ChE-408

Process intensification and green chemistry

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Cursus	Sem.	Type
Ing.-chim.	MA2, MA4	Opt.
Minor in Engineering for sustainability	E	Opt.

Contact language	English
Credits	3
Session	Summer
Semester	Spring
Exam	Written
Workload	90h
Weeks	14
Hours	**3 weekly**
Lecture	2 weekly
Exercises	1 weekly
Number of positions	

Summary

The first part of the course (~20%) is devoted to green chemistry and life cycle assessment. The remainder focuses on process intensification (fundamentals, detailed description of a few selected technologies, with a special focus on microreactors). Examples and exercises are included.

Content

Elements of Green Chemistry
Survey of the chemical industry; green chemistry basics; green metrics (atom economy, reaction mass efficiency, atom efficiency, effective mass yield, carbon efficiency, process mass intensity, energy intensity); industrial examples (phenol and Carbaryl production); green engineering principles
Essentials of Life Cycle Assessment
LCA aims and methodology; LCA metrics (impact categories); example: dimethyl carbonate production
Process Intensification
General principles and benefits; description of selected process intensification technologies (rotating packed beds, thin-film and rotor-stator spinning-disc reactors, oscillatory baffled reactors / crystallizers); moving from batch to continuous
Miniaturization
Characteristic process times; coupling of physico-chemical phenomena; effect of scale on process parameters
Effect of Mixing on Chemical Reactions
Macro-, meso- and micro-mixing; segregation; effect of total segregation on reactor performance; effect of partial segregation on reactor performance and selectivity; experimental mixing time characterization via physical and chemical methods
Mixing in Microchannels
Flow regimes in microchannels; mixing by pure diffusion; mixing time for laminar mixing in a shear field
Microreactors
Overview and benefits; passive micromixers (parallel lamination, serial lamination, chaotic mixers and segmented flow): flow regimes, mixing principles & examples; active micromixers (pressure disturbance, electrokinetic); commercial systems; industrial examples
RTD in microreactors
Microchannels; fixed-beds; static mixers; coiled tubes and flow inverters; segmented flow
Heat management in micro- and milli-reactors
Heat transfer in various geometries; thermal sensitivity; multipoint injection

Keywords

Green chemistry and engineering, life cycle assessment, process intensification, micro-structured reactors

Learning Prerequisites

Required courses

Transport phenomena
Chemical kinetics
Thermodynamics
Chemical reaction engineering
Thermal safety of chemical processes
Separation processes

Learning Outcomes

By the end of the course, the student must be able to:

- Estimate the "greenness" of a chemical process using the appropriate criteria and metrics
- Choose the best technology for carrying out a chemical reaction based on the relevant physico-chemical, economical and ecological criteria
- Design intensified processes with enhanced performance and sustainability
- Assess / Evaluate the impact of various technologies and operating conditions on key process factors such as heat transfer, mass transfer, mixing time and residence time distribution
- Describe the influence of micromixing on reactor performance and product distribution in homogeneous systems.
- Compute the residence time distribution, heat transfer performance and mixing time in micro-structured devices
- Design thermally safe micro- or milli-flow processes for highly exothermic reactions

Teaching methods

ex-cathedra with integrated exercise sessions

Expected student activities

Take notes during lectures
Participate to exercise sessions

Assessment methods

One final exam (written)

Resources

Bibliography

•Hessel, V., A. Renken, J.C. Schouten and J.-I. Yoshida (eds.). Micro Process Engineering—A Comprehensive Handbook. 2009. Wiley-VCH.
•Poux, M., P. Cognet and C. Gourdon. Green Process Engineering
From Concepts to Industrial Applications. 2015. CRC Press.
•Boodhoo, K. and A. Harvey. Process Intensification for Green Chemistry: Engineering Solutions for Sustainable Chemical Processing. 2013. John Wiley & Sons Inc.
•Kashid, M., A. Renken and L. Kiwi-Minsker. Microstructured Devices for Chemical Processing. 2015. Wiley-VCH.
•Poux, M., P. Cognet and C. Gourdon. Green Process Engineering. 2015. CRC Press.
•Hessel, V., Kralisch, D. and N. Kockmann. Novel Process Windows, 2015. Wiley.
•Cavani, F., G. Centi, S. Perathoner, F. Trifiro, Sustainable Industrial Processes. Sustainable Industrial Chemistry, 2009, Wiley-VCH.

Ressources en bibliothèque

- Process intensification for green chemistry / Boodhoo
- Sustainable industrial processes / Cavani
- Novel process windows / Hessel
- Micro process engineering / Hessel
- Microstructured devices for chemical processing / Kashid

- Green process engineering / Poux

Notes/Handbook
Slides in moodle

Moodle Link

- https://go.epfl.ch/ChE-408