UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	KATALIZA IN HETEROGENI REAKCIJSKI SISTEMI
Course Title:	CATALYSIS AND HETEROGENEOUS REACTION SYSTEMS

Študijski program in stopnja Study Programme and Level	Študijska smer Study Field	Letnik Academic Year	Semester Semester
MAG Kemijsko inženirstvo, 2. stopnja	**/**	**1.**	**1.**
USP Chemical Engineering, 2nd Cycle	**/**	**1st**	**1st**

Vrsta predmeta / Course Type: obvezni / Mandatory

Univerzitetna koda predmeta / University Course Code: IN211

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Klinične vaje Work	Druge oblike študija	Samost. delo Individual Work	ECTS
60	**15**	**/**	**/**	**/**	**75**	**5**

Nosilec predmeta / Lecturer: prof. dr. Janez Levec / Dr. Janez Levec, Full Professor

Jeziki / Languages:

Predavanja / Lectures:	**slovenski / Slovenian**
Vaje / Tutorial:	**slovenski / Slovenian**

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:

Študent oz. kandidat mora imeti predmet opredeljen kot študijsko obveznost.

Prerequisites:

The course has to be assigned to the student.

Vsebina:

- Mehanizmi reakcij na površini trdnega katalizatorja. Kinetika reakcij na površini. Teorija prehodnega stanja površinskih reakcij. Reaktivnost površine.
- Karakterizacija trdnih katalizatorjev. Katalizatorji v farmacevtski in petrokemični industriji ter katalizatorji v procesih varstva okolja.
- Transport snovi in toplote na površino trdnega katalizatorja,
- Transport snovi in toplote znotraj poroznega katalizatorja. Efektivnostni faktor in globalna hitrost reakcije.
- Eksperimentalno določanja kinetičnih enačb za katalitske reakcije.
- Analiza in načrtovanje reaktorjev za katalitske

Content (Syllabus outline):

- Reaction mechanisms on the surface of solid catalysts. Reaction kinetics on the surface. Theory of the transition state of surface reactions.
- Characterization of solid catalysts. Catalysts in pharmaceutical and petrochemical industries and catalysts in the processes of environmental protection.
- Heat and mass transfer to the surface of solid catalyst,
- Heat and mass transfer within a porous catalyst. Effectiveness factor and global rate of reaction.
- Experimental determination of kinetic equations for catalytic reactions.
- Analysis and design of reactors for catalytic reactions. Pseudo-homogenous and heterogeneous models. Fixed-bed reactor.

reakcije. Psevdo-homogeni in heterogeni modeli. Reaktor s strnjenim slojem. Kapalni reaktor. Reaktor z goščo. Reaktor s fluidiziranim slojem. Adiabatni reaktor s strnjenim slojem in stabilno obratovanje. - Heterogene nekataliske reakcije. Reakcija v sistemu kapljevina-kapljevina in kapljevina-trdno. Reakcija v sistemu plin-kapljevina. Načrtovanje reaktorjev za nekatalitske heterogene reakcije.	Trickle-bed reactor. Slurry reactor. Fluidized-bed reactor. Fixed-bed adiabatic reactor and stable operation. - Heterogeneous non-catalytic reactions. Reactions in fluid-fluid, fluid-solid, and gas-fluid systems. Designing reactors for non-catalytic heterogeneous reactions.

Temeljna literatura in viri / Readings:

- G.F. Froment and K. B. Bischoff, Chemical Reactor Analysis and Design, 2. izdaja, Wiley, 1990, 661 strani (70 %)
- I. Chorkendorff and J.W. Niemantsverdriet, Concept of Modern Catalysis, 2. izdaja, Wiley-VCH Verlag, 2007, 457 stani (30 %)

Cilji in kompetence:	**Objectives and Competences:**
Predmet študentu razvija sposobnost analize in sinteze kompleksnih procesov s snovno pretvorbo (reakcijo). Predmet je nadaljevanje predmeta Kemijsko reakcijsko inženirstvo in ponuja znanja, ki so potrebna pri obravnavanje in načrtovanju procesov ter reaktorjev, v katerih potekajo reakcije z več fazami. Specifične kompetence predmeta so: - poznavanje, razumevanje in uporaba zakonov o ohranitvi mase, energije in gibalne količine, ko se kemijske pretvorbe odvijajo v večfaznem sistemu. - poznavanje, razumevanje in uporaba matematičnih zapisov hitrosti kemijskih pretvorb v heterogenih sistemih, - poznavanje in uporaba zvez med transportom toplote in snovi med fazami ter hitrostjo zginevanja snovi na površini katalizatorja, - poznavanje in uporaba zvez med notranjim transportom in hitrostjo reakcije znotraj poroznega katalizatorja	Developing competences for carrying out analysis and synthesis of complex reaction processes. The course is a follow-up to the Chemical reaction engineering course and provides the knowledge that is necessary for planning and designing processes in multi-phase reactors. Subject-specific competences include: - understanding and applying the laws of mass preservation, energy, and momentum when chemical changes occur in multi-phase systems, - understanding and applying mathematical descriptions of the rate of chemical changes in heterogeneous systems, - understanding and applying correlations of heat and mass transfer between the phases and the rate of mass disappearance at the catalyst surface, - understanding and applying correlations between internal transport and the rate of reaction within a porous catalyst.

Predvideni študijski rezultati:	**Intended Learning Outcomes:**
<u>Znanje in razumevanje</u> Študent spozna osnovne zakonitosti v zapisovanju hitrosti kemijskih in fizikalnih sprememb na infinitizemalni ravni reaktorja vendar na molekularni skali. Razume, da le	<u>Knowledge and Comprehension</u> Student becomes aware of fundamental principles of formulating the rate laws on the molecular level within the infinitesimal reactor volume. He understands that the integration over the whole

integracija po prostoru reaktorja daje zvezo med obratovalnimi pogoji in dobitkom na makro skali.	reactor space provides the performance equation(s), which relates the operational conditions to the reactor yield.
Uporaba Ta znanja mu omogočajo analizo obratovanja obstoječih in načrtovanje novih reaktorjev za vodenje enostavnih reakcij in reakcij v sistemu z več fazami.	Application Possessing sufficient fundamental knowledge student can analyze the operation of simple existing reactors and understand the design of a new one.
Refleksija Študent je sposoben povezati znanja iz matematike, fizike, kemije, transportnih pojavov in pridobiti poglobljeno sliko o dogajanju v reaktorju na mikro nivoju. Pri zahtevnem načrtovanju kemijskih reaktorjev in drugih procesnih naprav, je ta sposobnost potrebna tudi za komuniciranje/sodelovanje z drugimi tehniškimi strokovnjaki.	Analysis Student is capable of using the knowledge of chemical kinetics and transport phenomena to formulate the reactor model and thus obtain a deeper insight on the processes on micro as well as macro reactor scale. This ability is also appreciated for communication and cooperation with materials and other engineering professionals.
Prenosljive spretnosti Študent je usposobljen tako za eksperimentalno delo na področju katalitskih procesov kot za strokovno delo pri prenašanju eksperimentalnih rezultatov in literaturnih podatkov v industrijsko prakso. Sposoben je analizirati obstoječe naprave, določiti optimalne pogoje obratovanja in načrtovati nove reaktorje za heterogene reakcijske sisteme.	Skill-transference Ability Developed skills of integrating fundamental chemical and engineering knowledge into processes that are taking place within a multiphase chemical reactor.

Metode poučevanja in učenja:	**Learning and Teaching Methods:**
Predavanja in seminarji.	Lectures, seminars.

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Pisni in ustni izpit.		Written and oral exam

Reference nosilca / Lecturer's references:

- PERKO, David, POHAR, Andrej, **LEVEC, Janez**. Hydrogenation of CO_2 and CO in a high temperature gradient field between catalyst surface and opposite inert cool plate. *AIChE journal*, 2014, vol. 60, no. 2, pp. 613-622.
- OBRADOVIĆ, Ana, LIKOZAR, Blaž, **LEVEC, Janez**. Steam methane reforming over Ni-based pellet-type and Pt/Ni/Al_2O_3 structured plate-type catalyst : intrinsic kinetics study. *Industrial & engineering chemistry research*, 2013, vol. 52, no. 38, pp. 13597-13606.
- PERKO, David, **LEVEC, Janez**. Kinetic study of methanol synthesis over CuO/ZnO/Al_2O_3/V_2O_3 catalyst deposited on a stainless steel surface. *Industrial & engineering chemistry research*, 2012, vol. 51, no. 2, pp. 710-718.