Sustainable Chemistry

Educational subject description sheet

Basic information

Field of study Joint Bachelor in Sustainability **Speciality** Sustainable Physics & Chemistry **Organizational unit** Faculty of Law and Administration **Study level** first cycle (joint degree programme) **Study form** full-time degree programme **Education profile** General academic **Mandatory** obligatory	**Education cycle** 2025/26 **Subject code** UJ.WPAJBSSPCS.8100.16410.25 **Lecture languages** english **Subject related to scientific research** Yes **Disciplines** Chemical sciences **ISCED classification** 0588 Interdisciplinary programmes involving broad field 05 **USOS code**
Subject coordinator	Piotr Szwedo
Lecturer	Mario Smet, Timo Leskinen, Pedro Camargo, Mohammad Alzeer

Period Semester 5	**Examination** graded credit **Activities and hours** Discussion class: 36	**Number of ECTS points** 5.0

Goals

C1	The course introduces the fundamental principles and definitions of sustainable chemistry. In this course, the students are introduced to the 12 principles of green chemistry, the UN sustainable development goals, circular economy, and life-cycle assessment. In addition, the course highlights the central role of chemistry in sustainable development by covering key advanced areas in chemistry and sustainability research including design of safer chemicals and greening chemical synthesis, the use of bio-based raw materials, the role of catalysis in energy production and environment remediation applications, and new materials for energy storage and conversion.

Subject's learning outcomes

Code	Outcomes in terms of	Effects	Examination methods
Knowledge – Student knows and understands:			
W1	the 12 principles of green chemistry and illustrate the connection to sustainability and circularity to achieve the UN SDGs	JBS_K1_W01, JBS_K1_W02, JBS_K1_W05, JBS_K1_W06	written credit, credit with grade
W2	how biomass and other waste-based feedstocks (plastic waste and CO2) can be transformed into chemical building blocks and biobased polymers	JBS_K1_W01, JBS_K1_W02, JBS_K1_W03, JBS_K1_W04, JBS_K1_W07	written credit, credit with grade
W3	how innovative techniques such as (organo)catalysis, Heterogeneous catalysis, photochemistry, electrochemistry, and flow chemistry can potentially enhance the sustainability on lab and industrial scale	JBS_K1_W04, JBS_K1_W06, JBS_K1_W07	written credit, credit with grade
W4	CCUS processes and can demonstrate the current benchmark techniques for decarbonising large-scale industries	JBS_K1_W03, JBS_K1_W04, JBS_K1_W06, JBS_K1_W07	written credit, credit with grade
Skills – Student can:			
U1	explain the most important mechanisms of take-up and toxicity of organic compounds and apply this knowledge to propose changes in the molecular structure resulting in lower toxicity with equal functionality	JBS_K1_U02, JBS_K1_U04	written credit, credit with grade
U2	describe synthesis and properties of the main types of biobased polymers and evaluate the biodegradability of a given polymer	JBS_K1_U02, JBS_K1_U04	written credit, credit with grade
Social competences – Student is ready for:			
K1	consider different visions of the future and develop their own evidence-based opinions on sustainable chemistry and its emploument in reference to the balance of values linked to economic development, social welfare, and environmental protection.	JBS_K1_K03, JBS_K1_K04, JBS_K1_K05	written credit, credit with grade

Calculation of ECTS points

Activity form	Activity hours*	
Discussion class	36	
preparation for classes	38	
preparation of a multimedia presentation	35	
preparation for final test	39	
Student workload	**Hours** 148	**ECTS** 5.0

* hour means 45 minutes

Study content

No.	Course content	Subject's learning outcomes
1.	Interactive lecture: Introduction • Why sustainable chemistry? The intrinsic conservative character of chemical practice and industry also because of safety concerns… • Different sets of principles of sustainable chemistry • Concepts linked to sustainability - E.g. circularity, how chemistry is connected to 17 sustainability goals by the UN	W1, K1
2.	Interactive lecture: Green chemistry • 12 principles of green chemistry, with practical examples	W1, K1
3.	Interactive lecture: Life-cycle assessment • Principles of life-cycle assessment	W1, K1
4.	Interactive lecture: Sustainable chemistry metrics • Concepts such as atom economy, E-factor – Ecoscore	W1, K1
5.	Interactive lecture: Greening of classical organic synthesis pathways	W1, K1
6.	Interactive lecture: Design of safer chemicals • the context of REACH • Main mechanisms of toxicity of organic molecules • Design principles, molecular and formulation aspects, ‘domestication’ of chemistry • Examples related to principles of chemical reactivity as discussed above • Retrometabolic design	U1, K1
7.	Interactive lecture: Biobased and biodegradable plastics • Concepts - biobased, biodegradable, and variations of these two • The main benefits and drawbacks of polymers with respect to sustainability, macromolecules but also additives • ‘Green plastics’ • PLA (is this really green?)	U2, K1

No.	Course content	Subject's learning outcomes
8.	Interactive lecture: From lab scale to industry • sustainable engineering principles • importance of yield in long processes • energy efficiency & integration • Introduction of different unit operations in the chemical industry • Safety (safety culture, what happens when things go wrong - cases)	W3, K1
9.	Interactive lecture: Circular economy in industries • waste prevention and recycling • Introduction to major industries that utilize circular raw materials	W1, W2, K1
10.	Exercise session: Designing of green production of chemicals – Group exercise	W1, U1
11.	Exercise session: Designing of green production of chemicals – Group presentations	W1, U1, K1
12.	Interactive lecture: Lignin as raw material • Structure and sources • Processing by fractionation & depolymerization • derivatization to new platform molecules • bisphenol A alternatives • resins & urethanes	W2, K1
13.	Interactive lecture: Organocatalysis • Organocatalysis versus transition metal catalysis • Case study: CO_2 as a useful building block for monomer synthesis towards more sustainable polycarbonates and polyurethanes	W2, W3, K1
14.	Interactive lecture: Nanostructured materials and heterogeneous catalysis • Heterogeneous catalysis • Nanostructured solid catalysts • Hetrogeneising catalytic reactions	W2, W3, K1
15.	Interactive lecture: Introduction to photocatalysis • Photocatalysis • Applications (H_2 production, environmental protection applications such as water treatment, oxidation VOCs)	W1, W2, W3, K1

No.	Course content	Subject's learning outcomes
16.	Interactive lecture: Introduction to electrochemistry and electrocatalysis • Electrochemistry/electrocatalysis • Batteries	W1, W2, W3, K1
17.	Interactive lecture: Applications of inorganic chemistry in catalysis and energy production and storage • Fuel cells (types, current advancement and challenges) • PEM fuel cells (using green H2) • Direct alcohol fuel cells (using bio-based ethanol)	W1, W2, W3, K1
18.	Interactive lecture: Decarbonisation of industry • CCUS • Decarbonisation strategies for large-scale industries	W2, W4, K1

Course advanced

Teaching methods :

conversation lecture

Activities	Examination methods	Credit conditions
Discussion class	written credit, credit with grade	final exam – 40%; assignments – 35%; presentations – 20%; questionnaire – 5%

Entry requirements

Inorganic chemistry and Organic chemistry 1

Literature

Obligatory

1. Lecture notes and provided scientific articles during lectures

Effects

Code	Content
JBS_K1_K03	The graduate can consider different visions of the future and develop own evidence-based opinions in reference to the balance of values linked to economic development, social welfare, and environmental protection.
JBS_K1_K04	The graduate can critically assess and verbalize own competencies and skills related to different aspects of sustainability as well as their need for development.
JBS_K1_K05	The graduate can defend the importance of scientific data and methods as a basis for decision-making.
JBS_K1_U02	The graduate can present and report knowledge, methodologies, ideas, problems and solutions, clearly and comprehensively, in different forms destined for different audiences – including discussions and debates which require defending a substantiated opinion, as well as conversations in a foreign language at the CEFR B2 level.
JBS_K1_U04	The graduate can plan and effectuate simple sustainability-related projects under supervision and in the context of personal lifelong learning, both individually and in a team, using appropriate transversal skills and taking shared responsibility for the outcome.
JBS_K1_W01	The graduate can describe the concept of sustainability and recognize the differences in relevant definitions, models and approaches.
JBS_K1_W02	The graduate can explain the axiological background of sustainability and summarize key stages of development of the concept.
JBS_K1_W03	The graduate can give examples of sustainability-related dilemmas and hypothesize on the optimal course of action.
JBS_K1_W04	The graduate can identify sustainability-related problems specific to selected cultural, geographical, and political contexts.
JBS_K1_W05	The graduate can identify essential international instruments and institutions related to sustainability and explain their potential role in resolution of a given problem.
JBS_K1_W06	The graduate can describe interconnections between various aspects of sustainability and identify their significance in the context of natural and social sciences, with a special focus on disciplines included in the selected specialisation track (law and politics; chemistry and physics; chemistry and biology; economics and geography; economics, management and engineering; humanities).
JBS_K1_W07	The graduate can apply the theory and methodology of disciplines included in the selected specialisation track to sustainability-related problems, taking into consideration practical limitations such as protection of intellectual property.