PRINCIPI ZELENE KEMIJE

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Principi zelene kemije
Course title:	Principles of Green Chemistry
Članica nosilka/UL Member:	UL FKKT

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Kemija, prva stopnja, univerzitetni	Ni členitve (študijski program)	2. letnik, 3. letnik		izbirni

Univerzitetna koda predmeta/University course code:	0086906
Koda učne enote na članici/UL Member course code:	KESI8

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
15	15	45 LV			75	5

Nosilec predmeta/Lecturer:	prof. dr. Jernej Iskra, prof. dr. Marjan Jereb
Vrsta predmeta/Course type:	izbirni/elective
Jeziki/Languages:	Predavanja/Lectures: Angleščina, Slovenščina Vaje/Tutorial: Angleščina, Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Študent oz. kandidat mora imeti predmet opredeljen kot študijsko obveznost.	The course has to be assigned to the student.

Vsebina:	Content (Syllabus outline):
Paradigma zelene kemije: Principi zelene kemije, trajnostni razvoj, krožno gospodarstvo. **Metrika zelene kemije:** Ovrednotenje okoljskih parametrov reakcije, atomska ekonomija, E-faktor, LCA… **Alternativna topila** (voda, ionske tekočine, superkritična topila, organska topila). **Alternativni procesi in aktivacija** (kataliza, katalizatorji na trdnih nosilcih, biokataliza, encimi, mikrovalovi, ultrazvok, fotokemija, elektrokemija). **Biomasa kot vir kemikalij** (biorafinerije).	**The paradigm of Green Chemistry**: Principles of green chemistry, sustainable development, circular economy. **Green Chemistry Metrics**: Assessment of environmental parameters of reaction, atom economy, E-factor, LCA… **Alternative solvents** (water, ionic liquids, supercritical solvents, organic solvents). **Alternative processes and activation** (catalysis, solid supported catalysis, biocatalysis, enzymes, microwaves, ultrasound, photochemistry, electrochemistry). **Biomass as source of chemicals** (biorefineries).

Temeljna literatura in viri/Readings:

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Green Chemistry: An Introductory Text, **Mike Lancaster,** 2. izd., RSC Publishing, 2010. **Dopolnilna literatura** *Introduction to Chemicals from Biomass*, **James H. Clark, Fabien Deswarte,** Wiley, 2008. *Green Chemistry Metrics: A Guide to Determining and Evaluating Process Greenness*, **Andrew Dicks, Andrei Hent,** Springer, 2015.

Cilji in kompetence:	**Objectives and competences:**
Cilj predmeta je razvijati zavest o še donedavna zapostavljenem vidiku kemije, ki posveča poseben poudarek 'sredstvom' ne samo 'cilju'. Eno od temeljnih vodil zelene kemije je optimizacija vsake stopnje oz. postopka v nekem procesu do te mere, da ima čim manjši vpliv na okolje (količina topil, presežki reaktantov, postopek izolacije in čiščenja), da je energetsko nepotraten (npr. mikrovalovna aktivacija namesto termične) in kot celota tudi čim bolj ekonomsko upravičen. Študenti si pri predmetu pridobijo naslednje **specifične kompetence**: - vsaj delno premagovanje nekaterih stereotipov v kemiji - praktičen pristop in izvedba transformacij pod 'zelenimi' pogoji - kritičnost presoje pri izbiri metod in tehnik za izolacijo in čiščenje produktov - osnove načrtovanja in možnosti alternativnih sinteznih pristopov - okrepitev ozaveščanja o globalnem problemu varovanja okolja	*Learning outcomes:* Development of knowledge of the so far neglected aspect of chemistry which devotes attention to 'means' and not only to 'aims.' One of the fundamental principles of Green Chemistry is optimization of each step or a proceeding in a certain process to minimize the impact on the environment. The amount of solvents, excess of reactants, isolation and purification procedure, energy efficiency (microwave activation instead of thermal, for example) and economic viability are the governing parameters in this regard. *Competences:* Overcoming some stereotypes in chemistry; Practical approach and realization of transformation under 'green' conditions; Critical judgement in choosing isolation and purification methods and techniques; Base planning and alternative synthetic approaches. Strengthen the perception of the global protection of the environment.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje Poleg spoznanja načel zelene kemije študenti pridobijo osnovno znanje in razumevanje postopkov in transformacij pod pogoji, ki so okolju prijazni. Pridobijo osnove o alternativnih in obnovljivih reakcijskih medijih, reagentih in katalizatorjih. Spoznajo se z nekaterimi manj pogosto obravnavanimi reakcijskimi sistemi. Uporaba Področje zelene kemije je eno novejših, hitro se razvijajočih področij, in hkrati trendov v kemiji. Grozeče, ponekod že katastrofalne posledice človekovega nepremišljenega delovanja, bodo človeštvo prisilile v mnogo bolj preudarno ravnanje. Težišče vsesplošnega razvoja v kemiji bo po vsej verjetnosti vedno močneje povezano z načeli zelene kemije. Refleksija Študenti se seznanijo z osnovami in problematiko zelene kemije, nadgradijo klasično pojmovanje kemije, analizirajo in primerjajo strategije in pristope klasične in zelene kemije. Prenosljive spretnosti Študent pridobi osnove kritične presoje in ocene postopkov ali procesov z vidika standardov, ki se nanašajo na varovanje in zaščito okolja. Utrdi znanje	Knowledge and Comprehension Besides cognition of the Green Chemistry principles, students acquire basic knowledge and comprehension of proceedings and transformations under environmentally friendly conditions. They acquire a basic knowledge on alternative and recyclable reaction media, reagents and catalysts. They get some insight into less discussed reaction systems. Application The field of Green Chemistry is one of a novel, fast developing areas and, simultaneously, trends in chemistry. Horrible and in some cases yet disastrous consequences of inconsiderate human actions are going to force the mankind to act much more prudent. The focus of the common development in the future is likely going to be more and more strongly linked with the Green Chemistry principles. Analysis Students acquire basic knowledge and problems of Green Chemistry, and they upgrade the 'classical' comprehension of chemistry. They analyse and evaluate 'classical' and Green Chemistry strategies and approaches. Skill-transference Ability Students acquire the basics of critical judgement and evaluation of proceedings or methods from the

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in spretnosti o praktičnem delu in dobri laboratorijski praksi.	viewpoint of protection of environment. They deepen their knowledge and skills of experimental work and good laboratory practice.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, seminarske in laboratorijske vaje.	Lectures, seminars and laboratory work .

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
- opravljene laboratorijske vaje in kolokvij iz vaj - pisni izpit: pozitivno (6-10); negativno (1-5)		- accomplished laboratory work - test - written exam

Reference nosilca/Lecturer's references:

- JEREB, Marjan, ZUPAN, Marko, STAVBER, Stojan. Effective and selective iodofunctionalisation of organic molecules in water using iodine-hydrogen peroxide tandem. *Chem. Commun.*, 2004, 2614-2615.
- JEREB, Marjan. Highly atom-economic, catalyst- and solvent-free oxidation of sulfides into sulfones using 30% aqueous H2O2. *Green Chem.*, 2012, 14, 3047-3052.
-- JEREB, Marjan, VRAŽIČ, Dejan. Iodine-catalyzed disproportionation of aryl-substituted ethers under solvent-free reaction conditions. *Org. Biomol. Chem.*, 2013, 11, 1978-1999.

SANZ-MARCO, Amparo, MOŽINA, Štefan, MARTINEZ-ERRO, Samuel, ISKRA, Jernej, MARTÍN-MATUTE, Belén. Synthesis of αα-iodoketones from allylic alcohols through aerobic oxidative iodination. Advanced Synthesis & Catalysis, 2018, 360, 3884-3888, doi: 10.1002/adsc.201800661. [COBISS.SI-ID 1538065091].
KAWADA, Kosuke, OKANO, Koji, ISKRA, Jernej, KRAJNC, Peter, CAHARD, Dominique. Selectfluor[sup](TM) on a PolyHIPE material as regenerative and reusable polymer-supported electrophilic fluorinating agent. Advanced Synthesis & Catalysis, 2017, 359, 584-589, doi: 10.1002/adsc.201601312. [COBISS.SI-ID 30090791.
MOŽINA, Štefan, STAVBER, Stojan, ISKRA, Jernej. Dual catalysis for the aerobic oxidation of benzyl alcohols - nitric acid and fluorinated alcohol. European journal of organic chemistry 2017, 448-452, doi: 10.1002/ejoc.201601339. [COBISS.SI-ID 30184487].
SLUBAN, Melita, COJOCARU, Bogdan, PÂRVULESCU, Vasile I., ISKRA, Jernej, CERC KOROŠEC, Romana, UMEK, Polona. Protonated titanate nanotubes as solid acid catalyst for aldol condensation. Journal of catalysis, 2017, 346, 161-169, doi: 10.1016/j.jcat.2016.12.015. [COBISS.SI-ID 30232871].
BEDRAČ, Leon, ISKRA, Jernej. Iodine(I) reagents in hydrochloric acid-catalyzed oxidative iodination of aromatic compounds by hydrogen peroxide and iodine. Advanced Synthesis & Catalysis, 2013, 355, 1243-1248, doi: 10.1002/adsc.201300127. [COBISS.SI-ID 26709799].
PODGORŠEK, Ajda, EISSEN, Marco, FLECKENSTEIN, Jens, STAVBER, Stojan, ZUPAN, Marko, ISKRA, Jernej. Selective aerobic oxidative dibromination of alkenes with aqueous HBr and sodium nitrite as a catalyst. Green chemistry, 2009, 11, 120-126. [COBISS.SI-ID 22360359].

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