UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Low Environmental Impact Processing

2627-2-F7603Q009-F7603Q00902

Aims

The second module (4 CFU, Low Environmental Impact Processes) of the course Safe and Sustainable by Design aims to provide students with the theoretical and practical knowledge required to evaluate and design chemical production processes with minimized environmental impact, within a sustainability-oriented and innovation-driven framework. The course aims to integrate organic chemistry principles, industrial chemistry concepts, green chemistry metrics, and circular bioeconomy strategies, in line with the Safe and Sustainable by Design (SSbD) approach. The topics covered in this module are closely related to those of the first module (Sustainability and Safety of Processes and Products in Different Frameworks), which also includes aspects related to human health impacts and safety. Where appropriate, concepts from the first module will be integrated to support a comprehensive understanding of the interconnections among sustainability, safety, and environmental impact.

Knowledge and Understanding
By the end of the course, students will be able to:

- understand the fundamental principles of organic chemistry relevant to industrial and environmental processes;
- describe the main characteristics of chemical processes in industrial chemistry;
- explain the 12 principles of green chemistry and their role in sustainable chemical design;
- understand and interpret key sustainability metrics (Atom Economy, Carbon Efficiency, E-Factor);
- define the concepts of circular bioeconomy and SSbD and their relevance to modern chemical innovation.

Applying Knowledge and Understanding
By the end of the course, students will be able to:

- apply green chemistry principles to the analysis of chemical processes;
- use sustainability metrics to evaluate the environmental performance of reactions and processes;
- interpret industrial case studies in terms of efficiency, waste reduction, and resource sustainability;
- relate chemical design choices to circular bioeconomy strategies and SSbD principles.

Making Judgements (Autonomy of Judgment)
By the end of the course, students will be able to:

- critically assess the environmental impact and sustainability of chemical processes;
- compare alternative synthetic routes based on green chemistry criteria and quantitative metrics;
- evaluate the coherence of industrial processes with circular bioeconomy and SSbD frameworks;
- identify trade-offs between efficiency, safety, and sustainability in chemical design.

Communication Skills
By the end of the course, students will be able to:

- use appropriate scientific terminology in green chemistry and industrial chemistry;
- clearly explain chemical processes, sustainability metrics, and design strategies;
- communicate results of process evaluation using structured scientific language;
- present and discuss case studies in a clear and coherent manner.

Learning Skills
By the end of the course, students will be able to:

- integrate knowledge from organic chemistry, industrial chemistry, and sustainability science;
- independently deepen their understanding of green and sustainable chemistry approaches;
- critically analyze new developments in circular bioeconomy and SSbD frameworks;
- apply acquired tools to future studies and interdisciplinary contexts in chemical sciences.

Contents

- Organic chemistry
- Definition of chemical process and industrial chemistry
- The 12 principles of Green Chemistry
- Metrics in Green Chemistry: atom economy, carbon efficiency and E-Factor
- Circular bio-economy as a tool in green and sustainable chemistry
- The green chemistry in the SSbD approach
- Case studies

Detailed program

Organic Chemistry
Fundamental concepts of organic chemistry relevant to sustainable chemical processes, including structure–reactivity relationships, functional groups, and basic reaction mechanisms. Emphasis is placed on understanding how molecular structure influences chemical behavior in industrial and environmental contexts.
Definition of Chemical Process and Industrial Chemistry
Introduction to the concept of chemical processes in industrial contexts, including batch and continuous operations. Overview of industrial chemistry principles with attention to efficiency, resource use, waste generation, and environmental impact.
The 12 Principles of Green Chemistry
Detailed presentation of the twelve principles of green chemistry as a framework for designing safer and more sustainable chemical products and processes. Focus on prevention of waste, atom economy, safer solvents, energy efficiency, renewable feedstocks, and inherently safer chemistry.
Metrics in Green Chemistry

Introduction to quantitative tools used to evaluate the sustainability of chemical processes, including: Atom Economy, Carbon Efficiency, E-Factor (Environmental Factor)
These metrics are used to assess resource efficiency, waste generation, and overall environmental performance of chemical transformations.
Circular Bioeconomy as a Tool in Green and Sustainable Chemistry
Overview of the circular bioeconomy concept as an integrated approach combining renewable resources, biomass valorization, waste reduction, and material recycling. Discussion of its role in replacing fossil-based feedstocks and enabling sustainable industrial systems.
Green Chemistry within the Safe and Sustainable by Design (SSbD) Approach
Analysis of green chemistry principles within the SSbD framework. The module highlights how safety, sustainability, and functionality can be integrated at the early stages of chemical design to minimize environmental and health impacts throughout the entire life cycle of chemicals and materials.
Case Studies
Application-oriented analysis of selected industrial and research case studies illustrating the implementation of green chemistry principles, circular bioeconomy strategies, and SSbD methodologies. Examples include sustainable chemical production, biomass valorization, and process intensification approaches.

Prerequisites

• Basic knowledge of organic and inorganic chemistry.
• Basic notions of thermodynamics.

Teaching form

The course consists of 4 CFUs (ECTS credits) for a total of 32 hours, structured as follows:

12 2-hours lectures (24 hours total), Frontal Teaching (Delivered Didactics): delivered both in-person and remotely. Lectures may begin with standard delivered teaching but may transition into an interactive format.

4 2-hours sessions (8 hours total), Interactive Teaching (Interactive teaching): delivered in-person (and potentially grouped into 2 4-hours sessions). During these sessions, students will work under the professor's supervision to apply the concepts covered in class to theoretical or real-world case studies.

Textbook and teaching resource

- Slides
- material on the EL page

Semester

I semester (October - January)

Assessment method

The final exam consists of a single oral exam at the end of the course, with a score between 18-30 / 30 cum laude, which comprises the discussion of various topics covered in the course, with an emphasis also on the connections between modules, such as to arrive at a critical evaluation of work from the point of view of sustainability in chemistry as a whole.
The final score will range from 18/30 to 30/30 with honors, based on the overall assessment, taking into account the following criteria:

1. conceptual knowledge and understanding
2. ability to apply knowledge and understanding
3. communication and argumentation skills
4. learning, self-assessment, and self-regulation skills

Grade < 18
Knowledge and Understanding: The student only partially identifies the characteristics of the concepts. The connections between the concepts are fragmented and poorly supported by theoretical knowledge. Ability to apply knowledge and understanding: The student identifies only a few relevant elements in a phenomenon, unable to integrate them into a coherent analysis. Communication and Argumentation Skills: In the oral exam, the student develops a basic argument, lacking logical structure and characterized by numerous expository inaccuracies. Learning, self-assessment, and self-regulation skills: The student is able to reconstruct only some aspects of their learning and professional development journey.

Grade 18-22
Knowledge and Understanding: The student recognizes and explains most of the conceptual features and is able to provide a relatively coherent explanation, albeit with some inaccuracies. Theoretical references are present but not always rigorously. Ability to apply knowledge and understanding: The student is able to recognize a significant number of elements and provide a partial explanation, while highlighting some gaps in the analysis. Communication and argumentation skills: In the oral exam, the student constructs a basic argument, with a minimal structure but with some inaccuracies. Learning, self-assessment, and self-regulation skills: The student demonstrates a basic awareness of their learning path, managing to draw essential connections between learning experiences, albeit with some inaccuracies.

Grade 23-27
Knowledge and Understanding: The student demonstrates a thorough understanding of conceptual characteristics. In the oral exam, explanations are well-articulated and supported by an appropriate use of theoretical references. Ability to apply knowledge and understanding: The student accurately identifies the essential elements of a phenomenon. The application of knowledge occurs with methodological rigor that is not always solid. Communication and argumentation skills: In the oral exam, the student develops a coherent and well-organized argument, demonstrating good command of language and a solid logical-argumentative structure. Communication is clear and effective. Learning, self-assessment, and self-regulation skills: The student analyzes his or her learning journey in a clear and structured manner, highlighting significant relationships between the various developmental stages and demonstrating a good capacity for critical reflection.

Grade 28-30
Knowledge and Understanding: The student demonstrates a thorough mastery of concepts, articulating complex connections and providing comprehensive explanations. Theoretical references are used with relevance and rigor. Ability to apply knowledge and understanding: The student demonstrates an advanced ability to analyze a phenomenon, comprehensively identifying and interpreting all salient elements. Knowledge is applied with methodological rigor, supported by solid and detailed argumentation. Communication and argumentation skills: In the oral exam, the student develops a solid and detailed argument, with a rigorous logical structure and a high level of textual coherence. The presentation is fluent and wellstructured. Learning, self-assessment, and self-regulation skills: The student demonstrates an advanced capacity for selfreflection, developing a detailed and in-depth analysis of their learning and professional development journey. The connections between learning experiences and theoretical concepts are clear, coherent, and rigorous.

Office hours

Always, after scheduling an appointment *via* phone or e-mail.

Sustainable Development Goals

GOOD HEALTH AND WELL-BEING | INDUSTRY, INNOVATION AND INFRASTRUCTURE