University of Mumbai

DEPARTMENT OF CHEMISTRY

(AUTONOMOUS)

INFORMATION BROCHURE

FOR M. Sc. DEGREE PROGRAMMES IN INDUSTRIAL POLYMER CHEMISTRY

DEPARTMENT OF CHEMISTRY
UNIVERSITY OF MUMBAI
VIDYANAGARI
SANTACRUZ (E)
MUMBAI – 400 098

In Collaboration with

Indian Rubber Manufacturers Research Association

An Autonomous Body under DPIIT, Min. of Comm. & Ind., Govt. of India

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2020-2021

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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 receipientof 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), 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 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 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 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

Hostel rooms will be allotted as per the University rules.

6. FINANCIAL ASSISTANCE

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

B) Ph.D: NIL

7. DEPARTMENT FACULTIES

	**NAME: Dr. (Smt.) Manjusha Karve** (Professor & Head- Analytical)		
PAPERS PUBLISHED:	**30**	**Ph. D STUDENTS GUIDED:**	**02**
M.Sc STUDENTS GUIDED (by research)	**06**	**RESEARCH PROJECTS COMPLETED:**	**01**
RESEARCH INTERESTS	Solvent Extraction, Solid phase Extraction, Environmental Analysis.		

	**NAME: Dr. Shivram S. Garje** (Professor-Inorganic)		
PAPERS PUBLISHED:	**62**	**Ph. D STUDENTS GUIDED:**	**08 (completed)** **05 (ongoing)**
Patents:	**01**	**Consultancy projects**	**-**
M.Sc STUDENTS GUIDED (by research)	**05**	**RESEARCH PROJECTS COMPLETED:**	**02 (completed)** **01(ongoing)**
RESEARCH INTERESTS	Materials Chemistry, Organometallics, Nanomaterials, Development of molecular precursors for nanomaterials and thin films, Nanocomposites and their applications		
Honors/Awards	➢ BOYSCAST Fellowship, DST ➢ Performance based Incentive Award, University of Mumbai.		

	**NAME: Dr. Navinchandra G. Shimpi** (Associate Professor-Physical)		
PAPERS PUBLISHED:	**85**	**Ph. D STUDENTS GUIDED:**	**13 (completed)** **06 (ongoing)**
Patents	**04**	**Consultancy projects**	**01(completed)**
M.Tech STUDENTS GUIDED:	**15**	**RESEARCH PROJECTS COMPLETED:**	**09 (completed)** **02 (ongoing)**
RESEARCH INTERESTS	Synthesis of nanomaterials, Conducting polymers, Biodegradable polymer nanocomposites, Gas sensing materials, Organic transformation reactions, Dye degradation and Shape memory polymers		
Honors/Awards	➢ AICTE Career Award for Young Teachers (CAYT). ➢ Young Scientist Award by APA, IIT, New Delhi (International) ➢ Fellow – Maharashtra Academy of Science ➢ Dyanjoti Puraskar,Shirsathe Foundation, Jalgaon		

	**NAME: Dr. Rajesh M. Kamble** (Associate Professor-Analytical)		
PAPERS PUBLISHED:	**33**	**Ph. D STUDENTS GUIDED:**	**02 (completed)** **05 (ongoing)**
Patents	**-**	**Consultancy projects**	**-**
M.Sc STUDENTS GUIDED (by research)	**01**	**RESEARCH PROJECTS COMPLETED:**	**03 (completed)**
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.		
Honors/Awards	-		

	**NAME: Dr. Vishwanath R. Patil** (Associate Professor-Physical)		
PAPERS PUBLISHED:	**48**	**Ph. D STUDENTS GUIDED:**	**16(completed)** **06 (ongoing)**
Patents	**33**	**Consultancy projects**	**01 (ongoing)**
M.Sc STUDENTS GUIDED (by research)	**04**	**RESEARCH PROJECTS COMPLETED:**	**02 (completed)** **01 (ongoing)**
RESEARCH INTERESTS	Design, Synthesis and characterization of novel AIE functional organic materials for applications in Organic Light Emitting Devices (OLEDs), Bio-imaging and Solar cells.		
Honors/Awards	➢ Prof. B. C. Haldar Memorial Research Award ➢ Best Researcher & Academician Award (Bionano Frontier & University of Mauritius)		

	**NAME: Dr. Suresh D. Pawar** (Associate Professor-Inorganic)		
PAPERS PUBLISHED:	**28**	**Ph. D STUDENTS GUIDED:**	**08 (ongoing)**
Patents	**-**	**Consultancy projects**	**-**
M.Sc STUDENTS GUIDED (by research)	**-**	**RESEARCH PROJECTS COMPLETED:**	**-**
RESEARCH INTERESTS	Solvent extraction, Coordination Chemistry, Nanomaterials, and Metallo organic framework.		
Honors/Awards	-		

	**NAME: Dr. Shilpee Sachar** (Assistant Professor- Inorganic)		
PAPERS PUBLISHED:	**20**	**Ph. D STUDENTS GUIDED:**	**04 (ongoing)**
Patents	**-**	**Consultancy projects**	**-**
M.Sc STUDENTS GUIDED (by research)	**-**	**RESEARCH PROJECTS COMPLETED:**	**-**
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.		
Honors/Awards	-		

	**NAME: Dr. Purav M. Badani** (Assistant Professor-Physical)		
PAPERS PUBLISHED:	**23**	**Ph. D STUDENTS GUIDED:**	**04 (ongoing)**
Patents	**-**	**Consultancy projects**	**01(completed)**
M.Sc STUDENTS GUIDED (by research)	**04**	**RESEARCH PROJECTS COMPLETED:**	**01(completed)**
RESEARCH INTERESTS	Molecular modeling, reaction dynamics and non-covalent interactions.		
Honors/Awards	-		

	**NAME: Ramchandra G. Thorat** (Assistant Professor-Organic)		
PAPERS PUBLISHED:	-	**Ph. D STUDENTS GUIDED:**	-
Patents	-	**Consultancy projects**	-
M.Sc STUDENTS GUIDED (by research)	-	**RESEARCH PROJECTS COMPLETED:**	-
RESEARCH INTERESTS	Synthetic Organic Chemistry		
Honors/Awards	-		

	**NAME: Bhushan B. Popatkar** (Assistant Professor-Analytical)		
PAPERS PUBLISHED:	**02**	**Ph. D STUDENTS GUIDED:**	-
Patents	-	**Consultancy projects**	-
M.Sc STUDENTS GUIDED (by research)	-	**RESEARCH PROJECTS COMPLETED:**	-
RESEARCH INTERESTS	Green chemistry, Development of new methods for the synthesis of heterocyclic compounds, water analysis		
Honors/Awards	-		

	**NAME: Dr. Sudesh T. Manjare** (Assistant Professor-Inorganic)		
PAPERS PUBLISHED:	**21**	**Ph. D STUDENTS GUIDED:**	**05 (ongoing)**
Patents	**01**	**Consultancy projects**	-
M.Sc STUDENTS GUIDED (by research)	-	**RESEARCH PROJECTS COMPLETED:**	**03 (Completed)**
RESEARCH INTERESTS	Synthesis and Bio-applications of Chalcogen-based		

	Small Molecular Probes, Synthesis of Organometallic Compounds, Metal Complexes and Their Applications in Organic Synthesis, Material Science and for Energy Conversion.
Honors/Awards	Post-doctoral Research Fellow from Institute for Basic Science in Korea Advanced Institute of Science and Technology (KAIST), Daejeon, South Korea.

	**NAME: Dr. Arun K. Kadu** (Assistant Professor-Physical)		
PAPERS PUBLISHED:	**05**	**Ph. D STUDENTS GUIDED:**	**02 (ongoing)**
Patents	**-**	**Consultancy projects**	**-**
M.Sc STUDENTS GUIDED (by research)	**-**	**RESEARCH PROJECTS COMPLETED:**	**01 (Ongoing)**
RESEARCH INTERESTS	Electrochemistry:Development of sensors,nano-composites for sensors and catalyst.		
Honors/Awards	-		

	**NAME: Dr. Anil V. Karnik** (Professor-Organic, UGC-BSR Fellow)		
PAPERS PUBLISHED:	**41**	**Ph. D STUDENTS GUIDED:**	**15 (completed)** **06 (ongoing)**
Patents	**01**	**Consultancy projects**	**01 (Completed)**
M.Sc STUDENTS GUIDED (by research)	**16**	**RESEARCH PROJECTS COMPLETED:**	**-**
RESEARCH INTERESTS	Chiral Chemistry, Synthetic Organic Chemistry, Heterocyclic Chemistry.		
➢ **Honors/Awards**	➢ Performance based Incentive award, University of Mumbai.		

	➢ Elected Fellow of Maharashtra Academy of Science

M.Sc ALL BRANCHES TOPPERS- 2016-17	SET QUALIFIED STUDENTS-2016-18
1. Ms. Ansari Sabrin**(Physical Chemistry; 7.16 CGPA)** **2.** Ms. Shaikh Nilofer **(Inorganic Chemistry; 7.57 CGPA)** 3. Ms. Pooja Zanje (**Organic Chemistry; 8.86 CGPA)** 4. Mr. Kisan Gupta **(Analytical Chemistry; 8.39 CGPA)**	1. Ms. Poornima Acharya 2. Mr. DivyeshShelar 3. Ms. Rajashree Prajapati 4. Mr. Sarfraz Shaikh 5. Mr. Jatin Lade 6. Mr. SachinGolhe 7. Ms. Shaikh AkshHina 8. Mr. Mangesh Pingale 9. Mr. Amit Surve 10. Ms. Ashvini Jadhav 11. Kishan Gupta 12. Madan Birajdar 13. Nitin Gulvi 14. Prakash Aaraj 15. Rakesh Raigawali 16. Suhas Salunkhe 17. Ms. Pooja Singh 18. Girish Kadam 19. Anju Ashokan
M.Sc ALL BRANCHES TOPPERS- 2018-19	
1. Ms. Jain Hansakumari Suresh Sushila**(Physical Chemistry; 7.72 CGPA)** **2.** Ms. Khan Zuha Firoz Gulnaz**(Inorganic Chemistry; 8.41 CGPA)** 3. Ms. Shinde Rupali Dasharath Darshani(**Organic Chemistry; 8.88CGPA)** 4. Ms. Naik Pragati Anil Anita**(Analytical Chemistry; 7.91 CGPA)**	
GATE QUALIFIED STUDENTS-2016-18	
1. Mr. DivyeshShelar 2. Madan Birajdar 3. Pooja Singh 4. Rakesh Raigawali	
NET-LECTURERSHIP QUALIFIED STUDENTS-2016-18	
1. Mr. Ganesh Pavale 2. Mr. Aleem Ansari 3. Mr. Rupesh Mestri 4. Ms. Poornima Acharya 5. Madan Birajdar 6. Rakesh Raigawali 7. Pooja Singh 8. Sampat Shingada	**SET QUALIFIED STUDENTS-2019-20** 1. Ms. Manisha Patel 2. Ms. Divya Mahatre

NET-LECTURERSHIP QUALIFIED STUDENTS-2019-20	NET-JRFQUALIFIED STUDENTS-2016-18
1. Ms. Manisha Patel 2. Ms. Rupali Shinde 3. Ms. Prajakta Pise	1. Mr. Siddharth Kamble 2. Mr. Navin Yadav 3. Mr. Sachin Dhodi 4. Mr. Ega Sai Prasad Somashekar 5. Madan Birajdar 6. Rakesh Raigawali

8. About IRMRA

Indian Rubber Manufacturer's Research Association, popularly known, as IRMRA is Premier National Research and Development organization registered in 1958 under societies act XXI of 1860 to provide hand holding scientific and technological support to the Indian Rubber & Allied Industries. Presently, IRMRA is functioning under the administrative control of Ministry of Commerce & Industry, Govt. of India. The institute is functioning in two locations situated at Wagle Industrial Estate, Thane – 400 604. Institute is funded by Ministry of Commerce & Industry, Govt. of India to create state of art R&D center to support Rubber Industries & end users to improve the quality of rubber products. IRMRA has modern state of art scientific and analytical facilities and is fully equipped with infrastructure for design & development, testing and certification, process optimization, technical consultancy, third party inspection, training, reverse engineering and allied aspects in quality and eco compliance for rubber and allied products. IRMRA is contemplating to establish its regional centers in different parts of country to cater the needs of clusters. To begin with, Eastern and Southern Regional Centers are being set up in SARPOL, Dulhagarh, Kolkata, WB and Sri City, Chittur District AP respectively.

The testing laboratories of IRMRA, including mechanical and chemical area are accredited by National Accreditation Board for Testing & Calibration Laboratories (NABL), Quality Council of India, Ministry of Commerce & Industry, GOI, in compliance with ISO/IEC 17025. In addition, the institute is certified for Quality Management System complying with ISO 9001:2008 and institute is recognized by

DSIR as Scientific & Industrial Research Organization (SIRO). The institute is also accredited by NABET as Business Membership Organisation (BMO) under Diamond Grade.

The institute is engaged in pursuit of higher research in all major areas of rubber and polymer Technology having qualified, trained and experienced scientists with doctoral and master's degree holders from premier universities / IITs. IRMRA, Thane is involved conducting various R&D programmes either sponsored by industry and or government organization such as DST, BARC, DBT, CSIR, NAIP, ICAR, IGCAR, MOD etc. in the area of product development, process development / optimization, application development, development of standard test methods, waste recycling etc.

<table>
<tr><td>  </td><td>IRMRA Head Office
Plot No. 254/1B, Road No.16-V
Wagle Industrial Estate,
Thane - 400 604, Maharashtra</td></tr>
<tr><td></td><td></td></tr>
<tr><td>  </td><td>IRMRA Extension Centre, Thane (Old)
Plot No. B-88, Road No. 24, Wagle Industrial Estate,Thane - 400 604, Maharashtra
.</td></tr>
</table>

	**IRMRA- South Centre** Sricity Trade Centre, Sri City, Andhra Pradesh-517646
	**IRMRA-East Centre** Rubber Park, Dhulagarh, Howrah-711302 West Bengal

9. **IRMRA has following quality accreditations / recognitions:**

- **ISO/IEC 17025 Accredited**
- **ISO 9001 Certified**
- **DGMS Accredited**
- **BIS Recognized for various Tyre& Non- Tyre Testing**
- **DSIR Recognized**
- **CEMILAC Approved**
- **NBQP Registered**
- **BMO Accredited**

Research & Development

Some of the R&D activities conducted or being conducted is as under:

- Design & Development of Rubber Dams for watersheds
- A value chain for coconut, fibre and its by-product: Manufacture of dissolved products of higher value and better marketability to enhance the economic returns of farmers (Coir Project).
- Radiation effects on styrene–butadiene– ethylene–propylene diene monomer-multiple walled carbon nanotube nano-composites: vulcanization and characterization.
- Development of NBR Based Polymer Nano-composites for High Temperature Application.
- Use of Electron Beam Radiations in Rubber Products especially Tyres, Belts etc – BRNS, BARC
- Design and Development of critical rubber products for defense application. Sponsored by MOD, Govt. of India.
- Development of critical rubber compounds for nuclear applications. Sponsored by Department of Atomic Energy, Government of India,

Training & Skill development

The institute conducts following training programmes on relevant areas of interest to the user industry:

- 04 days training on Laboratory Quality Management System (ISO/IEC 17025:2005) and is accredited by National Accreditation Board for Education and Training (NABET), Quality Council of India, Ministry of Commerce & Industry, GOI.
- Short term technical training courses on Rubber Technology & quality control.
- Facilitates conduct of projects/ dissertation work for students pursuing higher learning programmes from leading institutes like IITs, NITs.
- Summer training / internship in polymer and rubber technology.

Education Programmes

IRMRA has initiated the following education programs

- 1 Year Online certificate courseon, Rubber Material Science &Technology

- 2 Years full time Masters in Industrial Polymer Chemistry in collaboration with PG Department of Chemistry, Mumbai University.

10. Team of IRMRA Scientist & Faculties

Dr. K. Rajkumar- Director – IRMRA

Dr. K Rajkumar was appointed as the Director of IRMRA w.e.f. 12th March 2015 based on the recommendation given by Govt. of India and currently, he is the overall in-charge of IRMRA. Dr. Rajkumar has completed his M.Tech. in Rubber Technology (1997) from Rubber Technology Centre, Vels University and received his PhD degree in Polymer Nanocomposites (2015) from Bharathiar University, Coimbatore in 2015. He also secured an MBA in Operation Management from Sikkim Manipal University (2013). He has over 20 years of work experience.He has handled more than 30 sponsored projects and developed more than 25 critical products.He has published more than 50 research papers and has filed 3 patents in his credit.He has encouraged and guided more than 50 students in rubber technology and more than 400 lectures/training. He is the Chairman of BIS/PCD 29 Committee and Member of several committees like ISO TC 45, BIS ME 17, TED 7, BIS/PCD 13 and BIS/PCD 28. Dr. Rajkumar also secured an award from ICAR, Ministry of Agriculture, Govt. of India for his outstanding contribution in completion of project of "Design and Development of Rubber Dam for water sheds. He was involved in various important R&D Projects which include Development of shock vibration isolation mounts, estimation of life of SV mounts, development of hydraulic mounts, development of alternate materials including bio source based materials etc. are some of his major area of interest. He is a Lead Assessor of NABL and also a Lead Auditor of ISO 9001/QMS. He has travelled abroad (more than 20 countries) in different capacities.

1.

Mr. Mohammad Anis, Assistant Director – Processing

Mr. Mohammad Anis has completed his M.Sc. in Analytical Chemistry (1986) from Aligarh Muslim University, Aligarh and received his Postgraduate Diploma (Industrial and Analytical Chemistry from Ruia College, Matunga, Mumbai). He has over 25 years of work experience. He has handled many projects which are sponsored by Indian Navy,

BARC, and Defense sectors.He has published three technical papers. Presently he is heading Processing Department in IRMRA.

2. **Mr. T. V. Sethumadhavan**, Assistant Director – Product Development

Mr. T. V. Sethumadhavan has completed his M.Sc in Chemistry (1988) from Mahatma Gandhi University, Kerala and M.Tech degree in Polymer Technology (1991) from Cochin University of Science and Technology. He joined IRMRA in 2015 and has 27 years of work experience.He has handled 18 sponsored projects and developed 18 products. He has filed 2 patents in his credit. He encouraged and guided 5 students in rubber technology and delivered 7 lectures / trainings. Presently he is heading the Department for Product Development, Contract and Sponsored Research and Third Party Inspection Services in IRMRA. He is also responsible for new product development and project execution for defense, nuclear and other public sector units and other industries.

3. **Ms. Suchismita Sahoo**, Assistant Director- Chemical and Analytical Testing

Ms. Suchismita Sahoo has completed her M.Sc in Chemistry (2003) from Utkal University, Odisha and received her M.Tech degree in Rubber Technology (2006) from IIT Kharagpur. She joined IRMRA in 2015 and has 13 years of work experience.She has handled 4 projects and developed 2 products. She has published 7 research paperand has filed 3 patents in her credit. She encouraged and guided 11 students in rubber technology and delivered more than 25 lectures/trainings. Presently she is heading Chemical and Analytical Testing Laboratory in IRMRA.

4. **Dr Debdipta Basu –** Assistant Director & Center Head, East Center, IRMRA

Dr. Debdipta Basu has completed his Master degree in Material Science (2009) from Sardar Patel University, Gujarat and received his PhD degree in Polymers (2015) from Technical University of Dresden, Germany. He joined IRMRA in April 2018 and has 3 years of work experience. He has handled 8 sponsored projects and developed 5 products. He has published 15 research papers along with 3 articles / chapters in books. He has encouraged and guided 3 students in rubber technology and given 2 lectures/trainings. Presently he is heading the East Center of IRMRA, located in Kolkata.

5. **Dr. Rupesh Rohan –** Assistant Director & Center Head, South Center, IRMRA

Dr. Rupesh Rohan has completed his M.Tech in Rubber Technology (2009) from IIT, Kharagpur and received his PhD degree in Chemistry (2015) from National University of Singapore, Singapore. He joined IRMRA in June 2018 and has 3 years of postdoctoral research experience along with 3 years of Industrial experience. He has handled 7 projects and developed 3 products. He has published 29 research papers and has filed 1 patent in his credit. He has encouraged and guided 3 students in rubber technology and given 10 lectures/training. Presently he is heading Physical Testing, Academics and Training Department in IRMRA.

6. **Dr. Bharat Kapgate –** Assistant Director & Corporate, Head, IRMRA

Dr. Bharat Kapgate has completed his M.Sc. in Organic Chemistry (2008) from RTM Nagpur University and received his PhD degree in Rubber Chemistry & Technology

(2015) from VNIT, Nagpur.He joined IRMRA in October 2015 and has 2 years of academic experience prior toIRMRA. He has handled 5 projects and developed 3 products. He has published 20 research papers, 1 book chapter and has filed 1 patent in his credit. He has encouraged and guided 30 students in rubber technology and over 20 lectures/training. Presently he is heading Corporate Affairs in IRMRA.

Recent Publication:

1. Unusual low temperature relaxation behavior of crosslinked acrylonitrile-butadiene co-polymer. **Basu, Debdipta**, Shib Shankar Banerjee, Subhas Chandra Debnath, Mikhail Malanin, LyaysanAmirova, Philippe Dubois, Gert Heinrich, and Amit Das. Polymer (2020): 123309.
2. Synthesis and chemical modification of crystalline nanocellulose to reinforce natural rubber composites. Singh, Shiva, Gopal L. Dhakar, **Bharat P. Kapgate**, Pradip K. Maji, Chhavi Verma, Monika Chhajed, **Kasilingam Rajkumar**, and Chayan Das. Polymers for Advanced Technologies (2020).
3. Carbon cloth-MnO_2 nanotube composite for flexible supercapacitor. Soni, S., Pareek, K., Jangid, D. K., &**Rohan, R**. Energy Storage, e189.
4. In Situ Zirconia: A Superior Reinforcing Filler for High-Performance Nitrile Rubber Composites. Ambilkar, Shubham C., Naresh D. Bansod, **Bharat P. Kapgate**, Amit Das, Petr Formanek, **Kasilingam Rajkumar**, and Chayan Das. ACS omega 5, no. 14 (2020): 7751-7761.
5. A feasibility study on rubberized concrete mortar cubes used in construction industry. Venkatesan, G., Anjali, R., **Kapgate, B**., &**Rajkumar, K.** (2020). Materials Today: Proceedings.
6. Laboratory studies on strength behavior of concrete added with tire derived products. Venkatesan, G., M. Saravanakumar, Bharat P. Kapgate, and K. Rajkumar. Materials Today: Proceedings (2020).
7. Experimental investigation on natural fiber along with silica fume in conventional concrete. Venkatesan Govindan, Bharat P Kapgate, K Rajkumar. South Asian Journal of Engineering and Technology (2019).

8. Synthesis and Characterization of Phenol Furfural Resin from Moringa Oleifera Gum and Biophenol and Its Application in Styrene Butadiene Rubber. Riya Koley, Rajkumar Kasilingam Suchismita Sahoo, Santanu Chattopadhyay, Anil K. Bhowmick., Industrial & Engineering Chemistry Research, (2019).

9. Investigation of compressed hydrogen refueling process of 60 L type IV tank used in fuel cell vehicles, S. Sapre, K. Pareek, R Rohan, P K Singh,Energy Storage, (2019).

10. H2 refueling assessment of composite storage tank for fuel cell vehicle, Shitanshu Sapre, Kapil Pareek, Rupesh Rohan, Pawan Kumar Singh, International Journal of Hydrogen Energy, (2019).

11. Performance optimization of Co2O3-PVDF-CNT based Supercapacitor electrode through multi-response optimization method., Mayank Vyas, Kapil Pareek, Rupesh Rohan, Pawan Kumar., IONICS. (2019).

12. Phase Changing Stearate Ions as active fillers in Multifunctional Carboxylated acrylonitrile butadiene composite: Exploring the role of zinc stearate., Basu D., Agasty A., Das A., Chattopadhyay S., Sahu P., Heinrich G., Journal of Applied Polymer Science, (2019).

13. Evolution of coefficient of friction between tire and pavement under wet conditions using surface free energy technique., Singh, Dharamveer, Harsh Patel, Ayyanna Habal, Aditya Kumar Das, Bharat P. Kapgate, and Kasilingam Rajkumar, Construction and Building Materials, (2019).

14. Incorporation of titania nanoparticles in elastomer matrix to develop highly reinforced multifunctional solution styrene butadiene rubber composites., Das,Chayan, Naresh D. Bansod, Bharat P. Kapgate, K. Rajkumar, Amit Das., Polymer, 2019

15. Flexible supercapacitor based on three-dimensional cellulose/graphite/polyaniline composite., Sharma, Kshipra, Kapil Pareek, Rupesh Rohan, and Pawan Kumar, International Journal of Energy Research, 2019.

16. Functionalization of EPDM rubber toward better silica dispersion and reinforcement., Bansod, Naresh D., Bharat P. Kapgate, Pradip K. Maji, Anasuya Bandyopadhyay, and Chayan Das., Rubber Chemistry and Technology., 2018

17. A unique application of the second order derivative of FTIR–ATR spectra for compositional analyses of natural rubber and polychloroprene rubber and their blends., Manohar, N., J. Jayaramudu, S. Suchismita, K. Rajkumar, A. Babul Reddy, E. R. Sadiku, R. Priti, and D. J. Maurya., Polymer Testing, 2017.

18. A potential utilization of end-of-life tyres as recycled carbon black in EPDM rubber, Sagar, M., K. Nibedita, N. Manohar, K. Raj Kumar, S. Suchismita, A. Pradnyesh, A. Babul Reddy, Waste management, 2017

19. Surface modification of nylon fabric and its optimization for improved adhesion in rubber composites, Krishna Prasad, G., S. Periyasamy, S. K. Chattopadhyay, A. S. M. Raja, K. Rajkumar, and Santosh Jagadale, The Journal of The Textile Institute, 2017

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Patents:

Granted

1. **A Process of making Ozone Resistant Natural Rubber**

   Mrs. AnushreeDukhande& Dr. Madhu Sudan Banerji.

   Indian Patent Application Number 101/MUM/2004

2. **Use of Bio product as multieffective Rubber compounding agent**

Santosh Jagadale, K. Rajkumar
Indian Patent number 350542 Dated 01.02.2019

Filed

1. **Design, Development and Fabrication of Flexible booting-**

   Application number 201821013011 dated 06.04.2018.

   T V Sethumadhawan, Santosh Jagadale, K. Rajkumar

2. **Rubber segment bearing for propeller shaft –**

   T V Sethumadhawan, Chandan Chaudhary, K. Rajkumar

   TEMP/E-1/3514/2019-MUM

3. **Coconut Nut Shell Extract (CNSE) as a multifunctional additive in rubber compounds :**

   Suchismita Sahoo; Manohar Nawale; Kasilingam. Rajkumar; Bharat Kapgate; DebdiptaBasu; Shantaram Naik; Raju Shetty; Deepasha Bharti; Anil Kumar. Bhowmick TEMP/E-1 /16064/2019-MUM

4. **A Bio Based Sealant for Puncture Proof Tire-**

   TEMP/E- 1/9837/2019-MUM

   Suchismita Sahoo; ManoharNawale; Kasilingam. Rajkumar; Debdipta Basu; Surjendu Bag, Santosh Jagadale, Rohit Tripathi

5. **Ageing & ozone resistant bio-based rubber formulation containing curcumin & derivatives as an additive.**

   Suchismita Sahoo; Manohar Nawale; PritiRasam, Rupesh Rohan; Kasilingam. Rajkumar; Application number 201921036794 dated 12.09.2019

6. **Treatment of Silica with Turmeric and Its Constituents,**

   R. Rohan, M. Nawale, A. Jhadhav, R. Shetty, K. Rajkumar

   Intellectual Property India India provisional Application No. 202021000276, filing dated 03/01/2020.

11. NEED OF INDUSTRIAL POLYMER CHEMISTRY EDUCATION & ELIGIBILITY

There are about 7000 units comprising of 30 large scale, 300 medium scale and around 6500 small scale and tiny sector units. Rubber is one of the major industrial polymers. Indian Rubber Industry is expected to grow at over 8% per annum in this decade and the industry is envisaged to grow at the rate of 8% per annum. The per capita consumption of rubber in India is only 800 grams compared to 12 to 14 kilos in Japan, USA and Europe. The prospect of growth is further enhanced by a boom in the vehicle (automobile) industry, improved living standards of the people and rapid over-all industrialization. There exists a huge scope for expansion and development and exports in coming years. However, the largest part of the industry includes unorganized small & medium scale rubber industries. Unlike metal and plastic, rubber products are very complex and require a high expertise starting from raw material selection to processing techniques. Rubber product manufacturing involves multiple steps, a single rubber product contains more than 10-15 different ingredients, their mixing and molding requires highly skilled man power. The rubber industry is has a huge demand for the skilled manpower to up lift the level and status of rubber industry. Very few institutes in India offer an educational course on rubber technology; most of them offer courses on chemistry / chemical engineering / mechanical engineering that do not serve the need of the industry. • In view of this IRMRA in collaboration with Department of Chemistry, Mumbai University offers—‖M. Sc. Industrial Polymer Chemistry" for fresh graduates to grow their career in rubber & allied polymer industries. • Any student who has completed B. Sc. in Chemistry can apply for this course. Admission will be given on the basis of merit.

11. 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: 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 parent departments in semester III and each course will be of 4 credits.

Optional Courses:

- Optional Courses shall be offered by parent departmentsin 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 [OC1 & OC2] 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 OC1 and or OC2 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.

8 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 single major subject out of 600 (Sem V & VI) shall be considered.

b) Students securing first class and above shall be given priority over students not securing second class at T. Y. B. Sc. examination.

c) The CGPA shall be considered if the marks are equal.

d) All things being equal, 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).

e) 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" at only.

f) 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.

g) In case of there is a tie in (a), (b), (c), (d) or (e), then all students tied at the rank shall be admitted.

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

[2] <u>For other University students:</u>

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. Marksheet of F.Y to T.Y. B.Sc must be attached alongwith the form.

<u>Examination</u>

All examinations for all semesters are conducted by the respective 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.

13. SYLLABI FOR M. Sc. CHOICE BASED CREDIT SYSTEM (CBCS) FOUR-SEMESTER-COURSEIN CHEMISTRY

SEMESTER-I

Course Code	Title of the Course	No. of Credits	No. of hours per SEMESTE-R	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-ITHERMODYNAMICS-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-IIFUNDAMENTAL 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-IIIPHASE RULE AND ITS APPLICATIONS [15L]

Phase rule, Phase diagrams and their classification, Lambda transitions.

Two component system: Vapor pressure – composition diagrams, Phase diagrams for partially miscible liquids for two components, Critical solution temperature, influence of foreign substances on CST, fractional distillation of Zeotropic and Azeotropic mixtures.

Three component 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, Ternary Azeotropic mixtures, Preparation of absolute alcohol by azeotropic elimination of water.

Unit-IVCHEMICAL KINETICS [15L]

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

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

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

Derivation not expected

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

References books:

1. Peter Atkins and Julio de Paula, *Atkin's Physical Chemistry*, 7th ed., Oxford University Press, 2002.
2. K. J. Laidler and J. H. Meiser, *Physical Chemistry*, 2nd ed., CBS Publishers and Distributors, New Delhi, 1999.
3. Robert J. Silby and Robert A. Alberty, *Physical Chemistry*, 3rd ed., John Wiley and Sons (Asia) Pte. Ltd., 2002.
4. Ira R. Levine, *Physical Chemistry*, 5th ed., Tata McGraw-Hill, New Delhi, 2002.
5. G. W. Castellan, *Physical Chemistry*, 3rd ed., Narosa Publishing House, New Delhi, 1983.
6. D. A. McQuarrie and J. D. Simon, *Physical Chemistry - a molecular approach*, Viva Books Private Limited, New Delhi, 1998.
7. S. Glasstone, Text Book of Physical Chemistry, 2nd ed., McMillan and Co. Ltd., London, 1962.
8. D. A. McQuarrie, *Quantum Chemistry*, Viva Books Private Limited, New Delhi, first Indian ed., 2003.
9. B. K. Sen, *Quantum Chemistry including spectroscopy*, Kalyani Publishers, 2003.
10. A. K. Chandra, *Introductory Quantum Chemistry*, Tata Mc Graw-Hill, 1994.
11. R. K. Prasad, *Quantum Chemistry*, 2nd ed., New Age International Publishers, 2000.
12. D. O. Hayward, *Quantum Mechanics for Chemists*, Royal Society for Chemists, 2002.
13. Sydney T. Bowden, *The phase rule and the phase reaction*, McMillan and Co. Ltd., London, 1938.

14. A. N. Cambell, Alexander Findlay, *The Phase Rule and its Applications*, Dover publications.

15. G. L. Agarwal, *Basics Chemical kinetics*, Tata Mcgraw Hill, New Delhi.

16. K. J. Laidler, *Chemical Kinetics*, 3rd ed., Pearson Education.

17. R. P. Rastogi, R. R. Mishra, *An Introduction to Chemical Thermodynamics*, Vikas Publishing House Pvt. Ltd.

List of Books for further reading:

1. S. Glasstone, *Thermodynamics for Chemists*, Affiliated East-West Press, New Delhi, 1964.
2. W. G. Davis, *Introduction to Chemical Thermodynamics – A Non-Calculus Approach*, Saunders, Philadelphia, 1972.
3. I. M. Klotz and R. M. Rosenberg, *Chemical Thermodynamics*, 5th ed., John Wiley and Sons, Inc., 1994.
4. Peter A. Rock, *Chemical Thermodynamics*, University Science Books, Oxford University Press, 1983.
5. Ira N. Levine, *Quantum Chemistry*, 5th ed., Pearson Education (Singapore) Pte. Ltd., Indian Branch, New Delhi, 2000.
6. J. P. Lowe, *Quantum Chemistry*, 2nd ed., Academic Press, New York, 1993.
7. R. Anantharaman, *Fundamentals of Quantum Chemistry*, McMillan India Limited, 2001.
8. Mahendra R. Awode, *Quantum Chemistry*, S. Chand and Co. Ltd., New Delhi, 2002.

CHEM-102: INORGANIC CHEMISTRY-I

Unit-I INORGANIC REACTION MECHANISMS **[15L]**

(i) Rate of reactions, factors affecting the rate of reactions; techniques for the determination of rate of reactions.

(ii) Mechanisms and factors affecting the (I) ligand substitution reactions of (a) octahedral complexes with and without breaking of metal-ligand bond, (b) square planar complexes – trans-effect, its theories and applications and (c) tetrahedral complexes; (II) Redox reactions: inner and outer sphere mechanisms.

(iii) Complimentary and non-complimentary reactions.

(iv) Isomerization and racemization reactions.

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

(i) Recapitulation of classification of organometallic compounds, electron

counting and eighteen electron rule.

(ii) Sixteen electron rule.

(iii) Synthesis, structure and bonding of the following organometallic compounds:

(a) Alkyl and Aryl derivatives, (b) Carbenes and Carbynes, (c) Alkene complexes, (d) Alkyne complexes, (e) Allyl complexes, (f) Cyclopentadiene complexes and (g) Arene complexes (sandwich and half sandwich complexes).

Unit-III CHEMICAL BONDING **[15L]**

(i) **Hybridization:** Derivation of wave functions for the following orbital hybridisation types: sp (BeH_2); sp^2 (BF_3); sp^3 (CH_4) considering only sigma bonding.

(ii) Molecular Orbital Theory (LCAO-MO approach) for Electron deficient and Electron rich species.

(iii) Hydrogen bonding: concept, types, properties, methods of detection and importance. Van der Waal's forces, ion-dipole, dipole-dipole, London forces.

(iv) Bent's Rule: Reactivity of molecules: e.g. chlorofluorides of phosphorous, fluoromethanes, etc.

Unit-IV CHEMICAL REACTIVITY **[15L]**

(i) Hydration of cations and anions, Latimer equations, acidity of cations and oxocations, basicity of anions and oxoanions, classification of mono and polyatomic ions on the basis of pKa with predominance diagram. Classification of oxoacids, structural anomalies.

(ii) Recapitulation of hard soft acids and bases (HSAB) principle, Acid-base strength and softness and hardness; Classification of Lewis acids and bases based on frontier Molecular orbital topology, Reactivity matrix of Lewis acids and bases; Superacids and bases.

(iii) 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. D. Banerjea, Coordination Chemistry, Tata McGraw Hill, 1993.
2. F. Basalo and R. G. Pearson, Mechanism of Inorganic Reactions, 2nd Ed., Wiley, 1967.
3. M. L. Tobe and J. Burgess, Inorganic Reaction Mechanism, Longman, 1999.
4. P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, Inorganic Chemistry,

5th Ed., Oxford University Press, 2010.

5. R. Gopalan and V. Ramlingam, Concise Coordination chemistry, Vikas Publishing house Pvt Ltd., 2001

Unit-II

1. R. H. Crabtree, The Organometallic Chemistry of the Transition Metals, 5th Ed., Wiley Interscience, 2009.
2. R. C. Mehrotra and A. Singh, Organometallic Chemistry-A Unified Approach, 2nd Ed., New Age International Pvt. Ltd., 2000.
3. G. O. Spessard and G. L.Miessler, Organometallic Chemistry, Prentice-Hall, 1977.
4. K. F. Purcell and J. C. Klotz, Inorganic Chemistry, Saunders, 1977.
5. B. Douglas, D. H. McDaniel and J. J. Alexander, Concepts and Models of Inorganic Chemistry, 2nd Ed., John Wiley & Sons, 1983.
6. J. Huheey, F. A. Keiter and R. I. Keiter, Inorganic Chemistry – Principles of Structure and Reactivity, 4th Ed., Harper Collins, 1993.

Unit-III

1. J. Huheey, F. A. Keiter and R. I. Keiter, Inorganic Chemistry – Principles of Structure and Reactivity, 4th Ed., Harper Collins, 1993.
2. P. J. Durrant and B. Durrant, Introduction to Advanced Inorganic Chemistry, Oxford University Press, 1967.
3. R. L. Dekock and H.B.Gray, Chemical Structure and Bonding, The BenjaminCummings Publishing Company, 1989.
4. K. L. Kapoor, A textbook of Physical Chemistry, Volume 4, McMillan, 2001.
5. G. Miessler and D. Tarr, Inorganic Chemistry, 3rd Ed., Pearson Education, 2004.
6. R. Sarkar, General and Inorganic Chemistry, Books & Allied (P) Ltd., 2001.
7. C. M. Day and J. Selbin, Theoretical Inorganic Chemistry, Affiliated East West Press Pvt. Ltd., 1985.
8. J. N. Murrell, S. F. A. Kettle and J. M. Tedder, The Chemical Bond, Wiley, 1978.
9. G. A. Jeffrey, An Introduction to Hydrogen Bonding, Oxford University Press, Inc., 1997.
10. W. W. Porterfield, Inorganic Chemistry-A Unified Approach, 2nd Ed., Academic Press, 1993.
11. B. W. Pfennig, Principles of Inorganic Chemistry, Wiley, 2015.

Unit-IV

1. G. Wulfsberg, Inorganic Chemistry, Viva Books Pvt. Ltd., 2002.
2. B. Douglas, D. McDaniel and J. Alexander, Concepts and Models of Inorganic Chemistry, 3rd Ed., John Wiley & Sons, Inc., 2001.
3. P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, Inorganic Chemistry, 5th Ed., Oxford University Press, 2010.
4. G. Miessler and D. Tarr, Inorganic Chemistry, 3rd Ed., Pearson Education, 2004.
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6. J. Huheey, F. A. Keiter and R. I. Keiter, Inorganic Chemistry – Principles of Structure and Reactivity, 4th Ed., Harper Collins, 1993.
7. R. L. Madan and G. D. Tuli, Inorganic Chemistry,5th Ed., S. Chand, 2012.
8.. J. D. Lee, Concise Inorganic Chemistry, 5th Ed., Wiley, 2012.
9. B. R. Puri, L. R. Sharma and K. C. Kalia, Principles of Inorganic Chemistry, Milestone, 2014.
10. http://www.meta-synthesis.com/webbook.html

CHEM 103: ORGANIC CHEMISTRY-I

Unit-IPHYSICAL ORGANIC CHEMISTRY [15L]

1.1 Acidity-Basicity:

Different concepts and examples, Factors affecting acidity & basicity. Electrophilicity and Nucleophilicity; Ambident Electrophiles and Nucleophiles, Relationship between nucleophilicity and basicity.

1.2 Non-kinetic Methods of determining reaction mechanism:

Product profiles, Detection and identification of intermediates by chemical/trapping and spectroscopic means. Evidence from catalysis, cross-over experiments, isotopic labeling, Kinetic isotope effect-primary & secondary isotope effect, Stereochemical studies.

1.3 Linear Free Energy Relationships:

Effect of structure on reactivity, Hammett equation, substituent and reaction constants,Through conjugative effects of substituents, Linear free energy relationships in the determination of reaction mechanism,Taft Equation, steric parameter.

Unit-IISTEREOCHEMISTRY [15L]

2.1: Symmertry operations and symmetry elements:

Symmetry Operations, identification of principal axis, symmetry elements, definition and examples of molecules with different elements of symmetry including σ_v, $\sigma_h\sigma_d$

2.2 Molecules with tri and tetracoordinate chiral centres:

Compounds with carbon, silicon, nitrogen, phosphorous and sulphur chiral centres and their relative configurational stabilities.

2.3 Molecules with two or more chiral centres:

Configurational nomenclature, Constitutionally unsymmetrical molecules: Erythro-threo and syn-anti systems. Constitutionally symmetrical molecules with odd and even number of chiral centres: enantiomeric and meso forms, concept of stereogenic, chirotopic and pseudoasymmetriccentres.

2.4 Axial and Planar chirality:

Principles of axial, planar and helical chirality, Stereochemical features and configurational descriptors (R,S) for the following classes of compounds: allenes, alkylidene

cycloalkanes, spiranes, biaryls (including BINOLs and BINAPs), ansa compounds, cyclophanes and helicenes.

2.5 Prochirality:

Concept of prochirality, homotopic enatiotopic, and distereotopic ligand and faces: criteria based on symmetry and substitution/addition of molecules with different elements of chirality. Notation of prochirality, notation for molecules with pro-pseudo asymmetric centres. Notation for molecules with presence of a chiral and a pro-chiral centres. Top-right mnemonic.

Unit-IIIMETHODS OF C-C BOND FORMATION USING THE CARBONYL FUNCTON [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: Acyloin, Benzoin, Claisen, Darzen, Dieckmann, Knoevenagel, Mannich, Michael, Robinson Annulation and Stobbe.

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

Unit- IVSPECTROSCOPY [15L]

4.1 UV-Visible Spectroscopy:

Recapitulation of basic concepts and sample handling. Woodward-Fieser rules for calculation of $\lambda_{Max}$of conjugated dienes, polyenes, enones and aromatic carbonyl compounds.

Problems based on Woodward-Fieser rules.

4.2 IR Spectroscopy:

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

4.3 PMR Spectroscopy:

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

4.4 Mass Spectrometry:

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

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

References Books:

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

CHEM 104: ANALYTICAL CHEMISTRY I

Unit I: Concepts of Analytical Chemistry **[15L]**

1.1 Concepts of Analytical Chemistry: Classification of Analytical Methods: An overview of Classical methods, Types of Instrumental methods [2L]

Selection of an analytical methods and their performance criteria. [2L]

1.2 Concepts of optical methods: Electromagnetic spectrum, transitions, components in optical instruments, sources, description of LASER, wavelength selectors, monochromator functioning, effective band width, detectors and description of diode array type detector. [6L]

1.3 Atomic Absorption Spectrometry: Principle, interferences, use of electro thermal analyser, hydride generator and cold vapour for trace metal analysis. Importance of electro thermal analyser for analysis of biological samples, level of detection; hydride generator for environmental samples and cold vapour technique for mercury analysis. [5L]

Unit II: Atomic and molecular spectroscopy **[15L]**

2.1 Molecular transitions, derivative and dual wavelength spectroscopy. Application to trace analysis (d-d transition and charge transfer), biological samples and simultaneous determinations. [5L]

2.2 Atomic Emission Spectroscopy based on plasma source, advantages of plasma source. Applications in geo-analysis, metal samples, agriculture and food samples and environmental analysis. [5L]

2.3 Infrared spectroscopy: Concept of Fourier Transform Spectroscopy, instrumentation, advantages of FTIR and applications. Non-dispersive IR for detection of environmental gases. [5L]

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. Extraction equilibria of metal chelates. Factors favoring solvent extraction of metal chelates. Sorbents. [7L]

3.2 Chromatography: General classification of chromatographic methods. Concept of plate and rate theories: efficiency, resolution, selectivity and separation capability. Broadening of chromatographic peak and van Deemter equation. Optimization of chromatographic conditions. [8L]

UNIT IV: Column chromatography techniques **[15L]**

4.1 Gas Chromatography: Principle of GLC and GSC; Instrumentation: carrier gas supply, sample introduction systems, [4L]

packed & capillary columns; choice of detectors and comparative account of TCD, FID, ECD & thermionic detector. Temperature programming;

4.2 Applications in various fields. [3L]

4.3 High Performance Liquid Chromatography (HPLC): Types of liquid chromatography, column efficiency in LC; Instrument for LC: mobile phase reservoir and solvent treatment systems, pumping systems, sample introduction systems, columns, Detectors: UV, RI, EC and diode array. Modes of separation: partition, adsorption, ion exchange and size exclusion. [5L]

4.4 Applications in various fields. [3L]

Texts/ References:

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

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

CHEM 105: PHYSICAL CHEMISTRY PRACTICAL-I

Instrumental Experiments:

Conductometryand 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. Potassium trioxalatochromate (III)
2. Bis(enthylenediammine) copper (II) sulphate
3. Hexammine nickel (II) chloride/sulphate
4. Potassium dioxalatocuprate(II) dihydrate
5. Potassium trioxalatoaluminate(III) hydrate

Reference books:

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

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 preaparations 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 the exchange capacity of a cation ion - exchange resin.

SEMESTER-II

Course Code	Title of the Course	No. of Credits	No. of hours per SEMESTE-R	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-ITHERMODYNAMICS-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-IIAPPLIED ASPECTS OF QUANTUM CHEMISTRY [15L]

Application of Quantum Chemistry in Vibrational motion:

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

Application of Quantum Chemistry in Rotational motion:

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

Application of Quantum Chemistry in Atomic system:

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

Unit-IIIAPPLICATIONS 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, applications of thermodynamics to ultra-purity and controlled purity (Zone Refining and zone levelling).

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-IVMOLECULAR REACTION DYNAMICS [15L]

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

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

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

****Derivation not expected***

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

Reference books:

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

19. J.O'm. Bockris and A. K. N. Reddy, *Modern Electrochemistry*-Vol. 1 and 2, Plenum press, New York.

20. R. A. Robinson and R.H. Stokes, *Electrolyte Solutions*, 2nd Edition, Butterworths, London 1959.

21. R. P. Rastogi, R. R. Mishra, *An Introduction to Chemical Thermodynamics*, Vikas Publishing House Pvt. Ltd.

22. K. J. Laidler, *Chemical Kinetics*, 3rd ed., Pearson Education.

List of Books for further reading:

1. W. G. Davis, *Introduction to Chemical Thermodynamics – A Non-Calculus Approach*, Saunders, Philadelphia, 1972.

2. I. M. Klotz and R. M. Rosenberg, *Chemical Thermodynamics*, 5th ed., John Wiley and Sons, Inc., 1994.

3. Peter A. Rock, *Chemical Thermodynamics*, University Science Books, Oxford University Press, 1983.

CHEM-202: INORGANIC CHEMISTRY-II

Unit-I SOLID STATE CHEMISTRY AND NANOMATERIALS [15L]

(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_2 [fluorite (CaF_2), antifluorite (Na_2O), rutile (TiO_2) and layer structures viz., cadmium chloride ($CdCl_2$) and cadmium iodide, (CdI_2)].

(iii) Principles, merits and demerits with suitable examples of: ceramic method, precursor method, sol-gel method, microwave synthesis for the preparation of inorganic solids.

(B) Nanomaterials

(i) Introduction to nanomaterials.

(ii) **Preparative methods:** Chemical methods, Biological methods; Role of capping agents.

(iii) Applications of nanomaterials in electronics and biomedical field.

Unit-II MOLECULAR SYMMETRY AND GROUP THEORY [15L]

(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.

(vi) Symmetry criteria for optical activity, Symmetry restrictions on dipole moment.

Unit-III ENVIRONMENTAL CHEMISTRY **[15L]**

(i) **Chemical Toxicology:**

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) **Solar energy:**

Use of solar energy in space heating and water heating; Production of electricity using solar trough collectors, Power tower and solar pond; solar energy for driving vehicles.

(iv) **Power from other sources:**

Hydro power, Wind power, Geothermal energy, Ocean thermal energy conversion (OTEC), Tidal power.

Unit-IV **BIOINORGANIC CHEMISTRY** **[15L]]**

(i) **Biological oxygen carriers:**

Myoglobin, hemoglobin, hemerythrene and hemocyanine. Biochemical effect of cyanide, Hill equation, Bohr effect and their implications.

(ii) Reactions of dioxygen in biological system with examples of peroxidase, monooxygenase, superoxide dismutase and oxidase reactions.

(iii) **Nitrogen fixation:** Nitrogenase, Hydrogenases.

(iv) **Metal ion transport and storage:** Ionophores, transferrin and Ferritin.

(v) **Metal ions in medicines:** cis-platin and related compounds.

Reference books:

Unit-I

1. A. R. West, Solid State Chemistry and Its Applications, John Wiley & Sons, 1987.
2. L. V. Azaroff, Introduction to solids, Tata McGraw Hill Book Co, 1977.
3. H. V. Keer, Principles of Solid State, Wiley Eastern Ltd., 1993.
4. C. N. R. Rao and G. Gopalkrishnan, New Directions in solid state chemistry, 2nd Ed., Cambridge University Press, 1997.
5. Lesley E. Smart and Elaine A. Moore, Solid State Chemistry – An introduction, 3rd Ed., Taylor and Francis, 2005.
6. B. R. Puri, L. R. Sharma and K. C. Kalia, Principles of Inorganic Chemistry, Milestone, 2014.
7. S. K. Kulkarni, Nanotechnology-Principles and Practices, Capital Publishing Co., 2007.
8. G. Cao, Nanostructures and Nanomaterials- Synthesis, Properties and Applications, Imperial college Press, 2004.
9. 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, 2nd Ed., New Age International Publishers2009.
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, 2nd Ed., Wiley Eastern Ltd., 1989.
5. G. Raj, A. Bhagi and V. Jain, Group Theory and Symmetry in Chemistry, 3rd Ed., Krishna Prakashan, 2010.
6. P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, Inorganic Chemistry, 5th Ed., Oxford University Press, 2010.

7. R. S. Drago, Physical Methods in Inorganic Chemistry, Affiliated East-West Press Pvt. Ltd., 2014.

Unit-III

1. A. K. De, Environmental Chemistry, 7th Ed., New Age International Publishers, 2007.
2. G. S. Sodhi, Fundamental Concepts of Environmental Chemistry, 3rd Ed., Narosa Publishing House, 2013.
3. S. S. Dara and D. D. Mishra, A Textbook of Enviromental Chemistry and Pollution Control, S. Chand & Company Ltd., 2012.
4. D. Banerjea, Coordination Chemistry, Tata Mc Graw Hill, 1993.
5. S. K. Banerji, Environmental Chemistry, 2nd Ed., Prentice-Hall of India, 2005.
6. R. A. Bailey, H. M. Clark, J. P. Ferris, S. Krause and R. L. Strong, Chemistry of Environment, 2nd Ed., Academic Press, 2005.
7. J. E. Girard, Principles of Environmental Chemistry, 2nd Ed., Jones and Bartlett publishers, 2011.
8. H. Kaur, Environmental Chemistry, Pragati Prakashan, 8th Ed., 2014.

Unit-IV

1. I. Bertini, H.B.Gray, S. J. Lippard and J.S. Valentine, Bioinorganic Chemistry, 1st Indian Ed., Viva Books, 1998.
2. D. Banerjea, Coordination Chemistry, Tata Mc Graw Hill, 1993.
3. R. W. Hay, Bioinorganic Chemistry, Ellis Harwood, 1984.
4. J. A. Cowan, Inorganic Biochemistry-An introduction, VCH Publication, 1993.
5. S. J. Lippard and J. M. Berg, Principles of Bioinorganic Chemistry, University Science Publications, Mill Valley, Caligronic, 1994.
6. G. N. Mukherjee and A. Das, Elements of Bioinorganic Chemistry, Dhuri& Sons, 1988.

CHEM 203: ORGANIC CHEMISTRY-II

Unit-IPHYSICAL ORGANIC CHEMISTRY AND AROMATICITY [15L]

1.1 Transition state theory, Arrhenius equation and its application to estimate E_{act}, Hammond's postulate, Principle of microscopic reversibility, Kinetics v\s Thermodynamic control.

1.2 Influence of solvent polarity, solvent scales (Y-scale), solvatochromism, (Z and ET Scales), ionic strengths and salt effect, Acid-base catalysis, Bronsted catalysis equation.

1.3 Structural, thermochemical and magnetic criteria for aromaticity, including NMR characteristics of aromatic systems, DRE and REPE, London Diamagnetism, Diamagnetic exaltation and concept of closed configuration.

1.4 Application of HMO theory to monocyclic conjugated systems, Frost-Muslin diagrams, Huckel's (4n+2) π electron rule, Exceptions to (4n+2) π electron rule and 4n rules.

1.5 Aromatic, Antiaromatic and Homoaromatic compounds upto 18 carbon atoms. Aromaticity of benzenoid systems, heterocycles, metallocenes, azulenes, annulenesconjugated molecules with exocyclic double bonds and tropylium cations.

Unit-IIELIMINATION AND NUCLEOPHILIC SUBSTITUTION REACTIONS

[15 L]

2.1 Types of elimination reactions, $E_1$and E_2mechanisms.

2.2 Orientation of elimination reactions: Saytzeff and Hoffmann rules. E_2reactions of vinyl halide, E_1cB mechanism.

2.3 Pyrrolytic elimination: Chugaev reaction, Cope reaction, Hoffmann's and Pyrrolysis of acetates.

2.4 Aliphatic nucleophilic substitution at sp^3 carbon: S_N^1, S_N^2, S_N^i, S_NcA 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,Benzynemechanism, ipso, cine and tele substitutions, vicarious substitution.

Unit-IIIOXIDATION-REDUCTION [15 L]

3.1Preparation of reagents (wherever applicable), mechanism and applications of the following:

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

3.2 Dehydrogenation with DDQ and TCQ, and Ozonolysis

3.3Preparation of reagents (wherever applicable), mechanism and applications of the following:

Wolf-Kishner reduction, Clemmensen reduction, Meerwein-Pondorff-Verley reduction, Birch reduction, Reductions with $NaBH_4$, $LiAlH_4$and DIBAL.

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

Unit-IVREACTIONS AND REARRANGEMENTS [15 L]

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)

Reference 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, page no. 713-769, and B, Plenum Press.

3. Stereochemistry: Conformation and mechamism, P.S. Kalsi, New Age International, New Delhi.
4. Stereochemistry of carbon compounds, E.L Eliel, S.H Wilen and L.N Manden, Wiley.
5. Stereochemistry of Organic Compounds- Principles and Applications, D. Nasipuri. New International Publishers Ltd.
6. March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure, Michael B. Smith, Jerry March, Wiley.
7. Advanced Organic Chemistry: Reactions and mechanism, B. Miller and R. Prasad, Pearson Education.
8. Advanced Organic Chemistry: Reaction mechanisms, R. Bruckner, Academic Press.
9. Understanding Organic Reaction Mechanisms, Adams Jacobs, Cambridge University Press.
10. Writing Reaction Mechanism in organic chemistry, A. Miller, P.H. Solomons, Academic Press.
11. Principles of Organic Synthesis, R.O.C. Norman and J.M Coxon, Nelson Thornes.
12. Advanced Organic Chemistry: Reactions and mechanism, L.G. Wade, Jr., Maya Shankar Singh, Pearson Education.
13. Mechanism in Organic Chemistry, Peter sykes, 6th edition onwards.
14. Physical Organic Chemistry, Neil Isaacs
15. Modern Physical Organic Chemistry, Eric V. Anslyn and Dennis A. Dougherty
16. Comprehensive Organic chemistry, Barton and Ollis, Vol 1, Page No. 215-240.

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]

2.1 **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]**

2.2 **Mass spectrometry**:

Recapitulation, instrumentation; ion sources for molecular studies; electron impact, chemical ionization field ionization, field desorption, fast atom bombardment and 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.[**8L]**

3.2 Introduction to surface analytical techniques.**[3L]**

3.3 **Electron Spectroscopy for Chemical Analysis:** Principle, Instrumentation and applications.[**4L]**

Unit-IV: AUTOMATION IN CHEMICAL ANALYSIS AND ELECTROPHORESIS [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 Electrophoretic methods [**7L]**

Reference books:

1. D. A. Skoog, F. J. Holler, and T. A. Nieman, *Principles of Instrumental Analysis*, 5th ed., Philadelphia: Saunders College Publishing, 1998.
2. D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch, *Fundamentals of Analytical Chemistry*, 8th ed., Philadelphia: Saunders College Publishing, 2004.
3. G. D. Christian, *Analytical Chemistry,* 6th ed., John Wiley and Sons, New York, 2003.
4. G. H. Jeffery, J. Bassett, J. Mendham and R. C. Denney, *Vogel's Textbook of Quantitative Chemical Analysis*, 6th ed., ELBS, Longman Scientific & Technical, England, 2002.
5. H. H. Willard, L. L. Merrit, jr., J. A. Dean and F. A. Settle, Jr., *Instrumental Methods of Analysis*, 6th ed., CBS 1986.
6. R. D. Braun, *Introduction to Instrumental Analysis*, McGraw Hill, 1987.
7. G. H. Morrison and H. Freiser, *Solvent Extraction in Analytical Chemistry*, John Wiley & Sons, New York, 1966.
8. S. M. Khopkar, *Basic concept of Analytical Chemistry*, 3rd ed., Age International Publisher 2008.
9. T. Sekine and Y. Hasegawa, *Solvent Extraction chemistry*, Marcel Dekker, 1977.
10. P. G. Swell and B. Clarke, *Chromatographic Separations, Analytical Chemistry by open learning*, John Wiley & Sons, New York, 1987.
11. S. Sindsay, *High Performance Liquid Chromatography, Analytical Chemistry by open learning*, John Wiley & Sons, New York, 1987.
12. A. J. Bard and L. R. Faulkner, *Electrochemical Methods*, Wiley, New York, 1980
13. A. M. Bond, *Modern Polarographic Methods in Analytical Chemistry*, Marcel Dekker, New York, 1980.
14. L. C. Thomas and G. J. Chamberline, *Colorimetric Analytical Methods*, 9th ed., The Fintometer Ltd., Salisbury, England, 1980.
15. T. C. Morrili, R. m. Silverstein and G. C. Bassler, *Spectrometric Identification of Organic Compounds*, Wiley, 1981.

16. Vogel's Text Book of Quantitative Organic Analysis, 2th ed. ELBS.
17. R. A. Day, Jr. and A. L. Underwood, *Quantitative Analysis,* 6th ed., Prentice Hall of India Pvt. Ltd., New Delhi, 1993.
18. Jared L. Anderson, Alain Berthod, Veronica Pino, and Apryll M. Stalcup (ed),*Analytical Separation Science (Volume 1-5)*. WILEY-VCH 2015.
19. Jack Cazes (ed) *Ewing's Analytical Instrumentation Handbook,* 3rd edition, Marcel Dekker 2009.
20. R. Kellner, J.M. Mermet, M. Oto, M. Valcarcel, H. M. Widmer (ed), *Analytical Chemistry: A modern Approach to Analytical Science 2nd edition.* WILEY-VCH 2004.

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 $KI + I_2 \quad KI_3$ by distribution method.
7. Investigation of the reaction between acetone and iodine.

CHEM-206: INORGANIC CHEMISTRY PRACTICAL-II

Analysis of Complex Materials:

1. Devarda's Alloy: Cu by EDTA method, Al by Gravimetry using oxine
2. Cu-Ni Alloy: Cu by iodometric method; Ni gravimetrically by DMG method.
3. Solder Alloy: Sn gravimetrically by oxide method; Pb by EDTA method.
4. Lime Stone Ore: Loss on ignition; Ca by EDTA method.
5. Haematite Ore: Acid insoluble residue; Fe by redox titration.

Reference books:

1. A. I. Vogel, Vogel's Text Book of Quantitative Inorganic Analysis, 6th Ed., Pearson Education, 2000.
2. J. D. Woolins, Inorganic Experiments, Wiley-VCH Verlag GmbH and Co., 2003.
3. W. G. Palmer, Experiments in Inorganic Chemistry, Cambridge University Press, 1954.
4. G. Raj, Advanced Practical Inorganic Chemistry,
5. 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 NostrnadReinhond, 1972.
7. G. Pass and H. Sutcliffe, Practical Inorganic Chemistry, 2nd 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

Course Code	Title of Course	No. of Credits	No. of Hours	Examination		Total Marks
				Continuous Evaluation	End SEM	
IPCHEM 351	Basics of Polymer, Rubber & Additives	04	60	40	60	100
IPCHEM 352	Rheology & Processing Rubbers	04	60	40	60	100
IPCHEM 353	Testing of Rubber, allied materials & composites	04	60	40	60	100
IPCHEM 354	Industrial Polymer Chemistry Practical-I	04	-	-	100	100
IPCHEM 355	Industrial Polymer Chemistry Practical-II	04	-	-	100	100
IPCHEM 356 EC-I	Biopolymers and Bio composites	04	60	40	60	100
IPCHEM 357 EC-II	Polymer Nano Composites	04	60	40	60	100

No. of CREDITS: 24 **TOTAL MARKS: 600**

Note: Students will have to select one of the electives i.e. IPCHEM 356 EC-I or IPCHEM 357 EC-II

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

SYLLABUS: SEMESTER III

IPCHEM 351: BASICS OF POLYMERS, RUBBER AND ADDITIVES

Unit IPOLYMERS & POLYMERIZATION TECHNIQUES [15L]

Polymers: monomer, oligomer and polymer, Average Molecular Weight, Molecular weight, Distribution & Poly dispersity Index, classification of polymers, structure of polymer. Types of polymerization.

Polymerization Techniques: Mass Polymerization, Bulk Polymerization, Solution Polymerization, Emulsion Polymerization, Suspension Polymerization, Mechanisms with explanation. Characteristics, Relative advantages and disadvantages.

Classification of Polymers: Natural and synthetic polymers, Biopolymers, thermoplastic, thermosets, Elastomers, Fibers etc.

Structure Property Relationship in Polymers:Structure of polymers, amorphous, semi-crystalline and crystalline states in polymers, glass transition, melting and crystallization temperature. Effect of structure on the chemical, mechanical, electrical and optical properties of polymers.

Unit IIGENERAL PURPOSE RUBBER [15L]

Natural Rubber (NR): Origin–Natural Rubber Latex, tapping, processing, properties andapplications – Conversion of Latex into dry rubber – Properties of dry rubber – Classification based on technical specifications – Modifications of Natural Rubber

Styrene-Butadiene Rubber (SBR): Introduction, polymerization, types of SBR, structure &property variation in Emulsion SBRs and Solution SBRs. Compounding, Processing, Applications.

Polybutadiene Rubber (PBR): Manufacture, Structure and Properties of Polybutadienes,Processing and Applications.

Synthetic Polyisoprene (IR) Rubbers: Preparation of Synthetic Polyisoprene (IR) Rubbers, Properties, IISRP Numbering System, Processing, Applications.

Unit IIISPECIAL PURPOSE RUBBER [15L]

Preparation, properties and Application of: Nitrile Rubber & modified NBR (HNBR &XNBR), Butyl Rubber & Halogenated butyl rubbers, Polychloroprene Rubbers, Ethylene Propylene Rubber and Ethylene Vinyl acetate copolymers – Elastomers based on modified polyethylene (chlorinated polyethylene &chlorosulphonated polyethylene), Acrylate rubbers, Polysulphide rubbers, Hydrin rubbers, Silicones and Fluroelastomers etc.

Rubber blends: miscible and immiscible blends,

Thermoplastic Elastomers – **Preparation, properties and Application of**: SBS and SIS Blockcopolymers, Thermoplastic Polyurethane elastomers, Thermoplastic-co-polyesters, Thermoplastic elastomers based on Plastics, Dynamic Vulcanization

Unit IVNON-RUBBER ADDITIVES **[15L]**

Part A: Vulcanizing ingredients & other additives: Vulcanizing ingredients & their sequence of mixing: Activators and Accelerators: mechanisms of action. Other cure systems based on metal oxides, peroxides, etc. retarders, inhibitors anti-reversion agents.

Part B: Fillers

Carbon black-Its preparation, structure, properties and their effect on rubber properties

Silica fillers & coupling agents, Other fillers: Clay, Calcium carbonate, titania etc. Nano-fillers:

Reinforcement by filler: Reinforcement, Factors influencing elastomers reinforcement, fillers characteristics, main effects of fillers on vulcanizate properties, Influence of fillers characteristics on the cross linking process, Filler incorporation, the role of bound rubber, reinforcement and crosslink density.

Part C: Processing aids & other additives: Processing aids, plasticizers, process additives, release agents, Other additives like colourants, blowing agents, factice, Fire Retardants, Antistatic Agents, Deodorants and Reodorants, Biocides and Fungicides etc. **Antidegradants:** Introduction, Autoxidation of Hydrocarbon Polymers, Amine & Phenolic Antioxidants & other types, Antizonants, Prevention of Ozone Attack with the use of waxes & saturated polymer for Ozone Protection.

References:

1. F. W. BillmeyerJr., Text Book of Polymer Science, Ed. Wiley-Interscience, 1984.
2. V. T. Gowariker, N. V. Viswanathan, and J. Sreedar, Polymer Science, 1988.
3. M. Morton, Rubber Technology, Chapman Hall, 1995.
4. J. Brydson, Rubber Chemistry, Butterworths, 1978
5. B. Kothandaraman, Rubber Materials, Ane Books, 2008.
6. I. Franta, Elastomers and Rubber Compounding materials, Elsevier, 1989.
7. B. Kothandaraman, Rubber Materials, Ane Books, 2008.

IPCHEM 352: RHEOLOGY AND PROCESSING OF RUBBERS

Unit IRHEOLOGY OF RUBBERS **[12L]**

Definition of Rheology, Rheological Perspective, The importance of nonlinearity, Solids and liquids,Components of rheological research: Rheometer, Constitutive equations, Complex flows of elastic liquids.

Unit IICOMPOUNDING & MIXING TECHNIQUES [12L]

Rubber mixing mechanism, mixing machinery - Open mill mixing – Internal mixers – Continuous mixers – Factors affecting mixing – Flow behaviour of rubber compound, processibility test, Latex compounding and mixing. Troubleshooting.

Unit IIIPOSTCOMPOUNDING PROCESSING [12L]

Calendaring: Sheeting –Skim coating – Fractioning – Topping – Doubling – Profiling – Spreading – Roll configurations – Control of thickness. Extrusion; Ram type – Screw type – L/Dratio and its influence – Hot & cold feed extruders – Pin barrel extruder – Twin screw extruder – Criteria for machine selection. Troubleshooting.

Unit IVMOLDING & VULCANIZING TECHNIQUES [12L]

Molding: Mold design, Compression, transfer and injection moulding – Blanks & pre-heating techniques, preparation of surfaces for bonding. Curing: Autoclaves, Hot air chambers, curing of built up articles, continuous vulcanization, L.C.M. (Liquid Curing Media), Fluidized Bed, microwave curing. Hand building and forming equipment for tank, pipe lining, roller covering. Troubleshooting.

Unit IVFINISHING OF RUBBER PRODUCTS [12L]

Equipment‘s for flash and spew removal – Cryogenic techniques – Hand trimming – roller trim, buffing, tumbling, punching, grinding, shot blasting, painting, lacquering – Guards, Trip devices, Photoelectric and pressure sensitive devices – Maintenance of guards.

References:

1. Dr. B.R.Gupta, Rheology of Elastomers.
2. H.A.Barnes, J. F. Hutton and K. Walters, An Introduction to Rheology,Elsevier, 1989.
3. Rubber Processing, James L. White, Hanser Publishers, 1995.
4. C. M. Blow and C. Hepburn, Rubber Technology and manufacture, Butterworths, 1982.
5. C. W. Evans, Practical Rubber Compounding and processing, Applied Science, Publishers, London, 1981.
6. J. L. White, Rubber Processing Technology Materials, Principles, Hanser Publication, New York, 1995.
7. Kleemann, Weber, Elastomer Procesing, Hansar, 2005.

IPCHEM 353: TESTING OF RUBBER ALLIED MATERIALS & COMPOSITES

Unit IPRINCIPLES OF TESTING &RAW MATERIAL TESTING [15L]

Principles of Testing, Standards and specification, Nomenclature- ISO and other standards, Laboratory Management System as per ISO/IEC 17025:2005 and Quality Management System as per ISO : 9001:2015.

Molecular weight distribution using GPC, Analysis of antioxidant, process oil and other additives by using GC GCMS, UV-Vis spectrophotometer, ICP-OES and DSC. Polymer identification by FTIR, Ash Content, Melting point, Moisture content and Specific gravity

Unit IITESTING OF RAW RUBBER & UN-VULCANIZED RUBBER COMPOUND [15L]

Viscosity Characterization – Brookfield Viscosity, Mooney viscosity,

Mass, Density, Dimensions Compression plastimeter, plasticity retention index, rotation plastimeters, extrusion rheomter, Scorch and cure rate: oscillating disk rheometer, moving die rheomter, rubber process analyzer etc.

Unit IIITESTING OF VULCANIZATE [15L]

MechanicalProperties –Different types of Hardness,(Shore A, Shore D, IRHD and micro hardness) tear, tensile, compression, application of test data, abrasion resistance, Shear, Creep & Stress relaxation, Resilience, Aging and uniaxial, biaxial compression test.

Thermal Analysis: Instrumentation, Polymer Identification, Compositional analysis, volatile matter, Rubber, Polymer blends, C-black & ash estimation using Thermal Analysis (TGA). Glass transition, Heat capacity, Thermal history of polymers, State of cure studies by using DSC and Thermal Mechanical Analysis (TMA)

Unit IVPROCESS & QUALITY CONTROL [15L]

Effect of environment – Oxygen, heat, ozone and swelling media

Fatigue – Flex cracking and cut growth – Heat buildup **Dynamic mechanical testing of rubbers**—Storage modulus, loss modulus, Tan delta, Natural frequency, transmittance and damping factor.

Testing of rubber products like hoses, gaskets, automotive tubes, bearings, Testing of conveyor belts, V-belts and Mounts.

References:

1. Standard - ISO / IEC 17025:2005
2. Standard – ISO 9001:2015

3. C. D. Craver and T.Provder, Polymer Characterization, ACS Advances in chemistry Series, Volume 227, 1990

4. J. S. Dick, Rubber Technology Compounding and testing for Performance, Hanser Publisher, 2001.

IPCHEM 354: INDUSTRIAL POLYMER CHEMISTRY PRACTICAL-I

1. Preparation of Phenol formaldehyde resin – novolak and resol / polysufide rubber
2. Determination of: acid value / hydroxyl value of given polymer sample
3. Determination of saponification value of given oil
4. Estimation of total alkalinity of the latex
5. Viscosity measurement by Brookfield viscometer
6. Molecular weight determination of polymer by GPC
7. Determination of volatile matter, dirt, ash content in Rubber from Natural sources
8. Estimation of Cu, Fe and Mn in rubber by ICP
9. Rubber identification pyrolysis and spot test by specific reagents (ASTM solution)
10. TGA of different rubber
11. DSC analysis of Rubber Compounds
12. Mixing behaviour of NR on two roll mill / carbon black filled NR / carbon black filled SBR / carbon black filled SBR & NR blend / carbon black filled EPDM / carbon black filled NBR
13. Extrusion characteristics of a filled rubber mix- NR Ex / SBR / NBR / EPDM
14. Calendaring of rubber mix

IPCHEM 355: INDUSTRIAL POLYMER CHEMISTRY PRACTICAL-II

1. Identification and classification of natural rubber by using FTIR, Mooney, and other chemical methods.
2. Identification and classification of synthetic rubbers by using burning test, FTIR, Mooney, and other chemical methods.
3. Identification and classification of different type of carbon black
    a. DBP absorption
    b. IAN
    c. Surface area Calculation
4. Identification and classification of rubber compounding materials, namely,**Zinc oxide / Stearic acid** / **Sulfur** / **Antioxidants** / **Accelerators** / **Processing oils**

5. Evaluation of tyre tread compound by using abrasion resistance index, heat build-up and

   DMA.
6. Evaluation of properties of seal & gasket rubber compound
7. Tyre testing by Endurance, rolling resistance, plunger energy, bead unseat etc.
8. Testing of: LPG Hose, Pressure cooker rubber gasket / Hose testing / Mount / Conveyor

   Belt / Condom / Tube
9. Design & development of : Tyre tread material / Hose cover / Conveyor belt cover / Gasket compound / footwear compound / latex dipped products / mounts / rubber mats / door profiles / tube compound
10. Curing Process of Rubber Compound- NR filled / SBR filled / NBR filled / EPDM filled / BR filled
11. Curing Process of Rubber Compound- by transfer molding technique
12. Curing Process of Rubber Compound- by injection molding technique of metal to rubber bonded products
13. Curing Process of Rubber mounts / Rubber Gaskets / Rubber Seals / Rubber Gauntlets

ELECTIVE COURSES

IPCHEM 356: EC-I: BIOPOLYMERS & BIO COMPOSITES

Unit IBIOPOLYMERS & BIODEGRADATION [15L]

Biopolymers: Classification, Biopolymers from natural origin and mineral origin, isolation, properties.

Biodegradation: Mechanism of biodegradation (polyesters, polycarbonates, polyvinyl alcohol,polyurethanes and polyether‘s) factors influencing biodegradation. Types of biodegradable polymers – properties and application.

Unit IICHARACTERIZATION & TESTING FOR BIODEGRADABILITY [15L]

Test methods and standards for bio-degradable plastics, Criteria used in evaluation of biodegradable plastics, Description of current test methods – Scanning test for ready biodegradability, Test for inherent biodegradability, Test for simulation studies, Other methods for assessing polymer biodegradability.

Unit IIIBIOCOMPOSITES [15L]

Definition- classification- natural bio, fibre and nano fillers as reinforcement, biodegradable/ bio-based resins as matrices. Properties of biocomposites. Applications in automobile & buildings.

Unit IVAPPLICATIONS OF BIOPLOYMERS [15L]

Biopolymer Films, Biodegradable mulching, Advantages and Disadvantages, Chemical sensors – Biosensors, Functionalized Biopolymer Coatings and Films, Applications of biopolymers in horticulture Food Packaging, Functional Properties, safety and

Environmental aspects, Shelf life, Films and coatings in Food Applications, Materials for edible films and coatings, Biopolymer coatings for paper and paperboard, Bio-nanocomposite films and coatings

References:

1) R. Smith, Biodegradable polymers for industrial applications, Woodhead Publishing Ltd, CRC Press, 2005.

2) A. J. Domb, J. Kost and D. M. Wiseman, Handbook of Biodegradable polymers, Harwood Academic Publishers, 1997.

3) R. P.Wool, X. S. Sun, Bio-Based Polymers and Composites, Elsevier, 2005.

4)A.S. Singha and V. K. Thakur,Green Polymer Materials, Studium Press, 2012.

5) A. K.Mohanty, M.Misra and L. T. Drzal,Natural Fibers, Bio Polymers and Bio Composites, CRC Press, 2005.

IPCHEM 357: EC-II: POLYMER NANO COMPOSITES

Unit ICOMPOSITES [15L]

Characteristics, advantages, and need of composites –Polymer composite materials, classification and theory of composite materials; Polymer matrices - thermoplastics and thermosetting plastics; Fiber reinforcement of elastomers - short and long fiber composites – Other additives

Unit IINANOMATERIALS USED IN POLYMERS [15L]

Nanofillers in bulk polymers - overview of potential nanostructured fillers - types - nanoparticles, nanofibers, nanotubes, nanosheets; surface features and layers and its modification. Techniques used to characterize nanostructured materials –XRD, AFM, etc.

Unit IIICARBON NANOTUBES & THEIR APPLICATIONS [15L]

Structure of carbon nanotubes, processing methods for nanotube based polymer nanocomposites, nanotube alignment, characterization, properties and applications,

Unit VIPREPARATION & APPLICATION OF POLYMER NANO COMPOSITES[15L]

Preparations of polymer nanocomposites - melt blending, solution blending, latex coagulation, in-situ polymerization, characterization, properties and application.

Polymers in nanoelectronics, Magnetic polymer nanocomposites, Wear resisting polymer nanocomposites, Packaging, Bio-medical, surface coatings, etc.

References:

1) Yiu-Wing Mai and Zhong-Zhen Yu, Polymer Nanocomposites‖, Woodhead Publishing Limited, 2006.
2) K. Friedrich, S.Fakirov and Zhong Zhang, Polymer Composites from Nano to Macro‖, Springer 2005.
3) C.N.R.Rao, A.Muller, and A.K.Cheetham, The chemistry of Nanomaterials‖, Vol 1 & Vol.2, Wiley-VCH, 2005.
4) J. H. Kao, Polymer Nanocompsoites, McGraw-Hill Publishers, 2006.

SEMESTER-IV

Course Code	Title of the Course	No. of Credits	No. of Hours	Examination		Total Marks
				Continuous Evaluation	End SEM	
IPCHEM 451	Design & Development of Rubber Products	04	60	40	60	100
IPCHEM 452	Latex Science & Adhesives	04	60	40	60	100
IPCHEM 453	Tyre Science and Technology	04	60	40	60	100
IPCHEM 454	Research Project	08	*	80	120	200
IPCHEM 455 OC-I	Intellectual Property Rights & Cheminformatics	04	60	40	60	100
IPCHEM 456 OC-II	Research Methodology	04	60	40	60	100

No. of CREDITS: 24 TOTAL MARKS: 600

Students will have to select one of the optional courses i.e.IPCHEM 455 OC-I or IPCHEM 456 OC-II.

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

SYLLABUS: SEMESTER-IV:

IPCHEM 451: DESIGN & DEVELOPMENT OF RUBBER PRODUCTS

Unit IFORMULATION DESIGN OF RUBBER COMPOUNDS [15L]

Basics of compounding, Approach for compounding, Selection of Rubbers, Fillers, Curing agents and Special additives in Rubber Compounding. Rubber compounds feasibility for static and dynamic application, Rubber compounds for general purpose, oil resistant, heat resistant, fire resistant and weather resistance purposes.

Unit IIDESIGN & DEVELOPMENT OF TYRES [15L]

Different components of tyres and their compounding, Tyre materials &Tyreprocessingtechniques**.**

Unit IIICONVEYOR BELT TECHNOLOGY [15L]

Different types of conveyor belts, Mixing, Compounding and Calendaring, Building,Curing and Testing, Finishing and Packaging**. V-belt—Building**

Unit IVPRODUCT DEVELOPMENT OF HOSES [15L]

Different kind of hoses, Extrusion of cover, Reinforcement, curing by autoclave.

References:

1. Setright J.K., Automobile Tyres, Champan& Hall, 1972.
2. The Pneumatic Tire, (Ed) A N Gent & J D Walter, The University of Akron, August. 2005, published by NHTSA, DOT, USA
3. Elastomers: Criteria for Engineering Design, C Hepburn & R J W Reynolds, Applied Science Publishers, London, 1979.
4. KhairiNagdi, Rubber as an Engineering Material: Guideline for Uses, Hanser Publishers, 1993.

IPCHEM 452: LATEX SCIENCE AND ADHESIVES

Unit ILATEX SCIENCE [15L]

Definition of Latex, classification, Latex particle size and distribution, stabilityand destabilization of latices, Comparison between latices and polymer solution. Characteristic and processing of natural rubber latex.

Unit IILATEX APPLICATION [15L]

Latex dipped products, latex foam rubber, latex thread, latex and textile based rubber products, latex based surface coating, latex and paper.

Unit IIIRUBBER BASED ADHESIVES [15L]

Natural rubber adhesive, butyl rubber and polyisobutylene, nitrile rubber adhesive, styrene butadiene rubber adhesive, thermoplastic rubber in adhesive, carboxylic polymers in adhesive, neoprene based solvent and latex adhesive, polysulfide sealant and adhesives

Unit IVRESIN BASED REACTIVE ADHESIVES [15L]

Phenolics, epoxies, acrylics, anaerobics, cyanoacrylates – Uses of adhesives in civil engineering, automobile, aerospace, electrical & electronic industries.

References:

1. D. C. Blackley, High Polymer Latices, Vol 1 and 2, Maclaren & Sons, 1966.
2. R. F. Mausser, The Vanderbilt Latex Hand book, 3rd Edn.
3. R. Waterman, R. F. Mausser& E. E. Miller, Vanderbilt Latex Book on Process and Compounding Ingredients, R T Vanderbilt Publishers.
4. K. O. Calvert, Polymer Latex and Applications,1985.
5. I. Skiest (Ed), Hand book of Adhesives, Van Nostrand Reinhold, 1990.
6. Shields, Hand Book of Adhesives, Butterworths, 1984.

IPCHEM 453: TYRE SCIENCE AND TECHNOLOGY

Unit ITYRE STRUCTURE [15L]

A historical introduction on the design and development of tyres of various kinds and type the current status of tyre industry in India and its future prospects, tyre sizing and marking on the tyres, different types of tyres bias-belted tyre, tube and tubeless tyre, their basic functions and performance comparisons. Different components of a tyre, its geometry, basic functions. Functions of a pneumatic tyre-load carrying, vibration and noise reduction, tyre function as a spring, contribution to driving control and road adhesion, the tyre friction contribution to driving control, steering control and self aliging torque.

Unit II TYRE CARCASS AND BUILDING [15L]

Manufacturing techniques of various tyres like two wheeler and car tyres, truck tyres, OTR, farm tyres, aircraft tyres. Principles of designing formulations for various rubber components. Tyre reinforcement materials (Textile, steel, glass etc.). Criteria of selection, different styles and construction, textile treatment. Tyremould design, green tyre design principles, methods of building green tyres for bias, bias belted, radial and tubeless tyres, green tyre treatments. Tyre curing methods, post cure inflation, quality control tests. Tyre related products, their design and manufacturing techniques, tubes, valvesflaps, bladders. Different types, their features and operation of tyre building machines, bead winding machine, wire/glass processing machines, bias cutters, curing presses.

Unit III[15L]

Tyre wear, rubber friction and sliding mechanism, various factors affect- ing friction and sliding. Tyre stresses and deformation, tyre noise, mechanism of noise generation, effect of tread pattern, vehicle speed etc. onTyre wear, rubber friction and sliding mechanism, various factors affect- ing friction and sliding. Tyre stresses and deformation, tyre noise, mechanism of noise generation, effect of tread pattern, vehicle speed etc. on

Unit IVTESTING OF TYRE [15L]

Measurement of tyre properties, dimension and size-static and loaded. Tyre construction analysis, endurance test, wheel and plunger tests, trac- tion, noise measurements. Force and moment characteristics, cornering coefficient, aligning torque coefficient, load sensitivity and load transfer sensitivity. Rolling resistance, non uniformity, dimensional variations, force variations, radial force variation, lateral force variation, conicity and plysteer. Type, balance, mileage, evaluations. Tyre flaws and separations. X- ray holography etc. Foot print pressure distribution. BIS standards for tyres, tubes and flaps.

References:

1. TyreScience&Technology (Journal oftheTyreSociety) Akron,Ohio.
2. Tyre Technology 'Tom French', Adam Higher, New York.
3. Tyre Mechanics & Testing (Sponsored Course, Feb. '83) Roorke....
4. Mechanics of Pneumatic Tyres, Samuel C Lark, US Department of Transportation Washington. .
5. (a) Year Book, (b) Engineering Design Informations, The Tyre& Rim Association.
6. Tyre, Valve & Rim data, ITTAC, New York.
7. LJK Setright. "Automobile Tyres". Chapman & Hall, London.
8. Tyre Technology, F.J.Kovac, GOODYEAR Tyre and Rubber Com- pany, USA.

IPCHEM 454: RESEARCH PROJECT

Each student will be assigned a project involving some design and fabrication work, as well as

Theoretical and Experimental studies on some problem related to Rubber and Plastics

Technology. Continuous internal assessment marks for the project will be given during Project

Review meeting. The student has to prepare and present a detailed project report at the end of the semester and give a presentation about the work done. End semester examination mark will include viva voce examination.

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OPTIONAL COURSES

IPCHEM 455 OC-I: INTELLECTUAL PROPERTY RIGHTS & CHEMOINFORMATICS

Unit-I [15L]

Introduction to Intellectual Property: [2L]

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

Patents: [5L]

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

Industrial Designs: [2L]

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

Layout design of integrated circuits: [2L]

Circuit boards, Integrated Chips Importance for electronic industry.

Copyrights: [2L]

Introduction, How to obtain, Differences from Patents.

Trade Marks: [2L]

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

Unit-II[15L]

Geographical Indications: [2L]

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

Trade Secrets: [2L]

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

IP Infringement issue and enforcement: [5L]

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

Economic Value of Intellectual Property:

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

Different International agreements: [6L]

(a) World Trade Organization (WTO):

(i) General Agreement on Tariffs & Trade (GATT) , Trade

Related Intellectual Property Rights (TRIPS) agreement

(ii) General Agreement on Trade related Services (GATS)

Madrid Protocol

(iii)Berne Convention

(iv)Budapest Treaty

(b) Paris Convention

WIPO and **TRIPS, IPR** and Plant Breders 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 Cheminformatcs*. 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.

IPCHEM 456 OC-II: RESEARCH METHODOLOGY

Unit-ILITERATURE 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 communities, Blogs, preprint servers, Search engines, Scirus, Google Scholar, ChemIndustry, Wiki-Databases, ChemSpider, Science Direct, SciFinder, Scopus.

Information Technology and Library Resources: [5L]

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

Unit-IIDATA ANALYSIS [15L]

The Investigative Approach:

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

Analysis and Presentation of data:

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

Unit-IIIMETHODS 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 SAFTEY & ETHICAL HANDLING OF CHEMICALS [15L]

Safe working procedure and protective environment, protective apparel, emergency procedure, and first aid, laboratory ventilation, safe storage and use of hazardous chemicals, procedure for working with substances that pose hazards, flammable or explosive hazards,

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

Reference books:

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

14. FEES FOR M. Sc. (CHOICE BASED CREDIT SYSTEM) COURSE

Open category

No.	Account Head	Amount (Rs.)
1.	Tuition fee	45000/-
2.	Laboratory fee	10000/-
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/-
	Total	**59, 145/-**

Refundable deposit:

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

***Examination fees per Semester:** Rs. 4000/-

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 onissue 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

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.2/- during the first week from the last date prescribed for payment of the tuition fees and 50 paise per day after one week, subsequently.
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. That they will be required to attend in **each SEMESTER-not less than** 75% of the total number of lectures delivered for each course.

2. That in addition to attendance at lectures and practicals, they 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-.
3. That the work that will be assigned to them in the form of essays, tutorials etc. shall be in addition to the practical work that they are required to do for examination.

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.

14. CAREER OPPORTUNITIES IN CHEMISTRY

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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 opportUnit-ies in other steams. 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, Applied Chemistry Division, BARC in order to provide information on career opportUnit-ies 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 statues of chemistry teaching in various academic institutions issummarised 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. For post doctoral research, opportunities 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) has a number of laboratories spread all over country where chemical and allied research is carried out. Its head quartersis 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 chemistryexist 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, Bhubaneshwar - 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@csnnml.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. <u>Research Fellowships:</u> 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. <u>Post Doctoral Research Fellowships:</u> 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. <u>Opportunities in Industry</u>

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. **Ph.D admissions in the Department of Chemistry will be done as per the guidelines issued time to time by UGC, New Delhi and University of Mumbai, Mumbai.** The Minimum stantadards and procedure for the awards of M.Phil and Ph.D Degree will be as as per the circular Univ./VCD/947 of 2018 dated 15th June 2018 given by University of Mumbai

15. RESERVATION FOR M.Sc in CHEMITSRY

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 2020-21

STATEMENT SHOWING THE NUMBER OF SEATS AVAILABLE FOR STUDENTS OF DIFFERENT CATEGORIES FOR ADMISSION TO M. Sc. DEGREE COURSE IN INDUSTRIAL POLYMER CHEMISTRY FOR THE YEAR 2020-2021

Branch	Total Seats	Number of Seats for Reserved Category Students									Reserved Category	General Category
		SC	ST	DT(A) (VJ)	NT(B)	NT(C)	NT(D)	OBC	SBC	E.W.S. 10%	62%	38%
		13%	7%	3%	2.5%	3.5%	2%	19%	2%			
Industrial Polymer Chemistry	15	2	1@	--	--	1	--	3	--	1 + 1*	9	5 + 1#

1% seats are reserved for Orphan students

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 defense personnel
3. Students obtaining dexterity at National / State level Sports/ Cultural activities
4. Widow / Deserted female students
5. Wards of the Freedom Fighters

16. 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 given.

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. 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. <u>It would be the responsibility of the student tocheck for any errors in the synopsis and point out to the Head of the Department in writing within 3 days of the display of the synopsis.</u> No complaints will be entertained thereafter.

<u>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.</u>

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

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 / Reserved category Students**: Pay prescribed fee of **Rs. 59,145/-**[including Rs. 850/-Registration fee and Rs.25/- for the form of Registration] within the stipulated period and produce the receipt in the office of the Department of Chemistry.

3. 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 addressedto 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 tution fees will be given only if the student takes admission to one of the University of Mumbai's affiliated colleges.

Refund of tution 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.