# UNIVERSITY OF THE PUNJAB

## NOTIFICATION

It is hereby notified that the Syndicate at its meeting held on 09-03-2024 has approved the recommendations of the Academic Council made at its meeting dated 04-12-2023 regarding start of M.Phil in Green and Sustainable Chemistry alongwith Scheme of Studies and Course Outlines under Semester System at the Centre for Research in Ionic Liquids with effect from the Academic session, 2024-2026 and onward.

The Scheme of Studies/ Syllabi and Courses of Reading for M.Phil in Green and Sustainable Chemistry is attached herewith as Annexure 'A'.

Sd/-
**REGISTRAR**

**Admin. Block,**
**Quaid-i-Azam Campus,**
**Lahore.**

**No. D/ 2670 /Acad.** **Dated: 22-04 /2024.**

Copy of the above is forwarded to the following for information and further necessary action: -

1. Dean, Faculty of Sciences.
2. Director, Centre for Research in Ionic Liquids.
3. Controller of Examinations
4. Director, IT for placement at the website
5. Admin Officer (Statutes)
6. Secretary to the Vice-Chancellor.
7. PS to the Registrar.
8. Assistant Syllabus.

Assistant Registrar (Academic)
for Registrar

**Centre for Research in Ionic Liquids**
School of Chemistry
UNIVERSITY OF THE PUNJAB

Scheme of Studies and Course Outlines of

# MPhil in Green and sustainable Chemistry

Centre for Research in Ionic Liquids, School of Chemistry, University of the Punjab, Quaid-e-Azam campus 54590 Lahore, Pakistan.
Contact# +92-042-99230463 Ext. 875; Email: director.cril@pu.edu.pk

**Program Title:** MPhil in Green and Sustainable Chemistry

**Department:** Centre for Research in Ionic Liquids

**Faculty:** Faculty of Science

1. **Centre for Research in Ionic Liquids:**

**Introduction and Mission**

Centre for Research in Ionic Liquids has been established with the goal to connect research, education, and training in the field of Ionic liquids, its associated disciplines and their applications. It aims to work on green initiatives for development of sustainable environmental processes using ionic liquids. The primary focus of the centre is on fundamental studies related to green solvents 'Ionic Liquids' and their wide arena of applications, particularly, the development of integrated future biorefineries for lowering carbon impact on environment, fuel upgradation, effective utilization of natural carbon-rich renewable agricultural waste materials and many more. The designing and synthesis of a range of ionic liquids for the development of a consortium of these potent tailor made solvents to be provided to other research organizations to work on collaborative research projects for the exploration of their application.

Our vision is to become globally recognized Centre of Excellence for Green Chemistry and Green Solvents; Ionic Liquids related R&D.

Our mission is;

- To be a national and international leading Centre in Ionic Liquids and sustainable process developments.
- To be an industrial partner of choice in applied and fundamental research related to synthesis and applications of Ionic Liquids.

2. **Program Introduction**

The MPhil program in Green and Sustainable Chemistry is designed in view of increasing demand of graduates with expertise in green chemistry to lead the transformation of chemical and other industrial processes where chemistry and chemical engineering offer green alternative solutions in order to play a crucial role.

This program will offer its graduates the opportunity to design and implement new products and processes that will highlight the role that chemistry has to play for ensuring sustainable future.

The program will develop a deep understanding of sustainability issues and the principles of green technologies that will lead to the reduction or elimination of hazardous substances involved in the design, manufacture and application of chemical products. The course will also examine the environmental, economic and social benefits arising from the transformation of the chemical industries of the future.

## 3. Program Objectives

Modern society faces the great challenge of ensuring that a steadily growing population is equally supplied with energy, food, medicines, and everyday necessities without continuing to place an excessive burden on the environment. At the same time, the emission of greenhouse gases must be reduced in order to curb climate change. The development of new chemical substances and methods can make a major contribution to solving all these complex problems. To do this, however, it is essential to follow the principles of green chemistry while also taking into account the broader consequences of change in their applications in order to generate innovations in the interests of sustainable development.

## 4. Market Need/Rationale of the Program

The graduates of the MPhil Green and Sustainable Chemistry will find many career opportunities open to them in a range of areas including:

- Process development and pharmaceutical companies
- Food, cosmetics and cleaning product industries
- Agrochemical and polymer industries
- Manufacturing, environmental and sustainable services or companies
- Private and public biotech companies
- Government, consultancy and policy making
- Education

## 5. Admission Eligibility Criteria

- **Years of Study Completed**

Minimum 16 years of education with Chemistry/Chemical Science background.

- **Percentage/CGPA**

CGPA 3.0 (out of 4.0 in the semester system) or first division (in the annual system) in BS/MSc/Equivalent is required.

- **Entry Test with Minimum Requirement (For local Students)**

University (CRIL) test will be required; 40% entry test weightage.

- **Admission Formula**

As per PU admission formula.

## 6. Duration of the Program

4 Semesters (2 years) comprising of 30 (24 theory + 6 research) Credit hours (extendible up to 1 year or 2 semesters).

## 7. Categorization of Courses as Per HEC Recommendation and Difference

| Semester | Courses | Category Courses | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Core Courses** | **Basic Courses** | **Major Electives** | **Minor Electives** | **Any Other** | **Semester Load** |
| 1 | 4 | 9 | 0 | 3 | 0 | 0 | (4×3) = 12 |
| 2 | 4 | 9 | 0 | 3 | 0 | 0 | (4×3) = 12 |
| 3 | 0 | 0 | 0 | 0 | 0 | Research | 6 |
| 4 | 0 | 0 | 0 | 0 | 0 | Research | |
| PU | | | | | | | |
| HEC Guidelines | | | | | | | |
| Difference (HEC & PU) | **0** | **0** | **0** | **0** | **0** | **0** | **0** |

## 8. Scheme of Studies/Semester-Wise Workload

| # | Course Code | Course Title | Course Type | Credit Hours |
|---|---|---|---|---|
| **Semester-I** | | | | |
| 1 | GSC-501 | Principles and Concepts of Green Chemistry | Core | 3 + 0 |
| 2 | GSC-502 | Ionic Liquids as Green Solvents | Core | 3 + 0 |
| 3 | GSC-E | Elective-I | Core | 3 + 0 |
| 4 | GSC-503 | Green Chemistry Techniques | Core | 1 + 2 |
| **Credit Hours** | | | | **12** |
| **Semester-II** | | | | |
| 1 | GSC-504 | Green Chemistry and Sustainable Development Goals | Core | 3 + 0 |
| 2 | GSC-505 | Green Processing of Renewable Resources Using Ionic Liquids | Core | 3 + 0 |
| 3 | GSC-E | Elective-II | Core | 3 + 0 |
| 4 | GSC-506 | Mini Projects in Advanced Green Chemistry | Practical | 0 + 3 |
| **Credit Hours** | | | | **12** |
| **Semester-III &IV** | | | | |
| 1 | GSC-Res | Research and Thesis | | 6 |
| **Total Credit Hours** | | | | **30** |

**8i. List of Core Courses**

| # | Course Code | Course Title | Course Type | Prerequisite | Credit Hours |
|---|---|---|---|---|---|
| 1 | GSC-501 | Principles and Concepts of Green Chemistry | Core | | 3 + 0 |
| 2 | GSC-502 | Ionic Liquids as Green Solvents | Core | GSC-501 | 3 + 0 |
| 4 | GSC-503 | Green Chemistry Techniques | Core | GSC-501 | 1 + 2 |
| 5 | GSC-504 | Chemistry and Sustainable Development Goals | Core | | 3 + 0 |
| 6 | GSC-505 | Green Processing of Renewable Resources Using Ionic Liquids | Core | | 3 + 0 |
| 7 | GSC-506 | Mini Projects in Advanced Green Chemistry | Practical | GSC-501<br>GSC-505<br>GSC-506 | 0 + 3 |

**8ii. List of Elective Courses**

| # | Course Code | Course Title | Course Type | Pre-requisite | Credit Hours |
|---|---|---|---|---|---|
| 1 | GSC-507 | Molecular Design and synthesis of Ionic Liquids | Major Elective | | 3 + 0 |
| 2 | GSC-508 | Strategies for Green Organic Synthesis | Major Elective | | 3 + 0 |
| 3 | GSC-509 | Business Model Design for Innovative Chemical Technologies | Major Elective | | 3 + 0 |
| 4 | GSC-510 | Catalysis in Green Chemistry | Major Elective | | 3 + 0 |
| 5 | GSC-511 | Technological Applications of Ionic Liquids | Major Elective | | 3 + 0 |
| 6 | GSC-512 | Green Chemistry for Environmental Remediation | Major Elective | | 3 + 0 |

**Course Type:** Core (compulsory), practical (lab), major elective (professional), minor elective (specialization).

**Research Thesis:** 6 Credit hours in 2 semesters (3rd and 4th years)

9. **Award of Degree**
   Degree awarding criteria will be followed as per PU and HEC guidelines.
10. **NOC from Professional Councils (If Applicable):** Not Applicable
11. **Faculty Strength**
    Faculty strength requirement will be met as per HEC criteria upon seeking NOC from HEC for said program.
12. **Present Student Teacher Ratio in the Department:** Not Applicable
13. **Fee Structure:** As per University rule and fee structure.
14. **Number of seats:** 30

(Note: Two third seats will be on General Open merit while one third seats to be offered to PGD holder in "Chemistry & Entrepreneurship" offered by Centre for Research in Ionic Liquids, however if these seats may remain unfilled then these will be filled by open general merit as well.

15. **Session:** Spring 2024 onwards

**16. Course Outline Separately for Each Course**

| **Title** | **Principles and Concepts of Green Chemistry** |
|---|---|
| **Course Code** | GSC-501 |
| **Semester** | 01 |
| **Number of Credit Hours** | 03 |
| **Description and Course Learning Objectives** | GSC-501 presents the fundamentals of green chemistry and connects the science behind sustainability issues with efforts that can be taken to create solutions. Green Chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances. While there are many mechanisms and tools available to assess the impact of materials and processes on human health and the environment, there are few tools available to help design and create products as such.<br>On successful completion of this unit, students will be able to:<br>1. Demonstrate a broader and deeper understanding of the twelve principles of green chemistry and key metrics (Green Chemistry Metrics) and how to apply them to problem solving and access sustainability.<br>2. Evaluate technologies and products by applying the methods and tools of green chemistry in the practice of chemistry. Students will be able to evaluate, whether a chemical transformation can be classified as environment friendly and sustainable, or which parameters need to be optimized in order to achieve this.<br>3. Explain how the application of green chemistry principles can address the UN Sustainable Development Goals.<br>4. Identify the tools and strategies to improve the chemical reaction and process using the principles of green chemistry<br>5. Explain how the practice of green chemistry enhances competitiveness, innovation and faster time to market, while addressing critical ethical and sustainability issues.<br>6. Students will be aware of the social, ecological and economic dimensions with responsibility of the profession of chemist. |
| **Course Content** | Introduction to Green Chemistry, Principles of Green Chemistry (waste reduction, atom economy, non-hazardous syntheses, safe chemicals and solvents, minimal energy consumption, renewable energy consumption, renewable raw materials, simple chemistry, catalysis, degradability, real-time analysis, and accident prevention), green chemistry metrics to assess sustainability, legal and regulatory framework of chemical law and approval. Current trends, developments and innovations in sustainable chemistry from academic and industrial research. |
| **Recommended Books/References** | 1. Sankar P. Day, Nayim Sep, (2021), *A Textbook of Green Chemistry, Edition 1st*, Techno World Publisher.<br>2. M. Lancaster, (2016), *Green Chemistry: An Introductory Text, Edition 3,* RSC Publishers.<br>3. P. Anastas and P. Trevorrow, (2013), *Handbook of Green Chemistry, Green Processes, Designing Safer Chemicals,* Wiley Publishers. |

<table>
<tr><td colspan="2"></td><td colspan="4"><ol start="4"><li>A. Lapkin and D. Constable, (2008), Green Chemistry Metrics: Measuring and Monitoring Sustainable Processes, Wiley Publishers.</li><li>J. H. Clark, A. Hunt, C. Topi, G. Paggiola and J. Sherwood, (2017), Sustainable Solvents: Perspectives from Research, Business and International Policy (Green Chemistry Series), RSC Publishers.</li><li>M. North, J.H. Clark, (2015), Sustainable Catalysis (Green Chemistry Series), RSC Publishers.</li><li>G. Stefanifis, A. Stankiewicz, J.H. Clark, A. de la Hoz, J. Fan, R. Mato Chain, J. Santamaria, (2016), Alternative Energy Sources for Green Chemistry (Green Chemistry Series), RSC Publishers.</li><li>R. Höfer, A.S. Matharu, Z. Zhang, (2019), Green Chemistry for Surface Coatings, Inks and Adhesives: Sustainable applications (Green Chemistry Series), RSC Publishers.</li></ol></td></tr>
<tr><td colspan="6">Week-Wise Distribution of Course Contents</td></tr>
<tr><td colspan="2">Week</td><td colspan="4">Topic</td></tr>
<tr><td colspan="2">1st</td><td colspan="4">Origin of green chemistry, what is green Chemistry? Why green chemistry is called sustainable chemistry?</td></tr>
<tr><td colspan="2">2nd</td><td colspan="4">Need for green chemistry, goals of green chemistry</td></tr>
<tr><td colspan="2">3rd</td><td colspan="4">Illustration of 4R’s in the management of plastics</td></tr>
<tr><td colspan="2">4th</td><td colspan="4">Limitations/obstacles of green chemistry</td></tr>
<tr><td colspan="2">5th</td><td colspan="4">12 principles of green chemistry, waste reduction/pollution prevention, atom economy or atom efficiency</td></tr>
<tr><td colspan="2">6th</td><td colspan="4">Use of less hazardous and toxic chemicals, non-hazardous synthesis, safer products by design, safe chemicals and solvents</td></tr>
<tr><td colspan="2">7th</td><td colspan="4">Minimal energy consumption, renewable energy consumption, renewable raw materials,</td></tr>
<tr><td colspan="2">8th</td><td colspan="4">Mid Term Exams</td></tr>
<tr><td colspan="2">9th</td><td colspan="4">Reduce derivatives or minimization of steps (simple chemistry), use of catalytic reagents, degradability</td></tr>
<tr><td colspan="2">10th</td><td colspan="4">Real-time analysis, and accident prevention</td></tr>
<tr><td colspan="2">11th</td><td colspan="4">Green chemistry metrics to assess sustainability; concept of atom economy or atom efficiency, atom utilization</td></tr>
<tr><td colspan="2">12th</td><td colspan="4">Calculation of atom economy in different reactions such as rearrangement reaction, addition reaction, substitution reaction, elimination reaction, single-step oxidation, catalytic process, calculation of atom economy for multi-step chemical synthesis</td></tr>
<tr><td colspan="2">13th</td><td colspan="4">Environmental factor or E-factor, environmental quotient (EQ) or Q-value</td></tr>
<tr><td colspan="2">14th</td><td colspan="4">Legal and regulatory framework of chemical law and approval</td></tr>
<tr><td colspan="2">15th</td><td colspan="4">Current trends, developments and innovations in sustainable chemistry from academic and industrial research.</td></tr>
<tr><td colspan="2">16th</td><td colspan="4">Final Term Exams</td></tr>
<tr><td colspan="2">Teaching Strategies</td><td colspan="4">Participatory Lectures, Assignments/Presentations etc</td></tr>
<tr><td>Assessment Criteria</td><td>Marks %</td><td>Session</td><td>Mid</td><td>Final</td><td>Total%</td></tr>
<tr><td></td><td></td><td>25</td><td>35</td><td>40</td><td>100</td></tr>
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| | |
|---|---|
| **Recommendations** | All assignments must be completed and presented on time. |
| **Teaching-Learning Strategies** | Class lecture method, which includes seminars, discussions, assignments and projects. Audio-visual tools will be used where necessary. |
| **Assignment-Types and Number with Calendar** | According to the choice of respective teacher. |
| **Assessments and Examinations** | According to the university's semester rules. |

- Class attendance will be strictly observed as per university rules.
- Students are advised to keep the course outlines in record for their own reference and studies abroad.

**Governing Rules**

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| **Title** | **Ionic Liquids as Green Solvents** |
|---|---|
| **Course Code** | GSC-502 |
| **Semester** | 01 |
| **Number of Credit Hours** | 03 |
| **Description and Course Learning Objectives** | GSC-502 is aimed to make students learn about green solvents essential for any of the chemical reaction to make it environmentally benign. Particular focus is on ionic liquids that are the highlighted most important solvents of present and future. Different types, physicochemical properties and design-ability of ionic liquids and biocompatibility are the core contents of the course. |
| **Course Content** | Green solvents in chemistry, Ionic Liquids (ILs); Definition of ILs, Perspective of ILs, History of ILs, Generations of ILs, Types of ILs (with respect to their acidic, basic and neutral nature, with respect to their hydro-behavior), Nomenclature of ILs, Aprotic vs. protic ILs, Applications of ILs, Key properties and techniques for understanding ILs, Physical and chemical properties of ILs (viscosity, vapor pressure, melting point), Thermal and electrochemical properties, conductivity and ion transport, Deep eutectic solvents (DES), Active pharmaceutical ingredients (APIs), Biocompatible ILs |
| **Recommended Books/References** | 1. Douglas, R. Macfarlane, Mega Kar, and Jennifer M. Pingle, (2017), *Fundamentals of Ionic Liquids, from Chemistry to Applications*, Wiley VCH publishers.<br>2. Micheal Freemantle, (2010), *An Introduction to Ionic Liquids*, RSC Publishers.<br>3. Jason P. Hallett. (2010), *An Introduction to Ionic Liquids*, RSC Publishers.<br>4. Suojiang Zhang, Xinmei Lu, Sucai Li. (2009), *Ionic Liquids: Physicochemical Properties*, Elsevier Publishers. |
| **Week-Wise Distribution of Course Contents** | |
| **Week** | **Topic** |
| **1st** | Green solvents in chemistry, Ionic Liquids (ILs); Definition of ILs, Perspective of ILs |
| **2nd** | History of ILs, Different Generations of ILs |
| **3rd** | Types of ILs with respect to their acidic, basic and neutral nature |
| **4th** | Types of ILs with respect to their hydro- behavior |
| **5th** | Nomenclature of ILs |
| **6th** | Aprotic vs. protic ILs |
| **7th** | Synthesis of ionic liquids (Tailor-made properties) |
| **8th** | **Mid Term Exams** |
| **9th** | Applications of ILs |
| **10th** | Key properties and techniques for understanding ILs |
| **11th** | Physical and chemical properties of ILs |
| **12th** | Thermal and electrochemical properties, Conductivity and ion transport |

<table>
<tr><td colspan="2">13th</td><td colspan="4">Deep Eutectic solvents (DES)</td></tr>
<tr><td colspan="2">14th</td><td colspan="4">Active pharmaceutical ingredients (APIs)</td></tr>
<tr><td colspan="2">15th</td><td colspan="4">Biocompatible ILs</td></tr>
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<table>
<tr><td>Title</td><td colspan="5">Green Chemistry Techniques</td></tr>
<tr><td>Course Code</td><td colspan="5">GSC-503</td></tr>
<tr><td>Semester</td><td colspan="5">01</td></tr>
<tr><td>Number of Credit Hours</td><td colspan="5">03</td></tr>
<tr><td>Description and Course Learning Objectives</td><td colspan="5">Green Chemistry Practical course is designed to teach Chemistry in the context of a research-guided exercise in the laboratory. Students will learn about:<ul><li>Preparation of experiments, planning and execution of preparative work, analysis and interpretation of measurement results, preparation of protocols.</li><li>Ability to develop sustainable and safe synthesis pathways, utilize renewable resources, and address environmental analytical issues.</li></ul></td></tr>
<tr><td>Course Content</td><td colspan="5"><ul><li>Learning of new catalytic methods (e.g., bio-, photo- or organo-catalysis)</li><li>Utilization, conversion and analysis of renewable raw materials</li><li>Synthesis of Ionic Liquids</li><li>Use of ionic liquids as catalyst and solvents in organic synthesis</li><li>Determination of various components in food, cosmetics and daily use products</li><li>Plant mediated green synthesis of nanoparticles</li></ul></td></tr>
<tr><td>Recommended Books/References</td><td colspan="5"><ol><li>Sally A. Henrie, (2015), Green Chemistry-Laboratory Manual for General Chemistry, Taylor & Francis CRC Press.</li><li>Syed Kazim Moosvi, Waseem Gulzar Naqash, Mohd. Hanief Najar, (2021), Green Chemistry Principles and Designing of Green Synthesis, De Gruyter publishers.</li></ol></td></tr>
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<tr><td rowspan="2">Assessment Criteria</td><td rowspan="2">Marks %</td><td>Session</td><td>Mid</td><td>Final</td><td>Total%</td></tr>
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| **Title** | **Green Chemistry and Sustainable Development Goals** |
|---|---|
| **Course Code** | GSC-504 |
| **Semester** | 02 |
| **Number of Credit Hours** | 03 |
| **Description and Course Learning Objectives** | The students will learn how green and sustainable chemistry can be a central driver in the circular economy and addressing and achieving the UN Sustainable Development Goals. The course overviews the principles of green chemistry, linking these to the UN SDGs.<br>Objectives of the course are:<br>• To enable the students to identify the critical areas in terms of sustainable development for new products, materials or processes. They have basic knowledge of how to apply the methods and interpret the results.<br>• Students will learn to reflect on new developments as well as to design trans disciplinary projects and can also perceive possible effects of developments in the field of chemistry on society, the environment, and the economy.<br>• They are aware of their responsibility as chemists for social development.<br>• Effectively communicate detailed, complex, green and sustainable chemistry research concepts to both experts and non-experts through the application of a variety of key transferable skills such as IT, scientific writing, oral presentations, posters, team-working.<br>• Critically evaluate the environmental impact and sustainability of chemical processes and products, through the use of relevant metrics and whole systems thinking. |
| **Course Content** | Concept of sustainability and sustainable development, Chemistry and sustainable development goals, Waste, energy and law of thermodynamics, Measuring reactions and process efficiency, Processing of chemicals at scale, Sustainable energy, fuels and chemicals, Biomass as a source of energy, fuels and chemicals, The chemist as responsible citizen |
| **Recommended Books/References** | 1. Neil Winterton, (2021), *Chemistry for sustainable technologies: A foundation*, RSC Publishers.<br>2. Mark Anthony, Benvenuto Komas, (2022). *Green Chemistry and UN sustainability development goals*, De Gruyter Publishers.<br>3. Nancy E. Carpenter, (2014). *Chemistry for sustainable energy*, CRC Press Taylor & Francis Group. |
| **Week-Wise Distribution of Course Contents** | |
| **Week** | **Topic** |
| **1st** | Concept of sustainability and sustainable development, The sustainability challenges |
| **2nd** | What are the Sustainable Development Goals (SDGs)? |

| | | | | | |
|---|---|---|---|---|---|
| | | How will chemistry help achieve the SDGs?<br>Which SDGs are most relevant to chemistry? | | | |
| **3rd** | | What is waste? when waste becomes pollution? chemical waste: Sheldon's E-factor | | | |
| **4th** | | Approaches to chemical waste minimization, waste minimization hierarchy, inevitability of waste | | | |
| **5th** | | The central importance of thermodynamics; heat of reaction and kinetics | | | |
| **6th** | | Entropy and waste, work and the Carnot cycle, energy and exergy | | | |
| **7th** | | Measuring reactions and process efficiency; reaction yield, mass balance, conversion, selectivity, atom economy, material efficiency, energy efficiency, sustainability indices | | | |
| **8th** | | **Mid Term Exams** | | | |
| **9th** | | Processing of chemicals at scale; scale and its importance, technological integration, supply chains and infrastructure | | | |
| **10th** | | Process development, process chemistry and engineering | | | |
| **11th** | | Patenting | | | |
| **12th** | | Circular economy | | | |
| **13th** | | Sustainable energy, fuels and chemicals | | | |
| **14th** | | Biomass as a source of energy, fuels and chemicals | | | |
| **15th** | | The chemist as citizen; finding stuff out, science and ethics, science and public perception, individual action | | | |
| **16th** | | **Final Term Exams** | | | |
| **Teaching Strategies** | | **Participatory Lectures, Assignments/Presentations etc** | | | |
| **Assessment Criteria** | **Marks %** | **Session** | **Mid** | **Final** | **Total%** |
| | | **25** | **35** | **40** | **100** |
| **Recommendations** | | All assignments must be completed and presented on time. | | | |
| **Teaching-Learning Strategies** | | Class lecture method, which includes seminars, discussions, assignments and projects. Audio-visual tools will be used where necessary. | | | |
| **Assignment-Types and Number with Calendar** | | According to the choice of respective teacher. | | | |
| **Assessments and Examinations** | | According to the university's semester rules. | | | |

- Class attendance will be strictly observed as per university rules.
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| | |
|---|---|
| **Title** | **Green Processing of Renewable Resources Using Ionic Liquids** |
| **Course Code** | GSC-505 |
| **Semester** | 02 |
| **Number of Credit Hours** | 03 |
| **Description and Course Learning Objectives** | Diminishing fossil resources, increasing oil prices and numerous other drivers are rapidly forcing society to seek new, sustainable sources of carbon for future chemicals, energy and materials production. This module looks at the variables in this complex equation, from the design of a synthetic route, energy consumption, alternative feedstocks and engineering methods for efficient chemical production.<br>After positive completion of the course, students are able to identify renewable raw materials, understand the macroscopic properties of the major components and recognize them in products. Based on the knowledge acquired, students will<br>• Generate their own view of advanced biorefineries in the context of bioeconomic concepts as an alternative to finite resources.<br>• Analyze and use real examples to illustrate how the principles of green chemistry can be applied to chemical manufacturing.<br>• Critically analyze the changing trends in raw material utilization and to understand the potential of alternative feedstocks.<br>• Evaluate engineering methods for improving process efficiencies.<br>• Calculate and critically evaluate the mass and energy balance in a chemical production process.<br>• Critically analyze, discuss and the importance of energy efficiency and the range of energy sources, both economically and in terms of impact on climate change.<br>• Demonstrate a high level of practical ability in the design and execution of green chemical processes.<br>• Have an excellent knowledge of how biomass can be used as a feedstock for future production industries. |
| **Course Content** | Renewable raw materials as energy resource, circular economy based on lignocellulosic material, composition of lignocellulose, structure and properties of the main components, technical processes for the production and processing of renewable raw materials, molecular structure, properties, use and degradability of bioplastics |
| **Recommended Books/References** | 1. Helen Treichel, Gislaine Fongaro, Thamarys Scapini, Aline Frumi Camargo, Fábio Spitza Stefanski, Bruno Venturin, (2020), *Utilising Biomass in Biotechnology; A Circular Approach discussing the Pretreatment of* |

<table>
<tr><td colspan="2"></td><td colspan="4">Biomass, its Applications and Economic Considerations, Springer.<br>2. Sadia Naz, Maliha Uroos. In: Khan, A., Mavinkere Rangappa, S., Siengchin, S., Asiri, A. (eds). (2020), Ionic Liquids Based Processing of Renewable and Sustainable Biopolymers In Biofibers and Biopolymers for Biocomposites. Springer Cham.<br>3. G. Stefanifis, A. Stankiewicz, J.H. Clark, A. de la Hoz, J. Fan, R. Mato Chain, J. Santamaria, (2016), Alternative Energy Sources for Green Chemistry (Green Chemistry Series). De Gruyter Publishers.<br>4. Francisca A. e Silva, Ana C.A. Sousa et al. (2022), Waste Valorization Using Ionic Liquids, RSC Publishers.</td></tr>
<tr><td colspan="6">Week-Wise Distribution of Course Contents</td></tr>
<tr><td colspan="2">Week</td><td colspan="4">Topic</td></tr>
<tr><td colspan="2">1st</td><td colspan="4">Renewable raw materials as energy resource</td></tr>
<tr><td colspan="2">2nd</td><td colspan="4">Circular economy based on renewable raw materials</td></tr>
<tr><td colspan="2">3rd</td><td colspan="4">Lignocellulosic biomass; structure and properties of the main components cellulose and hemicellulose</td></tr>
<tr><td colspan="2">4th</td><td colspan="4">Lignocellulosic biomass; structure and properties of the main component lignin</td></tr>
<tr><td colspan="2">5th</td><td colspan="4">Lignocellulosic biomass characterization methods</td></tr>
<tr><td colspan="2">6th</td><td colspan="4">Waste biomass pretreatment methods; physical, chemical and biological.</td></tr>
<tr><td colspan="2">7th</td><td colspan="4">Problem in lignocellulose processing</td></tr>
<tr><td colspan="2">8th</td><td colspan="4">Mid Term Exams</td></tr>
<tr><td colspan="2">9th</td><td colspan="4">Ionic liquids as green solvents for sustainable biorefinery</td></tr>
<tr><td colspan="2">10th</td><td colspan="4">Dissolution, deconstruction using ionic liquids</td></tr>
<tr><td colspan="2">11th</td><td colspan="4">Platform chemicals</td></tr>
<tr><td colspan="2">12th</td><td colspan="4">Biofuels</td></tr>
<tr><td colspan="2">13th</td><td colspan="4">Lignin valorization</td></tr>
<tr><td colspan="2">14th</td><td colspan="4">Challenges in ILs based processing</td></tr>
<tr><td colspan="2">15th</td><td colspan="4">Molecular structure, properties, use and degradability of bioplastics</td></tr>
<tr><td colspan="2">16th</td><td colspan="4">Final Term Exams</td></tr>
<tr><td colspan="2">Teaching Strategies</td><td colspan="4">Participatory Lectures, Assignments/Presentations etc</td></tr>
<tr><td>Assessment Criteria</td><td>Marks %</td><td>Session</td><td>Mid</td><td>Final</td><td>Total%</td></tr>
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<tr><td colspan="2">Recommendations</td><td colspan="4">All assignments must be completed and presented on time.</td></tr>
<tr><td colspan="2">Teaching-Learning Strategies</td><td colspan="4">Class lecture method, which includes seminars, discussions, assignments and projects. Audio-visual tools will be used where necessary.</td></tr>
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<tr><td colspan="2">Assessments and Examinations</td><td colspan="4">According to the university’s semester rules.</td></tr>
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</table>

- Students are advised to keep the course outlines in record for their own reference and studies abroad.

**Governing Rules**

- Students are advised to go through the rules and regulations governing their class attendance, display of Centre ID card, use of mobile phones, eating/smoking, roaming, general behavior on the campus.
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<table>
<tr><td colspan="2">Title</td><td colspan="4">Mini Projects in Advanced Green Chemistry</td></tr>
<tr><td colspan="2">Course Code</td><td colspan="4">GSC-506</td></tr>
<tr><td colspan="2">Semester</td><td colspan="4">02</td></tr>
<tr><td colspan="2">Number of Credit Hours</td><td colspan="4">03</td></tr>
<tr><td colspan="2">Description and Course Learning Objectives</td><td colspan="4">Advanced Green Chemistry Laboratory course is designed to teach Chemistry in the context of a research-guided exercise in the laboratory.<br>Students will learn about:<br>• Preparation of experiments, planning and execution of preparative work, analysis and interpretation of measurement results, preparation of protocols.<br>• Ability to develop sustainable and safe synthesis pathways, utilize renewable resources, and address environmental analytical issues.</td></tr>
<tr><td colspan="2">Course Content</td><td colspan="4">Mini projects based on areas listed below;<br>• Recovery and recycling of critical raw materials<br>• Use of modern synthetic methods such as microwave and ultrasound<br>• Learning modern environmental analytical techniques<br>• Solvent-free green synthesis<br>• Extraction of valuable products from natural sources using ionic liquids<br>• Solid-state green synthesis of different nanoparticles<br>• Biomass-derived carbons and their applications</td></tr>
<tr><td colspan="2">Recommended Books/References</td><td colspan="4">1. Sally A. Henrie, (2015), Green Chemistry-Laboratory Manual for General Chemistry, Taylor & Francis CRC Press.<br>2. Syed Kazim Moosvi, Waseem Gulzar Naqash, Mohd. Hanief Najar, (2021), Green Chemistry Principles and Designing of Green Synthesis, De Gruyter publishers.</td></tr>
<tr><td colspan="2">Teaching Strategies</td><td colspan="4">Participatory Lectures, Assignments/Presentations etc</td></tr>
<tr><td>Assessment Criteria</td><td>Marks %</td><td>Session</td><td>Mid</td><td>Final</td><td>Total%</td></tr>
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| **Title** | **Molecular Design and Synthesis of Ionic Liquids** |
|---|---|
| **Course Code** | GSC-507 |
| **Semester** | 01 |
| **Number of Credit Hours** | 03 |
| **Description and Course Learning Objectives** | Students will be taught about the designing strategies for green solvents ionic liquids. After completion of the course students will have knowledge about:<br>• Tailor-made properties of ionic liquids for various fields of science and technology<br>• Synthesis of different types of ionic liquids in laboratory<br>• Characterization techniques for ionic liquids |
| **Course Content** | The structure of ions that forms ionic liquids, Structuring of ionic liquids, Synthesis of ionic liquids, formation of the cation: Quaternization/alkylation, Anion exchange, Metathesis, Ion exchange, Synthesis of ionic liquids via carbonate route, Solvate ionic liquids, chloroaluminate ionic liquids, Task-specific ionic liquids, Zwitter-ionic liquids, Polymer ionic liquids, Protic ionic liquids, Chiral ionic liquids, Characterization and analysis of ionic liquids |
| **Recommended Books/References** | 1. Douglas, R. Macfarlane, Mega Kar, and Jennifer M. Pingle, (2017), *Fundamentals of Ionic Liquids, from Chemistry to Applications*, Wiley VCH publishers.<br>2. Micheal Freementle, (2010), *An Introduction to Ionic Liquids*, RSC Publishers.<br>3. Jason P. Hallett. (2010), *An Introduction to Ionic Liquids*, RSC Publishers. |
| **Week-Wise Distribution of Course Contents** | |
| **Week** | **Topic** |
| **1st** | Structure of ions that form ionic liquids; Introduction, Ionic interactions and melting point, Thermodynamics of the melting point |
| **2nd** | Effect of ion size and crystal packing, Quantifying the Madelung constant |
| **3rd** | Charge delocalization and shielding, Ion symmetry |
| **4th** | Influence of cation substituents, Degrees of freedom and structural disorder |
| **5th** | Polymorphism, Hydrogen bonding, Dications and dianions |
| **6th** | Structuring of ionic liquids, iconicity, ion pairing and ion association |
| **7th** | Short-range structuring, Structural heterogeneity and domain formation |
| **8th** | **Mid Term Exams** |
| **9th** | Impact of structure on reactivity and application |
| **10th** | Synthesis of ionic liquids, formation of the cation: Quaternization/alkylation, Anion exchange, Metathesis |
| **11th** | Ion exchange, Synthesis of ionic liquids via carbonate route |
| **12th** | Solvate ionic liquids, chloroaluminate ionic liquids |

<table>
<tr><td colspan="2">13th</td><td colspan="4">Task-specific ionic liquids, Zwitter-ionic liquids</td></tr>
<tr><td colspan="2">14th</td><td colspan="4">Polymer ionic liquids, Protic ionic liquids, Chiral ionic liquids</td></tr>
<tr><td colspan="2">15th</td><td colspan="4">Characterization and analysis of ionic liquids</td></tr>
<tr><td colspan="2">16th</td><td colspan="4">Final Term Exams</td></tr>
<tr><td colspan="2">Teaching Strategies</td><td colspan="4">Participatory Lectures, Assignments/Presentations etc</td></tr>
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</table>

| | | | | | |
|---|---|---|---|---|---|
| **Title** | **Strategies for Green Organic Synthesis** | | | | |
| **Course Code** | GSC-508 (Elective) | | | | |
| **Semester** | 01 | | | | |
| **Number of Credit Hours** | 03 | | | | |
| **Description and Course Learning Objectives** | The course aim is the continuation study of basic principles of organic chemistry, but according to the fundamentals of green chemistry. This will help students to gain experience to predict the functional group transformations, simple reaction mechanisms, and the synthesis of organic molecules by green strategies, solvents and catalysis. | | | | |
| **Course Content** | Designing a Green synthesis; Choice of starting materials, reagents, catalysts and solvents.<br>Sustainability of green synthetic processes and procedures, One-pot organic reactions, Green synthetic techniques; Solvent-free synthesis, Reactions in water, Reactions in ionic liquids, ultrasonic reactions, microwave reactions. | | | | |
| **Recommended Books/References** | 1. V.K Ahluwalia and M.Kidwai, Kluver, (2012), *New trends in Green Chemistry*, Academic Publishers.<br>2. Roberto Ballini, (2019), *Green synthetic processes and procedures*, RSC Publishers.<br>3. Sankar P. Day, Nayim Sepay, (2022), *A Textbook of Green Chemistry*, Techno World Publishers. | | | | |
| **Week-Wise Distribution of Course Contents** | | | | | |
| **Week** | **Topic** | | | | |
| **1st** | Designing a Green synthesis; Choice of starting materials, reagents, catalysts and solvents. | | | | |
| **2nd** | Sustainability of green synthetic processes and procedures | | | | |
| **3rd** | One-pot organic reactions | | | | |
| **4th** | Multi-component reactions | | | | |
| **5th** | Multi-component reactions | | | | |
| **6th** | Solvent-free (solid state) synthesis | | | | |
| **7th** | Solvent-free (solid state) synthesis | | | | |
| **8th** | **Mid Term Exams** | | | | |
| **9th** | Reactions in water | | | | |
| **10th** | Reactions in ionic liquids | | | | |
| **11th** | Reactions in ionic liquids | | | | |
| **12th** | Ultrasonic reactions | | | | |
| **13th** | Ultrasonic reactions | | | | |
| **14th** | Microwave mediated synthesis | | | | |
| **15th** | Microwave mediated synthesis | | | | |
| **16th** | **Final Term Exams** | | | | |
| **Teaching Strategies** | **Participatory Lectures, Assignments/Presentations etc** | | | | |
| **Assessment Criteria** / **Marks %** | **Session** | **Mid** | **Final** | **Total%** | |
| | 25 | 35 | 40 | 100 | |
| **Recommendations** | All assignments must be completed and presented on time. | | | | |
| **Teaching-Learning Strategies** | Class lecture method, which includes seminars, discussions, assignments and projects. Audio-visual tools will be used where necessary. | | | | |

| | |
|---|---|
| **Assignment-Types and Number with Calendar** | According to the choice of respective teacher. |
| **Assessments and Examinations** | According to the university's semester rules. |
| • Class attendance will be strictly observed as per university rules.<br>• Students are advised to keep the course outlines in record for their own reference and studies abroad. | |
| **Governing Rules**<br>• Students are advised to go through the rules and regulations governing their class attendance, display of Centre ID card, use of mobile phones, eating/smoking, roaming, general behavior on the campus.<br>• Any violation thereof is punishable under the relevant rules. | |

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|---|---|
| **Title** | **Business Model Design for Innovative and Sustainable Technologies** |
| **Course Code** | GSC-509 (Elective) |
| **Semester** | 01 |
| **Number of Credit Hours** | 03 |
| **Description and Course Learning Objectives** | This module aims to introduce commercialization of green and sustainable chemistry through examples of the development of greener chemicals and consumer products, the role of environmental legislation governing their manufacture, the process of protecting inventions, and how those inventions can be brought to market. At the interface between technology and business models, you can explore the basis for innovation and growth in the sector. Working both independently and as part of a team you will develop a green and sustainable chemistry business case for a mock spin-out company that takes an idea from 'bench to business'.<br>On successful completion of this unit, you should able to:<br>• Identify and articulate the sources of innovation in the chemical sector in terms of value creation and capture through applying green/sustainable chemistry principles;<br>• Describe and explain the components of a business and show understanding of the economic drivers (including regulatory) for the industry;<br>• Characterize and interpret the financial considerations that determine the 'rules of the game' for the industry;<br>• Identify bottlenecks and other factors that set operational constraints and apply strategies that offer solutions to optimise the production system;<br>• Apply green/sustainable chemistry principles to circular economy initiatives life cycle analysis, and propose realistic solutions that can be adopted by industry;<br>• Engage, with a progressive voice, in regulatory discussions that will facilitate government and industry cooperation<br>• Critically evaluate the potential for and difficulties in achieving the use of greener chemical products.<br>• Communicate (written and oral) and defend several technical and non-technical concepts in the form of a business plan, accepting accountability for related decision-making.<br>• Engage in mock team-work professional activity demonstrating integration of several business planning concepts such as, intellectual property rights, environmental legislation, and circular economy law. |
| **Course Content** | Innovation management; Innovation: the creative pursuit of ideas, identifying an innovation, Intellectual property (IP) management, patents, copyright, trademark |

| | |
|---|---|
| | Entrepreneurship; Commercialization of innovation, Entrepreneurship: an evolving concept, under strategic issues in business plan development, recognizing opportunities and generating ideas, assessment of entrepreneurial plan (feasibility analysis), developing an effective business plan, cost-effectiveness, industry analysis and competitor analysis, preparing proper legal and ethical foundation, understanding the entrepreneurial perspective in person, case studies<br>Organization setup, product design, branding, marketing, company registration, licensing, ISO certification, SWOT analysis, Law of contract, Factories act<br>Understanding the entrepreneurial perspective in organizations<br>Corporate entrepreneurship, social entrepreneurship and the ethical challenges of entrepreneurship, pathways to entrepreneurial ventures, legal challenges for entrepreneurial ventures, sources of capital for entrepreneurial ventures, getting financing and funding, marketing challenges for entrepreneurial ventures, financial preparation for entrepreneurial ventures, strategic entrepreneurial growth, internal and external growth strategies, valuation of entrepreneurial ventures, harvesting the entrepreneurial ventures. |
| **Recommended Books/References** | 1. Donald F. Koratko, (2013), *Entrepreneurship – Theory process, practice by 8th edition*, Cenage Learning.<br>2. John Spence, (2009), *Awesomely simple: Essential business strategies for turning ideas into action by Spence*, 1st edition, Wiley Publishers.<br>3. Thieie Peter, (2014), *Zero to one: Notes on startups, or how to build the future*. Crown Currency Publishers.<br>4. R. Eric, Crown Business, (2011), *The lean startup: How today's entrepreneurship use continuous innovation to create radically successful business*, Currency Publishers.<br>5. Kawasaki Guy, (2014), *The art of the start 2: The time-tested, battle –hardened guide for anyone starting anything*, Penguin Books Limited Publishers. |
| **Week-Wise Distribution of Course Contents** | |
| **Week** | **Topic** |
| **1st** | Innovation management; Innovation: the creative pursuit of ideas, identifying an innovation, Intellectual property (IP) management, patents, copyright, trademark |
| **2nd** | Entrepreneurship; Commercialization of innovation, Entrepreneurship: an evolving concept, under strategic issues in business plan development, recognizing opportunities and generating ideas. |
| **3rd** | Assessment of entrepreneurial plan (feasibility analysis), developing an effective business plan. |
| **4th** | Cost-effectiveness, industry analysis and competitor analysis. |
| **5th** | Preparing proper legal and ethical foundation, understanding the entrepreneurial perspective in person, case studies. |

| | | | | | |
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| **6th** | | Organization setup, product design, branding, marketing, company registration, licensing. | | | |
| **7th** | | ISO certification, SWOT analysis, Law of contract, Factories act. | | | |
| **8th** | | **Mid Term Exams** | | | |
| **9th** | | Understanding the entrepreneurial perspective in organizations. | | | |
| **10th** | | Corporate entrepreneurship, social entrepreneurship and the ethical challenges of entrepreneurship. | | | |
| **11th** | | Pathways to entrepreneurial ventures, Legal challenges for entrepreneurial ventures. | | | |
| **12th** | | Sources of capital for entrepreneurial ventures, Getting financing and funding. | | | |
| **13th** | | marketing challenges for entrepreneurial ventures. | | | |
| **14th** | | Financial preparation for entrepreneurial ventures, strategic entrepreneurial growth, internal and external growth strategies. | | | |
| **15th** | | Valuation of entrepreneurial ventures, Harvesting the entrepreneurial ventures. | | | |
| **16th** | | **Final Term Exams** | | | |
| **Teaching Strategies** | | **Participatory Lectures, Assignments/Presentations etc** | | | |
| **Assessment Criteria** | **Marks %** | **Session** | **Mid** | **Final** | **Total%** |
| | | **25** | **35** | **40** | **100** |
| **Recommendations** | | All assignments must be completed and presented on time. | | | |
| **Teaching-Learning Strategies** | | Class lecture method, which includes seminars, discussions, assignments and projects. Audio-visual tools will be used where necessary. | | | |
| **Assignment-Types and Number with Calendar** | | According to the choice of respective teacher. | | | |
| **Assessments and Examinations** | | According to the university's semester rules. | | | |

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| | | | | | |
|---|---|---|---|---|---|
| **Title** | **Catalysis in Green Chemistry** | | | | |
| **Course Code** | GSC-510 (Elective) | | | | |
| **Semester** | 02 | | | | |
| **Number of Credit Hours** | 03 | | | | |
| **Description and Course Learning Objectives** | The design of a catalyst in a chemical transformation strives to optimize factors such as stability, turnover number, solubility, and ease of separation from the product. Minimizing or reducing the use of toxic catalysts and promoting the applicability of recyclable and eco-safe catalysts is the demand of sustainable future and basic theme of this course. | | | | |
| **Course Content** | Catalyst and catalysis, Biocatalysis in Green chemistry, Phase transfer catalysis, Catalysis by ionic liquids, Reaction using crown ethers, Asymmetric catalysis, Photocatalysis, Polymer supported catalysis, Catalysis by solid acids and bases, Nanocatalysis. | | | | |
| **Recommended Books/References** | 1. Sankar P. Day, Nayim Sep, (2021), *A Textbook of Green Chemistry, Edition 1st*, Techno World Publishers.<br>2. V.K Ahluwalia and M.Kidwai, Kluver, (2012), *New trends in Green Chemistry*, Academic Publishers.<br>3. Zhang and Cue, (2018), *Green Techniques for Organic Synthesis and Medicinal Chemistry by (Edited), Second Edition*, Wiley Publishers. | | | | |
| **Week-Wise Distribution of Course Contents** | | | | | |
| **Week** | **Topic** | | | | |
| **1st** | Catalyst and catalysis, Homogenous catalysis, Heterogeneous catalysis | | | | |
| **2nd** | Catalysis in Green chemistry | | | | |
| **3rd** | Examples of Biocatalysis | | | | |
| **4th** | Phase transfer catalysis | | | | |
| **5th** | Catalysis using ionic liquids (quaternary ammonium and phosphonium salts) | | | | |
| **6th** | Catalysis using deep eutectic solvents (DESs) | | | | |
| **7th** | Reactions using crown ethers | | | | |
| **8th** | **Mid Term Exams** | | | | |
| **9th** | Asymmetric catalysis | | | | |
| **10th** | Photocatalysis | | | | |
| **11th** | Polymer supported catalysis | | | | |
| **12th** | Catalysis by solid acids | | | | |
| **13th** | Catalysis by solid bases | | | | |
| **14th** | Catalysis by nanoparticles | | | | |
| **15th** | Catalysis by graphene oxide | | | | |
| **16th** | **Final Term Exams** | | | | |
| **Teaching Strategies** | **Participatory Lectures, Assignments/Presentations etc** | | | | |
| **Assessment Criteria** **Marks %** | **Session** | **Mid** | **Final** | **Total%** | |
| | 25 | 35 | 40 | 100 | |
| **Recommendations** | All assignments must be completed and presented on time. | | | | |

| | |
|---|---|
| **Teaching-Learning Strategies** | Class lecture method, which includes seminars, discussions, assignments and projects. Audio-visual tools will be used where necessary. |
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|---|---|---|---|---|---|
| **Title** | | **Technological Applications of Ionic Liquids** | | | |
| **Course Code** | | GSC-511 (Elective) | | | |
| **Semester** | | 02 | | | |
| **Number of Credit Hours** | | 03 | | | |
| **Description and Course Learning Objectives** | | GSC-511 is designed to make students well-aware of the significant role of ionic liquids in scientific different fields. | | | |
| **Course Content** | | Applications of ionic liquids in fields such as pharmaceutical science, food industry, drug delivery, biological applications, separation technology and electrochemistry | | | |
| **Recommended Books/References** | | 1. Suojiang Zhang, (2023), *Encyclopedia of Ionic Liquids (Edited)*, Springer Nature Singapore. | | | |
| **Week-Wise Distribution of Course Contents** | | | | | |
| **Week** | | **Topic** | | | |
| **1st** | | Active Pharmaceutical Ingredient Ionic Liquids | | | |
| **2nd** | | Pharmaceutical applications of ionic liquids | | | |
| **3rd** | | Ionic Liquids in food industry | | | |
| **4th** | | Ionic liquids in drug development | | | |
| **5th** | | Ionic liquids-based micro-extractions | | | |
| **6th** | | Ionic liquids based nanomaterials for drug delivery | | | |
| **7th** | | Ionic liquids for anti-cancer activities | | | |
| **8th** | | **Mid Term Exams** | | | |
| **9th** | | Ionic liquids in life sciences | | | |
| **10th** | | Electrochemical applications of ionic liquids | | | |
| **11th** | | Ionic liquids in batteries | | | |
| **12th** | | Ionic liquids in extraction and separation of biological molecules | | | |
| **13th** | | Ionic liquids for extractive desulfurization of fuels | | | |
| **14th** | | Ionic liquids for separation of hydrocarbons | | | |
| **15th** | | Ionic liquids for extraction of natural products | | | |
| **16th** | | **Final Term Exams** | | | |
| **Teaching Strategies** | | **Participatory Lectures, Assignments/Presentations etc** | | | |
| **Assessment Criteria** | **Marks %** | **Session** | **Mid** | **Final** | **Total%** |
| | | **25** | **35** | **40** | **100** |
| **Recommendations** | | All assignments must be completed and presented on time. | | | |
| **Teaching-Learning Strategies** | | Class lecture method, which includes seminars, discussions, assignments and projects. Audio-visual tools will be used where necessary. | | | |
| **Assignment-Types and Number with Calendar** | | According to the choice of respective teacher. | | | |
| **Assessments and Examinations** | | According to the university's semester rules. | | | |
| • Class attendance will be strictly observed as per university rules.<br>• Students are advised to keep the course outlines in record for their own reference and studies abroad. | | | | | |
| **Governing Rules** | | | | | |

- Students are advised to go through the rules and regulations governing their class attendance, display of Centre ID card, use of mobile phones, eating/smoking, roaming, general behavior on the campus.
- Any violation thereof is punishable under the relevant rules.

| **Title** | **Green Chemistry for Environmental Remediation** |
|---|---|
| **Course Code** | GSC-512 (Elective) |
| **Semester** | 02 |
| **Number of Credit Hours** | 03 |
| **Description and Course Learning Objectives** | GSC-512 is designed to make students well-aware of the significant role of Green Chemistry to protect environment. |
| **Course Content** | Green biotechnology for municipal and industrial wastewater treatment (WWT); Introduction, Need, Applications, Bioconversion of wastewater sludge to value-added products, Research/development needs and future prospects,<br><br>Remediation of heavy metals using waste: A green approach, The environmental pollution concerns, Essentials of bioremediation, Principles of remediation, Remediation of heavy metals,<br><br>Green techniques for the remediation of soil using composites, Process of compositing, Mechanism of compositing, Application of compositing to bioremediation, Heavy metals, Hydrocarbons, Pesticides, Gas stream purification,<br><br>Sustaining the atmosphere: Blue skies for a green earth; Preserving the atmosphere, Greatest threat: Global climate warning, Dealing with global climate change, Mitigation and minimization of greenhouse gas emissions, Control of particle emissions, Control of gases emissions, Control of hydrocarbons emissions and photochemical smog, Biological control of air pollution, Controlling of acid rain. |
| **Recommended Books/References** | 1. Stanley E. Manahan, (2013), *Fundamentals of Environmental and Toxicological Chemistry Sustainable Science, Fourth Edition*, CRC Press Taylor & Francis Group.<br>2. Rashmi Sanghi, Vandana Singh, (2012), *Green Chemistry for Environmental Remediation*, Wiley Publishers. |
| **Week-Wise Distribution of Course Contents** | |
| **Week** | **Topic** |
| **1st** | Green biotechnology for municipal and industrial wastewater treatment (WWT); Introduction |
| **2nd** | Need for efficient green biotechnology for WWT processes, Applications of green biotechnology in WWT processes |
| **3rd** | Bioconversion of wastewater sludge to value added products |
| **4th** | Research/development needs and future prospects, Remediation of heavy metals using waste: A green approach, The environmental pollution concerns, Essentials of bioremediation, Principles of remediation, Remediation of heavy metals |
| **5th** | Green technique for the remediation of soil using composites, Process of compositing |

<table>
<tr><td colspan="2">6th</td><td colspan="4">Mechanism of compositing, Application of compositing to bioremediation, Heavy metals, Hydrocarbons</td></tr>
<tr><td colspan="2">7th</td><td colspan="4">Pesticides, Gas stream purification</td></tr>
<tr><td colspan="2">8th</td><td colspan="4">Mid Term Exams</td></tr>
<tr><td colspan="2">9th</td><td colspan="4">Sustaining the atmosphere: Blue skies for a green earth</td></tr>
<tr><td colspan="2">10th</td><td colspan="4">Preserving the atmosphere, Greatest threat</td></tr>
<tr><td colspan="2">11th</td><td colspan="4">Global climate warning, Dealing with global climate change</td></tr>
<tr><td colspan="2">12th</td><td colspan="4">Mitigation and minimization of greenhouse gas emissions,</td></tr>
<tr><td colspan="2">13th</td><td colspan="4">Control of particle emissions, Control of gases emissions</td></tr>
<tr><td colspan="2">14th</td><td colspan="4">Control of hydrocarbons emissions and photochemical smog</td></tr>
<tr><td colspan="2">15th</td><td colspan="4">Biological control of air pollution, Controlling of acid rain</td></tr>
<tr><td colspan="2">16th</td><td colspan="4">Final Term Exams</td></tr>
<tr><td colspan="2">Teaching Strategies</td><td colspan="4">Participatory Lectures, Assignments/Presentations etc</td></tr>
<tr><td>Assessment Criteria</td><td>Marks %</td><td>Session</td><td>Mid</td><td>Final</td><td>Total%</td></tr>
<tr><td></td><td></td><td>25</td><td>35</td><td>40</td><td>100</td></tr>
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</table>

## Checklist for a New Academic Program

| Parameters | |
|---|---|
| 1. Department Mission and Introduction | ✓ |
| 2. Program Introduction | ✓ |
| 3. Program Alignment with University Mission | ✓ |
| 4. Program Objectives | ✓ |
| 5. Market Need/ Rationale | ✓ |
| 6. Admission Eligibility Criteria | ✓ |
| 7. Duration of the Program | ✓ |
| 8. Assessment Criteria | ✓ |
| 9. Courses Categorization as per HEC Recommendation | ✓ |
| 10. Curriculum Difference | ✓ |
| 11. Study Scheme / Semester-wise Workload | ✓ |
| 12. Award of Degree | ✓ |
| 13. Faculty Strength | ✓ |
| 14. NOC from Professional Councils (if applicable) | NA |

Convener and Director, CRIL

Director
Centre for Research in Ionic Liquids
School of Chemistry
University of the Punjab, Lahore