and PM Badani Computational and Theoretical Chemistry 1194 (2021) 113056.
3. Effect of substitution on dissociation kinetics of C<sub>2</sub>H<sub>5</sub>X (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: Mr. R. G. Thorat



- **DESIGNATION:** Assistant Professor
- **RESEARCH INTERESTS:** Synthetic Organic Chemistry

[10] NAME: Dr. Bhushan B. Popatkar



- **DESIGNATION:** Assistant Professor

<b>PAPERS PUBLISHED:</b>	<b>5</b>	<b>Ph. D STUDENTS UNDER GUIDANCE:</b>	<b>---</b>
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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

[11] NAME: Dr. Sudesh T. Manjare



- **DESIGNATION:** Assistant Professor

<b>PAPERS PUBLISHED:</b>	<b>27</b>	<b>RESEARCH PROJECTS:</b>	<b>03</b>
<b>Ph. D STUDENTS GUIDED:</b>	<b>02</b>	<b>Ph. D STUDENTS UNDER GUIDANCE:</b>	<b>03</b>

- **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. 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**, <https://doi.org/10.1039/D2DT01079H> (Impact Factor 4.390).
2. BOPHY based Fluorescent Probe for Hg<sup>2+</sup> via an NTe<sub>2</sub> Chelation, Gauri S. Malankar, Divyesh S. Shelar, Manikandan M, Malay Patra, R. J. Butcher and **Sudesh T. Manjare** *Dalton Trans.*, **2022**, <https://doi.org/10.1039/D2DT01086K> (Impact Factor 4.390).
3. 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).
- 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).
  - Organoselenium-based BOPHY as a sensor for detection of hypochlorous acid in mammalian cells, Gauri S. Malankar, Arunima Sakunthala, Ambuja Navalkar, Samir K. Maji, Saravanan Raju, **Sudesh T. Manjare**, *Analytica Chimica Acta* **2021**, 1150, 338205 (Impact Factor 6.558).
  - Cyclic Organoselenide BODIPY-Based Probe: Targeting Superoxide in MCF-7 Cancer Cells, Kashinath S. Madibone, Pratiksha P. Deshmukh, Ambuja Navalkar, Samir K. Maji, Purav M. Badani, and **Sudesh T. Manjare**, *ACS Omega* **2020**, 5, 14186–14193 (Impact Factor 3.512).
  - Phenylselenyl containing turn-on dibodipy probe for selective detection of superoxide in mammalian breast cancer cell line, Pratiksha P. Deshmukh, Ambuja Navalkar, Samir K. Maji, **Sudesh T. Manjare**, *Sensors & Actuators: B. Chemical*, **2019**, 281, 8–13 (Impact Factor 7.46).
  - Novel intramolecular  $\pi$ - $\pi$ -interaction in a BODIPY system by oxidation of a single selenium center: geometrical stamping and spectroscopic and spectrometric distinctions, Youngsam Kim, Taehong Jun, Sandip V. Mulay, **Sudesh T. Manjare**, Jinseong Kwak, Yunho Lee and David G. Churchill, *Dalton Trans.*, **2017**, **46**, 4111-4117 (Impact Factor 4.390).
  - Transition metal mediated formation of dicationic diselenides stabilised by N-heterocyclic carbenes: designed synthesis, Sangeeta Yadav, **Sudesh T. Manjare**, Ray J. Butcher, Harkesh B. Singh, *Dalton Trans.* **2016**, 45, 12015-12027 (Impact Factor 4.390).
  - Diselenide-based probe for the selective imaging of hypochlorite in living cancer cells, YoungSam Kim, Minsuk Choi, **Sudesh T. Manjare**, Sangyong Jon, David G. Churchill, *RSC Advances* **2016**, 6, 32013-32017 (Impact Factor 3.361).

[12] NAME: Dr. Arun K. Kadu



DESIGNATION: Assistant Professor

<b>PAPERS PUBLISHED:</b>	<b>5</b>	<b>Ph. D STUDENTS UNDER GUIDANCE:</b>	<b>02</b>
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**RESEARCH INTERESTS:**

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

**KEY PUBLICATIONS:**

1. 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.
2. 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
3. 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.
4. 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.
5. 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.

[13] NAME: Dr. A. V. Karnik



• DESIGNATION: UGC-BSR Fellow

<b>PAPERS PUBLISHED:</b>	<b>41</b>	<b>Ph. D STUDENTS UNDER GUIDANCE:</b>	<b>06</b>
<b>M.Sc (BY RESEARCH) STUDENTS GUIDED:</b>	<b>16</b>	<b>RESEARCH PROJECTS:</b>	<b>03</b>
<b>Ph. D STUDENTS GUIDED:</b>	<b>15</b>	<b>CONSULTANCY PROJECTS (IN PROGRESS)</b>	<b>01</b>

• **KEY AWARDS/HONORS:**

- Performance based Incentive award, University of Mumbai.
- Elected Fellow of Maharashtra Academy of Science

- **RESEARCH INTERESTS:** Chiral Chemistry, Synthetic Organic Chemistry, Heterocyclic Chemistry.

**KEY PUBLICATIONS:**

1. Chiral Heterocycle-based receptors for Enantioselective Recognition. Vaibhav N. Khose, Marina E. John, Anita D. Pandey and Anil V. Karnik. *Symmetry* 2018, 10, 34; doi:10.3390/sym10020034.
2. Sui Generis Helicene-Based Supramolecular Chirogenic system: Enantioselective Sensing, Solvent Control, and Application in Chiral group transfer reaction. Mohammed Hasan, Vaibhav N. Khose, Victor Borovkov, and Anil V. Karnik. *ACS Omega* 2017, 2, 592–598
3. Tailor-Made Supramolecular Chirogenic System Based on Cs-Symmetric Rigid Organophosphoric Acid Host and Amino Alcohols: Mechanistic Studies, Bulkiness Effect, and Chirality Sensing. Mohammed Hasan, Vaibhav N. Khose, Anita D. Pandey, Victor Borovkov, and Anil V. Karnik. *Organic Letters*, 2016, 18, 440-444.
4. Reversal of enantioselectivity induced by the achiral part of an organocatalyst in Diels–Alder reaction. Trupti S. Tawde, Swapnil J. Wagh, Jai V. Sapre, Vaibhav N. Khose, Purav M. Badani and Anil V. Karnik. *Tetrahedron: Asymmetry*, 2016, 27, 130-135.
5. Sterically Congested Chiral 7,8-Dioxa[6]helicene and Its Dihydro Analogues: Synthesis, Regioselective Functionalization, and Unexpected Domino Prins Reaction. Hasan, Mohammed; Pandey, Anita D.; Khose, Vaibhav N.; Mirgane, Nitin A. and Karnik, Anil V. *European Journal of Organic Chemistry*, 2015, 3702-3712.
6. Asymmetric Diels–Alder Reaction Involving Chiral Benzimidazoles as Organocatalysts. Nitin A. mirgane, and Anil V. Karnik. *Chirality*, 2011, 23, 404-407.
7. Synthesis and in vitro antibacterial evaluation of tetracyclic-ortho-fused 4Hnaphtho[1',2'-5,6]pyrano[3,4-d](1,2,3)selenodiazole and its derivatives. A. V. Karnik, A. M. Kulkarni, N. J. Malviya and B. L. Jadhav. *European Journal of Medicinal Chemistry* 2008, 43, 2615-2617.
8. Cascade enantioselective synthesis of  $\gamma$ -aryl- $\gamma$ -butyrolactones with a delayed stereoselective step. Anil V. Karnik and Suchitra S. Kamath, *Tetrahedron* 2008, 64, 2992-2996.
9. Enantioselective Benzoylation of  $\alpha$ -Amino Esters Using (S)-1-Benzoyl-2-(racetoxyethyl) benzimidazole, a Chiral Benzimidazolide. Anil V. Karnik and Suchitra S. Kamath. *J. Org. Chem.*, 2007, 72, 7435-7438.
10. Furo-Fused BINOL Based Crown as a Fluorescent Chiral Sensor for Enantioselective Recognition of Phenylethylamine and Ethyl Ester of Valine. Sunil P. Upadhyay, Raghuvir R. S. Pissurlenkar, Evans C. Coutinho, and Anil V. Karnik. *J. Org. Chem.*, 2007, 72, 5709-5714.

## **8. M. Sc. CHOICE-BASED CREDIT SYSTEM (CBCS)**

The Choice-Based Credit System (CBCS) has been introduced for the Master's Program from the Academic Year 2016-17. A minimum of **96** credits have to be earned by students across four Semesters. Semesters I and II form the First year of the M. Sc. programme and comprise the courses from four branches while Semesters III and IV are in the second year of the M. Sc. programme in the respective specialization chosen by the student at the time of admission to the M. Sc. Course.

### **The Salient features of Choice-Based Credit System (CBCS) are as follows:**

**Credit:** One credit shall be equal to one hour teaching per week per semester for 15 weeks.

#### **M. Sc. Course:**

- M. Sc. Course shall be given four teaching hours per week per paper. Each paper shall have 4 credits.
- There shall be four papers of 4 credits each per semester.
- Thus there shall be 16 theory lectures per week.
- There shall be 8 credit practical components for M. Sc.
- Two hours of laboratory component per week shall be considered as 1 credit. Thus, students shall perform 16 hours of practical per week per semester for 15 weeks.

**M. Sc. Program:** Ordinarily, M. Sc. Program shall consist of 96 credits over four semesters.

**Courses:** There shall be four types of courses:

- (i) Core Courses
- (ii) Elective Courses
- (iii) Optional Courses

**Core Courses:** Core-courses shall be offered by parent department.

- Core courses being the absolute necessity for a master's degree in a subject, shall be never less than 75% for any of the semesters.
- Semester I & II shall have 100% core courses.
- Semester III & IV shall have three theory papers (12 credits) each on core courses.
- Semester III shall have 8 credits of practical component. Students shall perform 16 hours of practical per week for 10-15 weeks.
- Semester IV shall have 8 credits of Project component. For this, students shall perform 8 hours per week practical work for 10-15 weeks.

#### **Elective Courses:**

- Elective Courses shall be offered by the parent department in Semester III and each course will be of 4 credits.

#### **Optional Courses:**

- Optional courses shall be offered by parent department in Semester IV and each course will be of 4 credits.

#### **Choice-Based Courses:**

- It shall be made mandatory to offer two Elective courses in the third semester and 2 Optional Courses [OC-1 & OC-2] in the fourth semester.
- The Optional course shall be interdisciplinary in nature.
- Each department shall offer 2 Optional courses for the benefit of students from other disciplines. There shall be a total of 4 lectures required per week for optional courses. There shall be a fixed slot for this component where lectures from core courses and Elective courses shall not be held.
- The Head of the Department shall communicate the internal marks for OC-1 and or OC-2 for the students from other departments to the head of their parent department. The internal marks for all the courses shall be communicated to the COE by the parent departments only.

### **The structure:**

- **Semester I:** Theory papers of 4 credits each only on core subject. 8 credits for practical component.
- **Semester II:** Theory papers of 4 credits each only on core subject. Credits for practical component.
- **Semester III:** Theory papers of 4 credits each only on core subject. One theory paper of 4 credits on 2 Elective courses. 8 credits for practical component.
- **Semester IV:** Theory papers of 4 credits each only on core subject. One theory paper of 4 credits on 2 Optional courses. 8 credits of Project component.

### **Admission to M. Sc. Choice-Based Credit System (CBCS) Course**

Admission to departments where entrance examination will not be necessary, the admission shall be decided only on the basis of T. Y. B. Sc. Norms give below:

#### **[1] T. Y. B. Sc. Marks component for Mumbai University Students**

- a) The marks secured by the student, without grace marks, with as a major subjects out of 1200 (Sem V & VI) shall be considered.
- b) Theory marks shall be given preference in case of a tie in (a).
- c) The students with first class shall be given priority over the students who have been declared passed in First Class with grace marks / Second Class with as a single major subject out of 600 (Sem V & VI).
- d) The students offering two major subjects, “The Subject Applied for Master’s Degree” as one of the subject at T. Y. B. Sc. be admitted in order of merit by considering marks secured in “The Subject Applied for Master’s Degree”.
- e) In case of there is a tie in (a), (b), (c), (d) or (e), aggregate marks without grace marks out of 600 shall be considered.
- f) In case of there is a tie in (a), (b), (c), (d) or (e), then all students tied at the rank shall be admitted as per their date/time of birth.
- g) In case there is a gap, 2% marks will be deducted.

The final merit list will be displayed on the website of the University and also on the Notice Board of the Department.

#### **[2] For other University students:**

- a) Marks declared by the concerned University at T. Y. B. Sc. Examination and as shown in mark sheet “The Subject Applied for Master’s Degree” will be considered for preparing the merit list as per quota available for other University students.
- b) In case there is a gap, 2% marks will be deducted.

### **Examination**

All examinations for all semesters are conducted by the departments for the students admitted in the departments.

The examinations shall be of two kinds:

- I. Internal assessment
- II. End Semester Examination

**Internal Assessment:** The internal assessment for theory papers shall be for 40% marks.

**End-Semester Examination:** The end semester assessment shall be for 60% marks for theory papers and 100% for practical examination.

**9. SYLLABI FOR M. Sc. CHOICE BASED CREDIT SYSTEM (CBCS) FOUR-  
SEMESTER-COURSE IN CHEMISTRY**



**SEMESTER-I**

Course Code	Title of the Course	No. of Credits	No. of hours per SEMESTER	Examination		Total Marks
				Mid Sem Marks	End-Sem Marks	
CHEM 101	Physical Chemistry I	4	60	40	60	100
CHEM 102	Inorganic Chemistry I	4	60	40	60	100
CHEM 103	Organic Chemistry I	4	60	40	60	100
CHEM 104	Analytical Chemistry I	4	60	40	60	100
CHEM 105	Physical Chemistry Practical I	2	-	-	50	50
CHEM 106	Inorganic Chemistry Practical I	2	-	-	50	50
CHEM 107	Organic Chemistry Practical I	2	-	-	50	50
CHEM 108	Analytical Chemistry Practical I	2	-	-	50	50
	Total	24			Total	600

**\* Practical component involves 16 h per week laboratory work for 15 weeks.**

**SYLLABUS: SEMESTER-I**  
**CHEM 101: 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*, 7<sup>th</sup> ed., Oxford University Press, 2002.
2. K. J. Laidler and J. H. Meiser, *Physical Chemistry*, 2<sup>nd</sup> ed., CBS Publishers and Distributors, New Delhi, 1999.
3. Robert J. Silby and Robert A. Alberty, *Physical Chemistry*, 3<sup>rd</sup> ed., John Wiley and Sons (Asia) Pte. Ltd., 2002.
4. Ira R. Levine, *Physical Chemistry*, 5<sup>th</sup> ed., Tata McGraw-Hill, New Delhi, 2002.
5. G. W. Castellan, *Physical Chemistry*, 3<sup>rd</sup> 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*, 2<sup>nd</sup> 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*, 2<sup>nd</sup> 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*, 3<sup>rd</sup> 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*, 5<sup>th</sup> 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*, 5<sup>th</sup> ed., Pearson Education (Singapore) Pte. Ltd., Indian Branch, New Delhi, 2000.

6. J. P. Lowe, *Quantum Chemistry*, 2<sup>nd</sup> 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.

## CHEM 102: INORGANIC CHEMISTRY-I

### UNIT I: INORGANIC REACTION MECHANISMS [15 L]

- 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).
- 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;
- Redox reactions: inner and outer sphere mechanisms. Complimentary and non-complimentary reactions.
- Isomerization and racemization reactions.

### UNIT II : ORGANOMETALLIC CHEMISTRY [15 L]

- Recapitulation of classification of organometallic compounds, electron counting and eighteen electron rule.
- Sixteen electron square planar complexes. 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]

- Hybridization: Derivation of wave functions for the following orbital hybridisation types: sp (BeH<sub>2</sub>); sp<sup>2</sup> (BF<sub>3</sub>); sp<sup>3</sup> (CH<sub>4</sub>) considering only sigma bonding.
- Molecular Orbital Theory (LCAO-MO approach) for Electron deficient and Electron rich species.
- Weak intermolecular forces: Hydrogen bonding: concept, types, properties, and importance. Van der Waal's forces: ion-dipole, dipole-dipole, London forces.  
Bent's Rule: Reactivity of molecules: e.g. chlorofluorides of phosphorous, fluoromethanes, etc.

### UNIT IV: CHEMICAL REACTIVITY [15 L]

- Recapitulation of acidity of cations and basicity of anions. Hard soft acids and bases (HSAB) principle, Acid-base strength and softness and hardness.
- Oxoanions, oxocations, Classification of oxoacids based on Pauling's rules, structural anomalies.
- 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.
- 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*, 3<sup>rd</sup> edition, Oxford University Press, 1999.

2. E. Housecroft and A. G. Sharpe, *Inorganic Chemistry*, Pearson Education Ltd. 2<sup>nd</sup> Edition, 2005.
3. Basalo and R. G. Pearson, *Mechanism of Inorganic Reactions*, 2<sup>nd</sup> 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, 2<sup>nd</sup> edition, 1991.

### Unit II

1. C. Mehrotra and A. Singh, *Organometallic Chemistry-A Unified Approach*, 2<sup>nd</sup> Ed., New Age International Pvt. Ltd., 2000.
2. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, *Inorganic Chemistry*, 6<sup>th</sup> 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*, 4<sup>th</sup> Ed., Harper Collins, 1993.

### Unit III

1. Huheey, F. A. Keiter and R. I. Keiter, *Inorganic Chemistry – Principles of Structure and Reactivity*, 4<sup>th</sup> Ed., Harper Collins, 1993.
2. L. Kapoor, *A textbook of Physical Chemistry*, Volume 4, Mc Millan, 2001.
3. Miessler and D. Tarr, *Inorganic Chemistry*, 3<sup>rd</sup> 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*, 5<sup>th</sup> 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*, 4<sup>th</sup> Ed., Harper Collins, 1993.
5. [p://www.meta-synthesis.com/webbook.html](http://www.meta-synthesis.com/webbook.html)

## CHEM 103: 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  $\lambda_{\text{Max}}$  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.

#### **11. 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.

## **CHEM 104: 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, 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*, 5<sup>th</sup> ed., Philadelphia: Saunders College Publishing, 1998.
2. D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch, *Fundamentals of Analytical Chemistry*, 8<sup>th</sup> ed., Philadelphia: Saunders College Publishing, 2004.
3. G. D. Christian, *Analytical Chemistry*, 6<sup>th</sup> 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*, 6<sup>th</sup> 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*, 6<sup>th</sup> 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*, 3<sup>rd</sup> 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*, 9<sup>th</sup> 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, 2<sup>th</sup> ed. ELBS.
17. R. A. Day, Jr. and A. L. Underwood, *Quantitative Analysis*, 6<sup>th</sup> 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*, 3<sup>rd</sup> 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 2<sup>nd</sup> edition*. WILEY-VCH 2004.

21. Solid phase Extraction- Principles, Techniques and Applications, N. J. K. Simpson, Marcel Dekker, New York, (2000).
- 22.

### **CHEM 105: 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.

### **CHEM-106: INORGANIC CHEMISTRY PRACTICAL-I**

#### **Synthesis, Purification and Analysis of the following Inorganic Preparations:**

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

### **CHEM 107: ORGANIC CHEMISTRY PRACTICAL-I**

#### **One step preparations (0.5 to 1.0 g scale):**

The candidate is expected to perform any 10 of the following preparations and submit the crystallized preparation and TLC analysis of the purified product, mp, % yields, etc.

1. Bromobenzene to p-nitro bromobenzene
2. Nitrobenzene to m-dinitrobromobenzene
3. Benzoin to Benzil
4. Anthracene to Anthraquinone
5. o-phenylenediamine to 2-methyl benzimidazole
6. o-phenylenediamine to 2,3-diphenylquinoxaline
7. Anthracene-Maleic Anhydride adduct
8. p-bromoacetanilide to p-bromoaniline
9. 5,5-diphenylhydantoin from urea and benzil
10. p-benzoquinone to 1,2,4-triacetoxybenzene

11.2-naphthol to BINOL

12.o-phenylenediamine to benzotriazole

**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. )

**CHEM 108: 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.

**SEMESTER-II**

Course Code	Title of the Course	No. of Credits	No. of hours per SEMESTER	Examination		Total Marks
				Mid sem Marks	End Sem Marks	
CHEM 201	Physical Chemistry II	4	60	40	60	100
CHEM 202	Inorganic Chemistry II	4	60	40	60	100
CHEM 203	Organic Chemistry II	4	60	40	60	100
CHEM 204	Analytical Chemistry II	4	60	40	60	100
CHEM 205	Physical Chemistry Practical II	2	-	-	50	50
CHEM 206	Inorganic Chemistry Practical II	2	-	-	50	50
CHEM 207	Organic Chemistry Practical II	2	-	-	50	50
CHEM 208	Analytical Chemistry Practical II	2	-	-	50	50
	Total	24			Total	600

**\*Practical component involves 16 h per week laboratory work for 15 weeks.**

## SYLLABUS: SEMESTER-II

### CHEM 201: 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 ( $\psi$ ) 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*, 7<sup>th</sup> ed., Oxford University Press, 2002.
2. K. J. Laidler and J. H. Meiser, *Physical Chemistry*, 2<sup>nd</sup> ed., CBS Publishers and Distributors, New Delhi, 1999.
3. Robert J. Silby and Robert A. Alberty, *Physical Chemistry*, 3<sup>rd</sup> ed., John Wiley and Sons (Asia) Pte. Ltd., 2002.
4. Ira R. Levine, *Physical Chemistry*, 5<sup>th</sup> ed., Tata McGraw-Hill, New Delhi, 2002.
5. G. W. Castellan, *Physical Chemistry*, 3<sup>rd</sup> 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*, 2<sup>nd</sup> 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*, 5<sup>th</sup> ed., Pearson Education (Singapore) Pte. Ltd., Indian Branch, New Delhi, 2000.
11. J. P. Lowe, *Quantum Chemistry*, 2<sup>nd</sup> 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*, 2<sup>nd</sup> 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*, 4<sup>th</sup> 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*, 2<sup>nd</sup> 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*, 3<sup>rd</sup> 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*, 5<sup>th</sup> ed., John Wiley and Sons, Inc., 1994.
3. Peter A. Rock, *Chemical Thermodynamics*, University Science Books, Oxford University Press, 1983.

## CHEM-202: 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)], AB<sub>2</sub> [fluorite (CaF<sub>2</sub>), antiferite (Na<sub>2</sub>O), rutile (TiO<sub>2</sub>) and layer structures viz., cadmium chloride (CdCl<sub>2</sub>) and cadmium iodide, (CdI<sub>2</sub>)].

#### (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<sub>2v</sub> 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 hemocyanin.
- (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. A. R. West, Solid State Chemistry and Its Applications, John Wiley & Sons, 1987.
2. C. N. R. Rao and G. Gopalkrishnan, New Directions in solid state chemistry, 2<sup>nd</sup> Ed., Cambridge University Press, 1997.
3. Lesley E. Smart and Elaine A. Moore, Solid State Chemistry – An introduction, 3<sup>rd</sup> Ed., Taylor and Francis, 2005.
4. B. R. Puri, L. R. Sharma and K. C. Kalia, Principles of Inorganic Chemistry, Milestone, 2014.
5. S. K. Kulkarni, Nanotechnology-Principles and Practices, Capital Publishing Co., 2007.
6. G. Cao, Nanostructures and Nanomaterials- Synthesis, Properties and Applications, Imperial college Press, 2004.
7. C. 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. K.V.Reddy, Symmetry and Spectroscopy of Molecules, 2<sup>nd</sup> Ed., New Age International Publishers 2009.
2. R. L. Carter, Molecular Symmetry and Group Theory, John Wiley & Sons, 1998.
3. A.S. Kunju and G. Krishnan, Group Theory and its Applications in Chemistry, PHI-Learning, 2010.
4. F. A. Cotton, Chemical Applications of Group Theory, 2<sup>nd</sup> Ed., Wiley Eastern Ltd., 1989.

## Unit III

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

## Unit IV

1. I. Bertini, H.B.Gray, S. J. Lippard and J.S. Valentine, Bioinorganic Chemistry, 1<sup>st</sup> Indian Ed., Viva Books, 1998.
2. D. Banerjea, Coordination Chemistry, Tata Mc Graw Hill, 1993.
3. G. 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, 5<sup>th</sup> 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, 5<sup>th</sup> 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*, 2<sup>nd</sup> Ed., John Wiley & Sons, 1983.
8. G. Miessler and D. Tarr, *Inorganic Chemistry*, 3<sup>rd</sup> Ed., Pearson Education, 2004.
9. R. L. Madan and G. D. Tuli, *Inorganic Chemistry*, 5<sup>th</sup> Ed., S. Chand, 2012.
10. J. D. Lee, *Concise Inorganic Chemistry*, 5<sup>th</sup> 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*, 3<sup>rd</sup> Ed., Krishna Prakashan, 2010.
13. P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, *Inorganic Chemistry*, 5<sup>th</sup> 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*, 3<sup>rd</sup> 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*, 2<sup>nd</sup> 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*, 2<sup>nd</sup> 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*, 2<sup>nd</sup> 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.

## CHEM 203: ORGANIC CHEMISTRY-II

### UNIT- I: MOLECULAR ORBITALS, MAGNITUDE OF COEFFICIENTS, ORGANIC REACTIVITY 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 allylation 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:  $S_N^1$ ,  $S_N^2$ ,  $S_N^i$ ,  $S_{NC}A$  reactions. Ion pair in  $S_N^1$  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:  $S_NAr$ ,  $S_N^1$ , Benzyne mechanism, ipso, cine and tele substitutions, vicarious substitution.

### Unit-III: OXIDATION-REDUCTION [15L]

**3.1 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.

**3.2 Dehydrogenation with DDQ and TCQ, and Ozonolysis**

**3.3 Preparation of reagents (wherever applicable), mechanism and applications of the following:** Wolf-Kishner reduction, Clemmensen reduction, Meerwein-Ponndorf-Verley reduction, Birch reduction, Reductions with  $\text{NaBH}_4$ ,  $\text{LiAlH}_4$  and DIBAL.

**3.4 Homogeneous reductions:** Wilkinson's catalysts and related systems.

**Unit-IV:REACTIONS AND REARRANGEMENTS [15L]**

**4.1 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.

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

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

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

**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 204: 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 spectroscopy:**  
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 & LC-MS [3]

#### **Reference books:**

1. D. A. Skoog, F. J. Holler, and T. A. Nieman, *Principles of Instrumental Analysis*, 5<sup>th</sup> ed., Philadelphia: Saunders College Publishing, 1998.
2. D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch, *Fundamentals of Analytical Chemistry*, 8<sup>th</sup> ed., Philadelphia: Saunders College Publishing, 2004.
3. G. D. Christian, *Analytical Chemistry*, 6<sup>th</sup> 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*, 6<sup>th</sup> 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*, 6<sup>th</sup> 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*, 3<sup>rd</sup> 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*, 9<sup>th</sup> 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, 2<sup>th</sup> ed. ELBS.
17. R. A. Day, Jr. and A. L. Underwood, *Quantitative Analysis*, 6<sup>th</sup> 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*, 3<sup>rd</sup> 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 2<sup>nd</sup> edition*. WILEY-VCH 2004.

## **CHEM 205: PHYSICAL CHEMISTRY PRACTICAL-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.

## **CHEM-206: 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.
5. Haematite Ore: Acid insoluble residue; Fe by redox titration.

### **Reference books for practicals**

1. A. I. Vogel, Vogel's Text Book of Quantitative Inorganic Analysis, 6<sup>th</sup> 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. G. Brauer, Handbook of Preparative Inorganic Chemistry, Vol. 1 and 2, Academic Press, 1967.
6. G. Marr and B. W. Rockette, Practical Inorganic Chemistry, Van Nostrnad Reinhold, 1972.
7. G. Pass and H. Sutcliffe, Practical Inorganic Chemistry, 2<sup>nd</sup> Ed., Chapman and Hall, 1985.

## **CHEM 207: ORGANIC CHEMISTRY PRACTICAL-II**

### **Separation of Binary mixture by microanalytical technique**

Separation of binary mixture 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) Solid-Solid (ii) Non-volatile liquid Non-volatile liquid (iii) Water-soluble/insoluble solid-Non-volatile

liquid with compounds from the same or different chemical classes in all three categories. The candidate is expected to carry out separation of 10 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)

**CHEM 208: 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.
5. Determination of silica by Molybdenum Blue method.
6. Flame Photometric determination of Li /Na/K by standard addition method.

**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*, 3<sup>rd</sup> 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 QUADRUPLE 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  $\gamma$ -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*, 4<sup>th</sup> 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*, 3<sup>rd</sup> 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, N-particle systems (distinguishable and indistinguishable).

**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 Batteries (Primary and secondary), Lithium and Lithium ion batteries.

**Fuel cells:** Classification, H<sub>2</sub>-O<sub>2</sub> fuel cell, choice of electrolyte, advantages, disadvantages.

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

**Electrochemical corrosion of metals:** Classification of corrosion processes, conditions for the occurrence of corrosion process, kinetic theory of corrosion and its application to pure metals, methods of corrosion protection, corrosion of technical metals.

**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*, 3<sup>rd</sup> ed., McGraw-Hill Book Co., 1949.
6. Frederick A. Lowenheim, *Modern Electroplating*, 3<sup>rd</sup> 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*, 3<sup>rd</sup> 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 Manual*, T. R. Publications (Madras), 1994.
15. J. H. Weil, *General Biochemistry*, New Age International Publishers, New Delhi.

## 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 / CaCO<sub>3</sub> 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 Bhusan
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<sub>2</sub> 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 Bhusan
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. Arnikaar, *Essential of Nuclear Chemistry*, New Age International, 1995.
25. G. C. Bond, *Heterogeneous Catalysis*, 2nd ed., Clarendon Press, Oxford, 1987.



## **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.

### **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*, 3<sup>rd</sup> ed., Longman, 1974.
3. B. P. Lewitt (ed.), *Findlay's Practical Physical Chemistry*, 9<sup>th</sup> 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*, 4<sup>th</sup> ed., L. D. Field, S. Sternhell and J. R. Kalman, Wiley.

**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.**

## SEMESTER-III: INORGANIC CHEMISTRY

### CHEM 321: SOLID STATE CHEMISTRY-I

#### Unit-I

[15L]

##### **(a) Crystal Chemistry:**

Structures of the compounds of the types: AB (PbO and CuO), AB<sub>2</sub> ( $\beta$ -cristobalite, CaC<sub>2</sub> and Cs<sub>2</sub>O), A<sub>2</sub>B<sub>3</sub> (Cr<sub>2</sub>O<sub>3</sub> and Bi<sub>2</sub>O<sub>3</sub>), AB<sub>3</sub> (ReO<sub>3</sub> and Li<sub>3</sub>N), ABO<sub>3</sub> (relation between ReO<sub>3</sub> and perovskite, BaTiO<sub>3</sub> and its polymorphic forms, oxide bronzes, ilmenite structure), AB<sub>2</sub>O<sub>4</sub> (normal and inverse and random spinel structures), Pyrochlores.

##### **(b) Linked polyhedra:**

Factors affecting linking of polyhedra, Corner sharing: tetrahedral structure (silicates) and octahedral structure (ReO<sub>3</sub>), Edge sharing: tetrahedral structure (SiS<sub>2</sub>) and octahedral structures of BiI<sub>3</sub> and AlCl<sub>3</sub>, 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 Stockbargar 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, mechanistic approach, study of solid solutions by X-ray powder diffraction and by density measurement.

**(b) Liquid Crystals:** Introduction and classification of different types of liquid crystals, polymorphism in liquid crystals, properties and applications of liquid crystals, inorganic liquid crystals.

#### Unit-IV

[15L]

##### **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), light harvesting, solar energy conversion, metal ion sensors, chemosensors, artificial photosynthesis.

### **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, magnetic properties of polynuclear and bridged complexes, diamagnetic correction using Pascal constants and calculation of magnetic moment.

Determination of magnetic susceptibility by Gouy, Faraday, Quinke's and NMR methods.

### **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 ( $10Dq$ ,  $B'$ ,  $\beta$ ,  $\beta^0$ ) from electronic absorption spectra of octahedral complexes ( $d^1$ - $d^9$ ) using Tanabe Sugano diagram, equation method and graphical method (whichever applicable). Comparing the spectra of octahedral, tetrahedral and square planar complexes of Nickel(II). Charge transfer spectra.

### **Unit-IV BIOINORGANIC CHEMISTRY**

[15L]

Non-heme iron proteins: Coordination geometry of the metal ion and functions (enzymes with a mononuclear high-spin Fe(II) centre and with mononuclear Fe (III) centre). 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**

[15L]

Introduction to X-ray diffraction, diffraction of waves by crystal, particle and solid, generation of X-rays (K-shell knockout), Bragg condition, Bragg method, 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, advantages of these methods, introduction to JCPDS format, index reflections, identification of Unit-cells from systematic absences in diffraction pattern, uses of powder X-ray diffraction, structure of simple lattices and X-ray intensities, structure factor and its relation to intensity and electron density, 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:**

Diffraction patterns 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, gas electron diffraction, scattering intensity versus scattering angle and elucidation of structures of simple gas molecules.

#### **(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-picrylhydrazyl (DDPH), pyrazine anion ( $\text{C}_4\text{N}_2^-$ ), benzene anion ( $\text{C}_6\text{H}_6^-$ ), bis(salicylaldiminato)copper(II),  $\text{IrCl}_6^{2-}$ , 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, reference substances and calibration, isomer shift,

temperature shift, 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.

Iodine compounds: I<sub>2</sub> and alkali metal iodide compounds.

## 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

##### **(a) Chemistry of Group 15 and 16 elements:** [15L]

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:** [15L]

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]

###### **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.

###### **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).

#### **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 of U and Fe using 8-hydroxyquinoline in chloroform and estimation of U
3. Separation and estimation of Cu(II) and Zn(II) in a mixture using anion exchange resin.
4. Separation and estimation of Ni(II) and Zn(II) in a mixture using anion exchange resin.
5. Separation and estimation of Cu(II) and Ni(II) by forming salicylaldoximinato complexes by varying pH and characterization of complexes using IR.

##### **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. Electral powder for Na/K content flame photometrically.
4. Fasting salt for chloride content conductometrically.
5. Cement for its Iron content by redox titration.
6. Washing soda for its  $\text{Na}_2\text{CO}_3$  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 Stability constant of  $[\text{Fe}(\text{SCN})]^{2+}$  by slope ratio method
3. *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.*
4. *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  $\text{VO}(\text{acac})_2$  /  $[\text{Mn}(\text{acac})_3]$  and its characterization by IR, conductivity measurement.
2. Preparation of Hexamine cobalt (III) chloride and its characterization by IR, and conductivity measurement.
3. Preparation of  $\text{MnO}_2/\text{ZnO}/\text{MgO}$  nanoparticles and its characterization by UV-Visible and XRD techniques.
4. Synthesis of bis(salicyl aldiminato)nickel (II) complex / tris(acetyl acetonato)aluminium (III) complex and its characterization using IR and NMR.
5. Synthesis of bis(salicyl aldiminato)copper (II) complex and its characterization by IR and ESR.
6. Synthesis of calcium oxalate/magnesium oxalate and its characterization by TGA/DTA.
7. Synthesis of Prussian blue and its characterization by Mössbauer spectra and cyclic voltammetry.
8. Solid phase synthesis of trans-bis(glycinato)copper(II) and its characterization by IR, and conductivity measurement.

#### **Reference books for inorganic chemistry semester III:**

##### **CHEM-321:**

##### **Unit-I:**

1. Ulrich Muller, *Inorganic structural chemistry*, 2<sup>nd</sup> edition, Wiley (2006).
2. A. F. Wells, *Structural inorganic chemistry*, 5<sup>th</sup> edition, Clarendon press, Oxford (1984).
3. A. R. West, *Solid state chemistry and its chemical applications*, John Wiley & Sons, (1984).

##### **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*, 3<sup>rd</sup> 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*, John Wiley & Sons, (1984).
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*, 3<sup>rd</sup> Ed. Taylor and Francis, (2005).

### **CHEM 322:**

#### **Unit-I:**

1. J. R. Gispert, *Coordination Chemistry*, Wiley-VCH (2008).
2. D. Banerjea, *Coordination chemistry*, 3<sup>rd</sup> edition, Asian Books Pvt. Ltd. (2009).
3. R. Gopalan and V. Ramalingam, *Concise coordination chemistry*, Vikas Publishing 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*, 3<sup>rd</sup> editions, John Wiley & Sons, Inc.(2001).

#### **Unit-II:**

1. R. A. Dutta & A. Syamal, *Elements of magnetochemistry*, 2<sup>nd</sup> edition, Affiliated East-West Press Pvt. Ltd. (1993).
2. D. Banerjea, *Coordination chemistry*, 3<sup>rd</sup> edition, Asian Books Pvt. Ltd. (2009).
3. R. Gopalan and V. Ramalingam, *Concise coordination chemistry*, Vikas Publishing 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*, 4<sup>th</sup> 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, 2<sup>nd</sup> 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*, 2<sup>nd</sup> 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*, 3<sup>rd</sup> Ed., Taylor and Francis, (2005).
2. Fmiza Hammer, *Inorganic spectroscopy and related topics*, Sarup & Sons (2008).
3. R. S. Drago, *Physical methods for Chemists*, 2<sup>nd</sup> 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).

### **Reference books for practicals**

#### **CHEM 326:**

##### **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, 15<sup>th</sup> Edition (1984).
3. J. D. Lee, 5<sup>th</sup> Edn., *Concise Inorganic Chemistry*, ELBS, (2010).
4. M. Weller, T. Overton, J. Rourke and F. Armstrong, *Inorganic chemistry*, 6<sup>th</sup>edition, Oxford University Press (2015).

##### **Unit-II:**

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

##### **Unit-III:**

1. S. F. A. Kettle, *Coordination compounds*, Thomas Nelson and Sons Ltd. (1975).
2. D. Banerjea, *Coordination chemistry*, 3<sup>rd</sup> edition, Asian Books Pvt. Ltd. (2009).
3. R. Gopalan and V. Ramalingam, *Concise coordination chemistry*, Vikas Publising 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, 15<sup>th</sup> Edition (1984).
3. J. D. Lee, 5<sup>th</sup>Edn.,*Concise Inorganic Chemistry*, ELBS, (2010).

#### **CHEM 327:**

##### **Unit-I:**

1. J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, *Inorganic chemistry- Principles of structure and reactivity*, 4<sup>th</sup> edition, Pearson (2006).
2. P. L. Soni, *Textbook of Inorganic Chemistry*. Sultan Chand & Sons Publisher, 15<sup>th</sup> 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*, 3<sup>rd</sup> 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, 15<sup>th</sup> Edition (1984).
2. Lesley E. Smart and Elaine A. Moore, *Solid state chemistry – An introduction*, 3<sup>rd</sup> 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*, 4<sup>th</sup> edition, Pearson (2006).
2. P. L. Soni, *Textbook of Inorganic Chemistry*. Sultan Chand & Sons Publisher, 15<sup>th</sup> Edition (1984).

##### **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, 2<sup>nd</sup> edition, (2013).

**SEMESTER-III: ORGANIC 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 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  $\alpha$ ,  $\beta$ -unsaturated ketones. [4L]
- 1.3 Photochemistry of unsaturated system-olefins, cis-trans isomerizations and, Di- $\pi$  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  $\alpha$  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  $(4n+2)$   $\pi$  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  $(4n+2)$   $\pi$  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,  $\alpha$ -C-H ACTIVATION AND REACTIONS, RADICALS AND ORGANOMETALLIC CHEMISTRY**

**Unit-I YLIDS,  $\alpha$ -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.  $\alpha$ - 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  $\pi$ -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-mercurels 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 trialkylsilyl cyanide 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  $\alpha$ -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:**

$\pi$ -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)<sub>3</sub> and Sc(OTf)<sub>3</sub> 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]

1.1Introduction, 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, AB<sub>2</sub>-AX<sub>2</sub>, ABX, AMX and A<sub>2</sub>B<sub>2</sub>-A<sub>2</sub>X<sub>2</sub> 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.<sup>13</sup>C -NMR:<sup>13</sup>C nucleus,<sup>13</sup>C- chemical shifts,Calculation of <sup>13</sup>C- chemical shifts, proton coupled <sup>13</sup>C - spectra,<sup>13</sup>C spectra Integration, proton decoupled <sup>13</sup>C- spectra. Off- resonance decoupling,DEPT technique, heteronuclear coupling of carbon to <sup>19</sup>F and <sup>31</sup>P [3L]

4.3.<sup>19</sup>F-NMR: Principles and applications [2L]

4.4.<sup>31</sup>P- 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 B<sub>12</sub>. [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-benzilic 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- $\alpha$ -D-glucofuranose

**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:** [5L]  
Principles, instrumentation and applications.
- 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:** [7L]  
Suppressor reactions, instrumentation, standard operating conditions, singlecolumn ion chromatography, coupled ion-chromatography. Applications.
- 3.2 **Size Exclusion Chromatography:** [4L]  
Theory, type of packings, molecular mass determination. Large scale purification of large bio molecules.
- 3.3 **Super Critical Fluid Chromatography:** [4L]  
Instrumentation, effect of pressure, mobile phases, comparison with LC and GC. Applications.
- 4.1 **Unit-IV** [15L]  
**Method development in HPLC:** [7L]  
Selection of stationary phases and mobile phases, gradient elution, polarity index, comparison of detectors, hybrid columns, chiral separations and PLRP-S. Concept of Preparative chromatography and UPLC.
- 4.2 **Membrane based Separations:** [8L]  
Principles and applications of microfiltration, ultrafiltration, reverse osmosis, dialysis and electrodialysis. Liquid membranes.

## **Reference books:**

1. Solvent Extraction Separation of Elements with Liquid Ion Exchangers, S. M. Khopkar, New Age Science Ltd., (2009).
2. Solvent Extraction Principles and Practice, 2<sup>nd</sup> 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, WILEY Publishers, 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, 1<sup>st</sup> 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. Selection of the HPLC Method in Chemical Analysis, S. C. Moldoveanu, V. David, Elsevier, (2017).
12. Principles of Instrumental Analysis, D. A. Skoog, F. James Hollier, T. A. Naiman, Harcourt College Publishers, Harcourt India Pvt. Ltd., (1998).
13. Chemical Separations and Measurements Introduction to Separation Science, B. L. Kauger, L. R. Snyder, C. Howath, John Wiley, New York, (1973).

## **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 (<sup>1</sup>H-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 ( $^{13}\text{C}$  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:** [10L]  
 Based on joint applications of IR,  $^1\text{H}$  NMR,  $^{13}\text{C}$  NMR, and Mass spectrometric techniques.
- 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]

**Reference books:**

1. Donald Pavia; Gary Lampman, Introduction to Spectroscopy, 4<sup>th</sup> Edition.
2. Barbara H. Stuart, Infra-red Spectroscopy: Fundamentals and Applications.
3. R. M. Silverstein; F. X. Webster, Spectroscopic Identification of Organic Compounds, 6<sup>th</sup> 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 Applications, 3<sup>rd</sup> Edition.

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

### **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.

**Unit-II: CLINICAL CHEMISTRY: (APPLICATIONS OF BIOANALYTICAL APPROACH TO MEDICINES)** [15L]

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-III ANALYTICAL 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-IV MEMBRANE 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), 14<sup>TH</sup> 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.

## **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 phosphene 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  $\text{SO}_3^{3-}$ .

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  $\text{SO}_3$ , Combined alcohols, total combined  $\text{SO}_3$ , 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 **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.

4.2 **Extraction of herbal materials:**

Choice of solvent for extraction

Methods used for extraction and principles involved in extraction.

4.3 **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.

4.4 **Various chromatographic techniques for the separation, identification, purification and estimation.**

**Reference books:**

1. Nuclear and Radiochemistry, 3<sup>rd</sup> Edition, G. Friedlander, J. W. Kennedy, E. S. Macias and J. M. Miller, Wiley, New York, 1981.
2. Nuclear and radiochemistry, K. H. Lieser, 2<sup>nd</sup> 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, 3<sup>rd</sup> 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, ampheteric detergents).

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

10. Uric acid, Sugar, Cholesterol.
11. Analysis of Arsenic from hair by hydride generation technique.

**Electroanalytical methods:**

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

**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.
7. **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 C<sub>18</sub> column and acetonitrile + water (60:40) mobile phase. Determination of number of theoretical plates.



**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  $\pi$  systems, Dissociation energy and aromaticity,  $\pi$ -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, Gaussian orbitals, Basis sets, Angular momentum of many-electron atoms, 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, Group theory and quantum mechanics, 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: Hartree-Fock SCF method and configuration interaction, Walsh diagrams. Introduction to SCF-LCAO-MO methods

##### **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*, 5<sup>th</sup> 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*, 4<sup>th</sup> 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*, 3<sup>rd</sup> 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*, 3<sup>rd</sup> 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, Applications of electrochemical methods in organic synthesis.

#### **Unit III CHRONOTECHNIQUES & SENSORS** **[15L]**

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*, 5<sup>th</sup> ed., Philadelphia: Saunders College Publishing, 1998.
2. D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch, *Fundamentals of Analytical Chemistry*, 8<sup>th</sup> 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*, 2<sup>nd</sup> ed.
6. A. Braithwaite and F. J. Smith, *Chromatographic Methods*, 5<sup>th</sup> ed., Kluwer Academic Publisher, 1999.
7. F. W. Fifield and D. Kealey, 5<sup>th</sup> 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, dendtires

### 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 polycondation, Kinetics of polycondation.

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

Polymer solutions: Solubility parameter, Solubility of crystalline and amorphous polymers, Thermodynamics of polymer solutions, Flory-Huggins theory of polymer solutions

**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-I    [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*, 8<sup>th</sup> 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*, 3<sup>rd</sup> 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*, 2<sup>nd</sup> 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*. 2<sup>nd</sup> 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*, 6<sup>th</sup> ed., Marcel Dekker, Inc., 2003.
6. A. Ravve, *Principles of Polymer Science*, 2<sup>nd</sup> 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. Diffusion in Solids: Fick's laws of diffusion, mechanism, Kirkendall effect, diffusion and ionic conductivity.

##### **(ii) Electrical Properties:**

Band structures of metals, insulators, semi-conductors and inorganic solids; Applications of semiconductors; Other electrical properties: Thomson, Peltier and Seebeck effects, thermocouples and their applications, Hall effect, dielectric, ferroelectric, piezoelectric and pyroelectric materials and 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 in transformer cores, information storage, magnetic bubble memory devices and as permanent magnets.

#### **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]

##### **Introduction to nanotechnology:**

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

##### **Some important properties of nanomaterials:**

Optical properties of metal and semiconductor nanoparticles, magnetic properties.

##### **Some special nanomaterials:**

##### **Carbon nanotubes:**



Types, synthesis using various methods, growth mechanism, electronic structure; quantum dots: properties and applications. Aerogels: types of aerogels, properties and applications of aerogels.

Applications of nanomaterials in electronics, energy, automobiles, sports and toys, textile, cosmetics, medicine, space and defense. Environmental aspects of nanotechnology.

## **CHEM 422: ORGANOMETALLIC CHEMISTRY & CATALYSIS**

### **Unit-I ORGANOMETALLIC CHEMISTRY OF p-BLOCK ELEMENTS** [15L]

Organometallics of boron group elements (organoboron, organoaluminium, gallium, indium and thallium organyls). Organometallics of carbon group elements (organogermanium, organotin and organolead compounds). Organometallics of nitrogen group elements (organometallics of arsenic, antimony and bismuth). Organometallics of oxygen group elements (organoselenium and organotellurium).

### **Unit-II** [15L]

#### **(a) Organometallic chemistry of f-block elements:**

Neutral binary  $\sigma$ -organyls, agostic interactions, carbene complexes, alkynyl compounds,  $\eta^5$ ,  $\eta^6$ ,  $\eta^7$  and  $\eta^8$  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, disilylation and diboration 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 (alkene metathesis, alkyne metathesis, alkene-alkyne metathesis).

#### **(b) Organometallics in C-X bond formations reactions:**

C-C, C-S, C-N bond formation reactions, Heck, Suzuki, Sonogashira, Stille reactions and Reppe Synthesis.

## **CHEM 423: INSTRUMENTAL METHODS, SPECTROSCOPY & GROUP THEORY**

### **Unit-I** [15L]

#### **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 like  $\text{CO}_3^{2-}$ ,  $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$ ,  $\text{NO}_2^-$ ,  $\text{NH}_3$ ,  $\text{CN}^-$ ,  $\text{CO}$ , olefins ( $\text{C}=\text{C}$ ) and  $\text{CH}_3\text{COO}^-$ . Determination of structures of inorganic molecules.

### **Raman spectroscopy:**

Introduction to basic principles and instrumentation. Applications of Raman spectroscopy in determination of molecular structures like diatomic molecules, triatomic molecules, structure of complex ions in solutions, nitric acid, sulphuric acid.

### **Nuclear Magnetic Resonance:**

Introduction to basic principles and instrumentation. Spectra of paramagnetic materials: Contact shift, application of contact shift, lanthanide shift reagent. Use of  $^1\text{H}$ ,  $^{19}\text{F}$ ,  $^{31}\text{P}$ ,  $^{11}\text{B}$  NMR spectra in structural elucidation of inorganic compounds.

## **Unit-II MICROSCOPY FOR SURFACE CHEMISTRY [15L]**

Introduction to surface spectroscopy, microscopy, problems of surface analysis, distinction of surface species, sputter etching and depth profile and chemical imaging. Principle, instrumentation and applications of following techniques: ion scattering spectra (ISS), secondary ion mass spectroscopy (SIMS), Auger emission spectroscopy (AES), ESCA, scanning electron microscopy (SEM), atomic force microscopy (AFM) and transmission electron microscopy (TEM).

## **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, instrumentation and applications

## **Unit-IV APPLICATIONS OF GROUP THEORY [15L]**

Introduction to of basic concepts of symmetry, Matrix representation of symmetry operations, reducible and irreducible representations, The great orthogonality theorem, Construction of character tables for point groups  $\text{C}_{2v}$ ,  $\text{C}_{3v}$  and  $\text{D}_{2h}$ , 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.

Application of group theory to infrared and Raman spectroscopy, Symmetry adapted linear combinations, symmetry aspects of MO theory, sigma- and pi-bonding in  $\text{AB}_4$  (tetrahedral and square planar),  $\text{AB}_5$  (trigonal bipyramidal) and  $\text{AB}_6$  (octahedral) molecule.

### **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*, 3<sup>rd</sup> 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*, 3<sup>rd</sup> Ed., Taylor and Francis, (2005).

#### **Unit-II:**

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*, 3<sup>rd</sup> Ed., Taylor and Francis, (2005).
3. M. Weller, T. Overton, J. Rourke and F. Armstrong, *Inorganic chemistry*, 6<sup>th</sup> 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*, 3<sup>rd</sup> edition, Wiley-VCH (2005).
3. R. C. Mehrotra and A. Singh, *Organometallic chemistry- A unified approach*, 2<sup>nd</sup> edition, New Age International (P) Ltd. (2000).
4. R. H. Crabtree, *The organometallic chemistry of the transition metals*, 5<sup>th</sup> edition, John Wiley & Sons (2009).
5. D. F. Shriver and P. W. Atkins, *Inorganic chemistry*, 3<sup>rd</sup> edition, Oxford University Press (1999).
6. Gary O. Spessard and Gary L. Miessler, *Organometallic Chemistry*, 3<sup>rd</sup> edn., Oxford University Press (2015).

#### **CHEM 423:**

##### **Unit-I:**

1. R. S. Drago, *Physical methods for Chemists*, 2<sup>nd</sup> 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. International 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. 2<sup>nd</sup> Edition (2005).

### **Unit-II:**

1. D. A. Skoog and F. J. Holler and T. A. Nieman, *Principles of instrumental analysis*, 5<sup>th</sup> 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*, 5<sup>th</sup> 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*, 4<sup>th</sup> edition, Pearson (2006).
3. D. F. Shriver and P. W. Atkins, *Inorganic chemistry*, 3<sup>rd</sup> 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*, 3<sup>rd</sup> Ed., John Wiley & Sons, Inc. (200&0).
6. K. V. Reddy, *Symmetry and Spectroscopy of molecules*, New Age International (P) Ltd. 2<sup>nd</sup> 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, Pericyclic Reactions, 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 JH<sub>2</sub> and JH<sub>3</sub> [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  $\beta$ -carotene and ubiquinone.

#### 3.4. Prostaglandins: [3L]

Classification, General structure and biological importance. Structure determination and synthesis of PGE<sub>1</sub> and PGF<sub>1 $\alpha$</sub>

#### 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 B<sub>1</sub>, B<sub>2</sub>, B<sub>6</sub>, 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,  $\beta$ - Vetivone, 4-Demethoxy daunomycin, caryophyllin, etc.

**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 QUALITY IN ANALYTICAL CHEMISTRY

[15L]

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 PHARMACEUTICAL ANALYSIS-I

[15L]

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 PHARMACEUTICAL ANALYSIS-II**

[15L]

- 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.

**Reference books:**

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 5<sup>th</sup> 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, 3<sup>rd</sup> Ed. S. Sigia. John Wiley, N.Y. (1972).
6. Pharmaceutical Drug Analysis (Methodology-Theory-Instrumentation Pharmaceutical assays-Cognate Assays), Ashutosh Kar, New Age Int. Pvt. Ltd. New Delhi (2010).
7. Indian Pharmacopoeia 2010, Vol. I, II, III and Addendum 2012, 6<sup>th</sup> Ed. The Indian Pharmacopoeia Commission, Ghaziabad, 2010.
8. British Pharmacopoeia.
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.

**CHEM 442: ADVANCED INSTRUMENTAL TECHNIQUES AND NANOTECHNOLOGY**

	<b><u>Unit-I</u></b>	<b>[15L]</b>
	<b>Principles, instrumentation and applications of following:</b>	
1.1	Electron spectroscopy: XPS (ESCA), AUGER & Electron microprobe method	
1.2	Reflectance spectroscopy	
1.3	Photoacoustic spectroscopy	
	<b><u>Unit-II</u></b>	<b>[15L]</b>
	<b>Principles, instrumentation and applications of following:</b>	

2.1	<b>Electron microscopy:</b> Scanning electron microscopy, Scanning probe microscopes: The Scanning Tunneling Microscope, Atomic Force Microscope.	
2.2	Chemiluminescence method	
2.3	<b>Polarimetry:</b> ORD, CD	
	<b><u>Unit-III HYPHENATED TECHNIQUES</u></b>	<b>[15L]</b>
3.1	Introduction, need for hyphenation, possible hyphenation, Interfacing devices and applications of the following: GC-MS, GC-IR, MS-MS, HPLC-MS, ICP-MS, Spectroelectrochemistry and radio-chromatography.	
	<b><u>Unit-IV NANOTECHNOLOGY: ADVANCES IN NANOMATERIALS</u></b>	<b>[15L]</b>
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, 4<sup>th</sup> Edition, Wiley Interscience, New York, 2004.
10. LC/MS: A Practical User Guide, W. C. McMaster, Hooker, 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, Chichester, 1998, New York.
13. Nanotechnology: Principles and Practices, J. K. Kulkarni, Capital Publishing Co., 2007

## **CHEM 443: ANALYSIS OF ORES, FOOD, AGRO /AGRICULTURE**

### **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, organic carbon, CaCO<sub>3</sub> (free lime), cation exchange capacity, gypsum requirements, micro and macro nutrients in soil. Soil micro-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.

### **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.

### **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 Degradation of different insecticides, fungicides and weedicides in soil.
- 4.5 Pesticide 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, 2<sup>nd</sup> Ed., A. I. Vogel, CBS, (1987).
3. Chemical Analysis of Food and Food Products, H. B. Jacob, Van Nostrand Reinhold, (1958).

4. Association of Official Analytical Chemists.

**CHEM 446: RESEARCH PROJECT**

**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**

<b><u>Unit-I</u></b>	<b>[15L]</b>
<b>Introduction to Intellectual Property:</b>	<b>[2L]</b>
Historical Perspective, Different types of IP, Importance of protecting IP.	
<b>Patents:</b>	<b>[5L]</b>
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.	
<b>Industrial Designs:</b>	<b>[2L]</b>
Definition, How to obtain, features, International design registration.	
<b>Layout design of integrated circuits:</b>	<b>[2L]</b>
Circuit boards, Integrated Chips Importance for electronic industry.	
<b>Copyrights:</b>	<b>[2L]</b>
Introduction, How to obtain, Differences from Patents.	
<b>Trade Marks:</b>	<b>[2L]</b>
Introduction, How to obtain, Different types of marks-Collective marks, certification marks, service marks, Trade names, etc.	
<b><u>Unit-II</u></b>	<b>[15L]</b>
<b>Geographical Indications:</b>	<b>[2L]</b>
Definition, rules for registration, prevention of illegal exploitation, importance to India.	
<b>Trade Secrets:</b>	<b>[2L]</b>
Introduction and Historical Perspectives, Scope of Protection, Risks involved and legal aspects of Trade Secret Protection.	
<b>IP Infringement issue and enforcement:</b>	<b>[5L]</b>
Role of Judiciary, Role of law enforcement agencies-Police, Customs, etc.	
<b>Economic Value of Intellectual Property:</b>	
Intangible assets and their valuation, Intellectual Property in the Indian Context- Various Laws in India Licensing an technology transfer.	
<b>Different International agreements:</b>	<b>[6L]</b>
<b>(a) World Trade Organization (WTO):</b>	
(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 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*, 2<sup>nd</sup> 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*, 4<sup>th</sup> Ed. Chapman Hill, London.
4. Harris, D. C., (2007), *Quantitative chemical analysis*, 6<sup>th</sup> 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

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

**(\*fee structure is likely to undergo revision from the academic year 2022-23)**

**Open category**

No.	Account Head	Amount (Rs.)
1.	Tuition fee	1000/-
2.	Laboratory fee	6000/-
3.	Registration form fee	25/-
4.	Registration fee	850/-
5.	Library fee	1000/-
6.	Gymkhana fee	200/-
7.	University sports and cultural activities	30/-
8.	Disaster Relief fund	10/-
9.	Group insurance	40/-
10.	Vice-Chancellor's fund	20/-
11.	e-Charges	20/-
12.	e-Suvidha	50/-
13.	Identity card fee	50/-
14.	Student welfare	50/-
15.	Magazine	100/-
16.	Utility	250/-
17.	Admission processing fee	200/-
18.	Other fees / Extracurricular activities	250/-
19.	Development fee	500/-
20.	Computer/Internet	500/-
	<b>Total</b>	<b>11, 145/-</b>

**Refundable deposit:**

1.	Caution money	Rs. 150/-
2.	Library deposit	Rs. 250/-
3.	Laboratory deposit	Rs. 400/-
	<b>Total</b>	<b>Rs. 800/-</b>

**\*Examination fees (SEMESTER--I & II): Rs. 1200/-**

### Reserved category

No.	Account Head	Amount(Rs.)
1.	Admission processing fee	200/-
2.	Identity card fee	50/-
3.	Disaster Relief fund	10/-
4.	Group Insurance	40/-
5.	Student welfare	50/-
6.	Vice-Chancellor's fund	20/-
7.	e suvidha	50/-
8.	Registration fee for M. Sc. SEMESTER- I only	850/-
9.	Registration form fee	25/-
	<b>Total</b>	<b>1295/-</b>

### Refundable deposits

1.	Caution money	Rs. 150/-
2.	Library deposit	Rs. 250/-
3.	Laboratory deposit	Rs. 400/-
	<b>Total</b>	<b>Rs.800/-</b>

- **Examination Fees (SEMESTER- I & II): Rs. 1232/- (subject to increase 5% each calender year i.e. January)**

### The procedure for providing the Photo / Xerox copies of answer sheets and revaluation

- Students should submit their forms for photocopy (*i.e. verification*) / revaluation (*i.e. rechecking*) within ten working days from the date of declaration of the results or on issue of the statement of marks by the department.
- No application after the due date will be entertained on any ground whatsoever.
- The respective results will be displayed on the notice boards if any changes or otherwise.

Form fees for photocopies and revaluation	:	Rs. 10/-
Charges for photocopies	:	Rs. 100/- per paper
Charges for revaluation	:	Rs. 500/- per paper
For reserve categories charges for photocopies	:	Rs. 50/- per paper

For reserve categories charges for revaluation	:	Rs. 250/- per paper
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**Fees for Ph. D. course:**

**(\*fee structure is likely to undergo revision from the academic year 2022-23)**

**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/-
	<b>Total</b>	<b>19,290/-</b>

(A) Refundable deposit	Amount(Rs.)	(B) Project fee	Amount(Rs.)
1. Caution money	150/-	1. Registration fee	1000/-
2. Library deposit	250/-	2. Registration form	25/-
3. Laboratory deposit	400/-		
<b>Total</b>	<b>800/-</b>	<b>Total</b>	<b>1025/-</b>

1. Fees are payable within the stipulated period mentioned in the notification.
2. In case of fresh entrants to the Department, the tuition fees for the first year and the deposit become due on the date specified in the letter of admission.
3. Notice for the payment of the fees for the second year (SEMESTER- III and IV) would be put up on the notice board one week prior to the commencement of SEMESTER- III.
4. Fine for the late payment of the tuition fees for the post-graduate courses is fixed as Rs.15/- per 1000/- per month for M.Sc. students and Rs.60/- per 1000/- per month for Ph.D. students.
5. Tuition fees once paid is not refunded.
6. The caution money deposit is refunded when a candidate leaves the Department. A claim for the refund of caution money deposit must be made in the prescribed form available in the Department along with the original receipt within one year from the date of leaving the Department, failing which the deposit will be forfeited.
7. All the research students are required to pay the tuition fees till they submit their thesis.
8. The research student who wishes to discontinue his/her studies is required to pay the tuition fees till the date of cancellation.
9. Transference Certificate/ Migration Certificate will be issued to the student who wishes to join other college/University only after clearing all the dues.

The attention of students seeking admission to M. Sc. (Choice-Based Credit System) Degree course is particularly invited to the following rules relating to the post-graduate studies.

1. Students will be required to attend in **each SEMESTER nnot less than** 75% of the total number of lectures delivered for each course.
2. In addition to attending lectures and practicals, students will be required to carry out regularly the work assigned to them in the form of essays, problems, tutorials, etc. They shall be required to maintain a record in a properly bound journal. The work carried out by the students shall be reviewed by respective teacher/s at the end of each SEMESTER.

### **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.

## **10. CAREER OPPORTUNITIES IN CHEMISTRY**



**Reproduced with kind permission of Indian Chemical  
Society (Mumbai Branch)**

**Preface**

It is being felt that meritorious students do not continue to study Chemistry at advanced level due to a variety of reasons such as better job opportunities in other streams. As knowledge of Chemical sciences plays a vital role in human society, it is essential that for a balanced society. It has good teachers and researchers in Chemistry both in academic and Industry. It was felt by the Mumbai Chapter of Indian Chemical Society that quite often students do not have a clear picture of the different avenues for chemists. In this booklet it is attempted to give a general picture where chemists can make their contribution in academics, research and in industry.

Indian Chemical Society Mumbai Branch conducts an Annual Aptitude Test in Chemistry to motivate students to take challenging careers in chemistry. Lectures on career guidance are also arranged especially for students of chemistry. The compilation was prepared by Dr. D. B. Naik (Rtd.), Applied Chemistry Division, BARC in order to provide information on career opportunities in Chemistry especially at doctoral level. While every care is taken to ensure accuracy of information, students are requested to check the details with individual research institution. It is hoped that the present compilation will be use to young students in choosing a right career of their choice.

**Indian Chemical Society (Mumbai Branch)**

**Career opportunities in Chemistry**

Knowledge of Chemistry plays a vital role in human society. In the technological development of 20th century chemistry contributed immensely in synthesis of new and high purity materials, their characterization and applications, understanding of reaction mechanisms etc. Scientific and technological development has pronounced effect on health and comforts of human beings. In this developmental process, new materials and processes have been adopted which have led to the deterioration of the environment. For better environment management clean production processes and also methods for waste management have become most important. Irrespective of developments in other fields of science, chemical sciences will sustain its important role in human society. Present day chemistry is not just synthesis and characterization of substances. It encompasses physical and biological sciences. There is an ample scope to apply the knowledge of chemical sciences. The present status of chemistry teaching in various academic institutions is summarised below.

**1. Chemistry teachers in schools:**

Graduates in Chemistry with B. Ed., degree are employed to teach chemistry subjects to school students. As young children are curious about more and more of the natural processes, there is always excitement in teaching in schools. Sometimes, these teachers will be required to teach Mathematics and Physics also.

**2. Lecturers in colleges:**

As an independent subject, chemistry is taught from first year junior college onwards. Usually post graduates in Chemistry teach in junior colleges. In degree colleges, as students major in Chemistry subject, Doctorates in addition to post graduates are employed to teach

chemistry. Recently, UGC (University Grant Commission) has started Lectureship exams. It is mandatory to clear these exams for getting employed as lectures. Some of the colleges especially in bigger cities are equipped with good laboratories where in it is possible to carry out research work.

3. Post graduate teachers Doctorates in different branches of chemistry teach post graduate students in different universities. In addition to teaching, there is scope to carry out research work and guide doctoral students.

Presently the emoluments for college as well as post graduate teachers are fairly attractive.

In India, very few of the University departments have good research facilities. There are quite a number of National Research Centres spread over the country where modern facilities are available to carry out frontline research.

1. Indian Institute of Science Bangalore, Bangalore 560 012  
Departments of Physical and Inorganic Chemistry, Organic Chemistry, Solid State Chemistry Unit-, Material Research Centre.
2. Indian Institute of Technology Bombay, Powai, Mumbai - 400 076.  
Department of Chemistry offers 5 years integrated and 2 years M. Sc. course in Chemistry. For integrated M. Sc. course admission is through JEE. For 2 years M. Sc. course entrance test is held in July. For admission to Ph. D. interviews are held in June and December. Financial assistance as teaching assistantship is provided. For post doctoral research, opporUnit-ies are available as research associate. Fields of research available are Bioorganic Chemistry, Bioinorganic Chemistry, Synthetic Organic Chemistry, Electrochemistry and Theoretical Chemistry.
3. Indian Institute of Technology Madras, Chennai - 600 036,
4. Indian Institute of Technology Kanpur - 208016,
5. Indian Institute of Technology Kharagpur - 721 302.  
Offers one 5 years integrated M. Sc. course in Industrial Chemistry and two years M. Sc. course in Chemistry. It also offers Ph. D. program in different fields of chemistry. Research fields are pharmaceutical and allied chemistry, industrial chemistry and material science.
6. Indian Institute of Technology Delhi, New Delhi -  
Offers 2 years M. Sc. in Chemistry, Entrance for M. Sc. is through a written test. It also offers M. Tech. course in Modern Methods of Chemical analysis for which entrance is through GATE and NET tests.
7. Indian Institute of Technology Gowhati -  
For integrated post graduate courses, candidates are selected by joint entrance test. IITs announce their Ph. D. programmes in different disciplines in National Newspapers every year in and candidates are selected after interview.
8. Indian Association for Cultivation of Science, Jadhavpur, Calcutta - 700 032.  
(Photochemistry, Organic Synthesis, Theoretical Chemistry, Biochemistry)  
Council of Scientific Industrial Research (CSIR) ([www.csir.ernet.in](http://www.csir.ernet.in)) has a number of laboratories spread all over country where chemical and allied research is carried out. Its

head quarters is in New Delhi, CSIR, Rafi Marg, New Delhi,  
email: csirhq@sirnetd.ernet.in.

Some of the major research institutes of CSIR where opportunities for research in chemistry exist are given below.

1. Central Drug Research Institute  
Chathar Manzil Road, PB 173  
Lucknow - 226 001  
Development of new drugs and diagnostics, cellular and molecular studies to understand disease processes and reproductive physiology. Systematic evaluation of medicinal properties and natural products. Biochemical, Molecular Biological Chemical, pharmacological research.
2. Central Leather Research Institute  
Adyar, Chennai 600020 : clrim@giasmd01.vsnl.net.in  
www.clri.org  
CLRI conducts for AnnaUniversity courses in leather technology leading to B.Tech., M.Tech., and Ph.D. degrees. CLRI also offers number of short term and long term vocational programmes.
3. National Chemical Laboratory, Dr. Homi Bhabha Road, Pune 411 008  
Research in Advanced materials, Biotechnology, Catalysis, Organic Chemical Technology, Pilot plant studies, Biotechnology.
4. Indian Institute of Chemical Technology, Hyderabad - 500 007.  
Studies of agrochemicals, drugs and pharmaceuticals, inorganic chemicals and materials, Organic synthesis, polymers, catalysis, process development.
5. Regional Research Laboratory Trivandrum, Kerala - 695019  
To develop technology for optimum use of regional resources, to develop industry in the region through research, development and technology transfer, Photochemistry, Organic synthesis.
6. Regional Research Laboratory, Bhubaneswar - 751013  
Research in problems relating to industry and raw materials of the region.
7. Central Electrochemical Research Institute  
Karaikudi 630006, Tamil Nadu  
Email : cecrik@cscecri.ren.nic.in  
Research in both the frontier areas of electrochemistry and the problems of relevance to Indian industry. It is playing a leading role in human resource development for the electrochemical and related industries. In this regard CECRI offers a variety of courses to scientific and technical personnel in industries, government and academic institutions.
8. Regional Research Laboratory, Jammu-Tawi 180 001  
Email: rrlj@nde.vsnl.net.in  
Drug and medicinal plants, introduction of exotic plants, plant chemistry, extraction and processing of drugs.
9. Central Salt and Marine Chemicals Research Institute,

Waghawadi Road, Bhavanagar - 364 002

10. National Institute of Oceanography  
Miramar, Panaji Goa - 403004  
Email : ocean@csnio.ren.nic.in  
Investigations on physical, chemical, geological and biological oceanography
11. Central Glass and Ceramic Research Institute  
196, Raja Mallik Road, Jadavpur, Kolkata - 700032.  
Email: cscgcri@giascl.l.vsnl.net.in  
Research on synthesis and applications of speciality glasses.
12. Centre for Cellular and Molecular Biology (CCMB)  
Hyderabad - 500 007.  
Research in frontier and multidisciplinary areas of modern biology with a view of aiding biochemical and bioengineering
13. Indian Institute of Petroleum  
Dehra Dun - 248 005  
Email: iipddn@de12.vsnl.net.in  
R & D in the field of petroleum, natural gas and petrochemicals and utilisation of petroleum products.
14. National Environmental Engineering Research Institute  
Nehru Marg, Nagpur, 440 020  
Email: dirneeri@nagpur.dot.net.in  
Studies in Chemical, biological and microbiological research, instrumentations and field research; water, studies related to sewage and industrial waste, air pollution, industrial hygiene
15. Regional Research Laboratory, Jorhat, Assam 785 006  
Research in coal, petroleum, pulp and paper, natural product chemistry, cement, drugs, synthetic organic chemicals, essential oils, medicinal plants, material science.
16. National Metallurgical Laboratory  
Jamshedpur 831 007, Singhbhum Dist. Bihar  
Email: nml@csnml.ren.nic.in  
Ore dressing, production, physical and chemical metallurgy
17. National Institute of Science, Technology & Development Studies  
Hill Side Road, New Delhi - 110 012  
Email: postmast@csnistad.ren.nic.in  
Conducts research on technological and social change and resource planning and utilisation for regional development.
3. **Research Fellowships:** After post graduate degree in Chemistry, one can carry out research work leading to doctoral degree (Ph.D.) in University departments, CSIR laboratories, Indian Institutes of Technology, and other national centres. National Eligibility Test (NET) examination is held twice the year for selection and award of Junior Research Fellowships (JRF). A total of nearly 1000 are normally selected for the

grant of fellowship both from CSIR and UGC. Award of SRFs and Research Associates is done through personal interviews by Expert Committees. Senior Research Associates (erstwhile Pool Officers) scheme is meant to support highly qualified S & T personnel through temporary placement.

**4. Post Doctoral Research Fellowships:** After completion of doctoral degree in various branches of Chemistry, these researchers can carry out post doctoral work at different institutes around the world. At many Universities and research centres, professors are able to offer these fellowships from their funds. Many a times this goes through individual contacts / previous acquaintances. With advent of internet these positions are advertised. There are some government as well as semi government agencies which offer fellowships to carry out post doctoral fellowships. Following are the few agencies.

1. Alexander von Humboldt Foundation  
Jean-Paul Str. 12, D-53173, BONN, Germany
2. German Academic Exchange Service (DAAD)  
New Delhi Office,  
176, Golf Links, New Delhi 110 003

In India, under CSIR research associate fellowship, one can carry out post doctoral research work in different CSIR laboratories and other research establishments. In recent years, Department of Atomic Energy has started offering a limited number of K. S. Krishnan post doctoral fellowship. Usually the advertisements come in National newspapers and the selected candidates carry out research in different DAE Unit-s. There is also possibility of candidates being absorbed in regular service.

**5. Opportunities in Industry**

Besides the opportUnit-ies in academics, there is an ample scope in industry for chemistry graduates / postgraduates / Ph.D.'s. The role of chemicals in our day-today life is increasing dramatically from household goods, medicines, functional materials to environmental friendly technologies, etc. Several of technologies are being replaced with new ones, superior products are being launched in the market. Indian chemical industry too is responding to these changes. With increasing globalization and privatization several multinational companies have started their business in India. Well trained professionals in chemical sciences could help in building strong Indian Chemical Industry which will not only cater to domestic market but will also offer products at competitive price in the international market. Specialists in each area would find opportUnit-ies in industry.

Organic chemists: Organic chemicals (bulk and fine), pharmaceuticals, agrochemicals, food products, development of new technologies, etc.

Inorganic chemists: Inorganic and metalloorganic compounds, inorganic materials for electronic industry etc.

Analytical chemists: Quality control employing modern instrumental techniques, better and efficient detection methods etc.

Physical Chemists: Research and Development departments in institution/industries dealing with modern materials including nanomaterials, catalysts, polymers, modern techniques for characterization of materials etc.

## **11. IMPORTANT RULES AND 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**

I .....have 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

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

**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 2022-2023**

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	3	2	1	-	1*	-	3	1	2	13	6 + 1 <sup>@</sup>
Analytical	20	2	2	-	1	1	1	4	-	2	13	6 + 1 <sup>Φ</sup>
Inorganic	20	2	1	1	1	-	-	4	1	1 + 1 <sup>#</sup>	12	7 + 1*
Physical	20	3	1	-	-	1	1	3 + 1 <sup>@</sup>	-	2	12	7 + 1 <sup>#</sup>
<b>Total</b>	<b>80</b>	<b>10</b>	<b>6</b>	<b>2</b>	<b>2</b>	<b>3</b>	<b>2</b>	<b>15</b>	<b>2</b>	<b>8</b>	<b>50</b>	<b>30</b>

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

### 13. INFORMATION FOR ADMISSION TO M.Sc. DEGREE COURSES IN CHEMISTRY

#### INTRODUCTION

A candidate for being eligible for admission to the M. Sc. Degree in Chemistry must have passed the Bachelor of Science degree examination with Chemistry as a major subject with 6/3 Unit-s or an examination of another University recognized as equivalent thereto. The M. Sc. (By Paper) degree course in Chemistry is of four-SEMESTER- duration. The structure of the M. Sc. degree course by papers is as per the syllabus.

#### **INSTRUCTIONS TO APPLICANTS:**

#### **GENERAL INSTRUCTIONS TO APPLICANTS FOR FILLING UP THE APPLICATION FORM**

Please read the handbook carefully before filling the admission form.

1. Merit is the only criterion for admission and seats are reserved as per Government of Maharashtra's directives in this connection.
2. Admissions of students belonging to the reserved category i.e.

SC/ST/DT/NT/OBC/SBC etc. are as per Government of Maharashtra's directives.

Application form must be accompanied by caste certificate issued by the Competent Authority. In case of OBC/SBC and DT/NT students, the requisite Non-Creamy Layer certificate issued in the Current Financial Year should be appended to the application. Application form without proper certificates will not be accepted.

3. There are no agencies operating on behalf of the Department and there is no capitation fee or donation in regard of admissions. Be careful of any persons claiming to offer admission to the Department. No extraneous considerations should be brought to exert pressure on the admissions committee. It will be strictly dealt with. We take pride in fairness and openness in admissions and all matters and give justice to one and all.

4. **Applications must be accompanied by:**

- a) *Attested copies* of the mark-sheets of First, Second and Third Year B. Sc. examinations along with their originals.
- b) Date of birth certificate (H.S.C. passing certificate/School Leaving certificate etc.)
- c) Students coming from the University other than University of Mumbai are required to obtain a provisional statement of Eligibility from the Eligibility Section, University of Mumbai, Dr. Ambedkar Bhavan, Vidyanagari, Mumbai -400 098.
- d) Account for any break in education should be mentioned in the form and the documentary evidence for the same must be provided along with the application form.

## **ADDITIONAL INSTRUCTIONS FOR FILLING UP THE APPLICATION FORM**

1. Students are advised to indicate their order of preference for *all* the *four* disciplines (Organic, Analytical, Physical and Inorganic Chemistry). If a student indicates preference for only one specialization he/she will be considered *only* for that specialization on merit basis. *No subsequent changes would be permitted.*
2. Applicants who have passed B. Sc. Examination from OTHER UNIVERSITIES should mention the aggregate marks secured by them in Chemistry (Theory and Practicals separately) at the First, Second and Third Year B. Sc.

After the scrutiny of admission forms submitted by the students, a synopsis showing the merit numbers of the students for different categories will be displayed on the notice board and on the web-site of the University. No individual correspondence will be made in this regard. It is the responsibility of the candidates to visit the notice Board and web-site regularly. It would be the responsibility of the student to check for any errors in the synopsis and point out to the Head of the Department in writing within time frame mentioned in the notification. No complaints will be entertained thereafter.

The detailed schedule for admission will be displayed on the same day. It would be the responsibility of the student to check the schedule and present himself/herself for admission on the day mentioned in the schedule.

Pleading ignorance about information displayed on the notice board and the web-site shall not be entertained.

### **APPLICANTS SUCCESSFUL IN GETTING ADMISSION WILL BE REQUIRED TO GO THROUGH THE FOLLOWING ADMISSION PROCEDURE:**

1. **Submit the original Statement of Marks of T. Y. B. Sc. Examination.**
2. **Open Category Students:** Pay prescribed fee of **Rs. 11145/-** [including Rs. 850/- Registration fee and Rs.25/- for the form of Registration] in the Allahabad Bank, Kalina Branch, Wadia High School, Ground Floor, Opposite Vidyanagari Campus within the stipulated period and produce the receipt in the office of the Department of Chemistry.
3. **Reserved category Students:** Pay prescribed fee of **Rs. 1295/-** [including Rs. 850/- Registration fee and Rs. 25/- for the form of Registration] in the Allahabad Bank, Kalina Branch, Wadia High School, Ground Floor, Opposite Vidyanagari Campus within the stipulated period and produce the receipt in the office of the Department of Chemistry.
4. In addition, all the students have to pay the refundable deposits of **Rs. 800/-** (Caution money: Rs. 150/- + Library deposit: Rs.250/- + Laboratory deposit: Rs.400/-)

### **CANCELLATION PROCEDURE**

Cancellation of Seats makes a heavy demand on the time spent by the administration. Hence

the following procedure must be scrupulously followed.

Application for cancellation of seat should be addressed to the Head of the Department in duplicate as per the Proforma B. Application for refund of fees should be addressed to the Registrar, University of Mumbai in Duplicate as per the Proforma C and submitted to the Head of the Department.

Kindly note that refund of tuition fees will be given only if the student takes admission to one of the University of Mumbai's affiliated colleges.

Refund of tuition fees will not be made if the student takes admission to any other college/institute, not affiliated to University of Mumbai, and/or does not take admission to any course.