UCLouvain

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2021

Advanced Reactor and Separation Technologies for the Production of Base Chemicals and Polymers

5.00 credits	30.0 h + 15.0 h	Q1

Teacher(s)	De Wilde Juray ;Luis Alconero Patricia ;Mignon Denis ;
Language :	English
Place of the course	Louvain-la-Neuve
Main themes	a) (Petro)chemicals & Polymers: Refining and petrochemicals: After an introduction and overview of refining and the (petro)chemical industry, three specific processes are studied in detail, analyzing as well the flow-sheets, thermodynamic, kinetic and eventual catalytic aspects, the reactor concepts, aspects related to the separation and purification of reactants and products, the energy requirements and the environmental impact, and the process safety. In the context of process intensification, advanced reactor technologies and their modeling are also dealt with. Polymerization processes: after a general introduction to polymerization processes, the various types of processes are reviewed and illustrated at hand of industrial examples. A special emphasis is put on the production processes of polymers produced in large amounts worldwide, such as polyethylene (HDPE, LDPE), polypropylene (PP), polystyrene (GPPS, HIPS), PVC. Some specific problems, such as the control of polymerization reactors are also addressed. b) Advanced Separation Technologies: Separation technologies are the cornerstone in the industry since they contribute with around 75% of the production cost. In addition to simple distillation, absorption or extraction, more complex techniques are required for challenging separations. The following advanced separation techniques will be addressed during the second part of the course: Enhanced Distillation (Extractive Distillation ; Salt Distillation ; Pressure-Swing Distillation ; Homogeneous Azeotropic Distillation ; Heterogeneous Azeotropic Distillation ; Reactive Distillation). Batch Distillation (Differential Distillation ; Binary Batch Rectification ; Batch Stripping and Complex Batch Distillation) Membrane Separations (Gas Permeation and pervaporation ; Membrane contactors).
Learning outcomes	**At the end of this learning unit, the student is able to :** **Contribution of the course to the program objectives** Referring to the LOs of the KIMA diploma, the following LOs are aimed at: • Axe 1: 1.1, 1.2; • Axe 2: 2.2, 2.3, 2.4, 2.5; • Axe 3: 3.1, 3.2, 3.3; • Axe 4: 4.1, 4.2, 4.4; • Axe 5: 5.3, 5.5, 5.6; • Axe 6: 6.1, 6.2, 6.3. **Specific learning outcomes of the course** Disciplinary learning outcomes At the end of this course the student will be able to: - Give an overview of the (petro)chemical industry. 1 - Give an overview of the major processes using natural gas, petroleum, coal or biomass as a feedstock. - Describe in detail: • the process flow sheet (species and heat) and the interaction with other processes, • the process safety, • the feedstock and product requirements, • the process conditions, • the chemistry and reaction thermodynamics and kinetics, • the catalyst if used, • the reactor type used and the appropriate reactor model(s), • the measures taken to increase the energy efficiency and to reduce the environmental impact, for three example processes, e.g.: • hydrocracking, • phthalic acid anhydride, • Fischer-Tropsch.

	- Interpret flow sheets of processes in general. - Take a variety of measures to increase the energy efficiency and to reduce the environmental impact of processes. - Explain the operation and modeling of advanced reactor technologies. - Explain key issues of molar mass control for free radical and step-growth polymers in ideal and non ideal batch and continuous reactors - Explain the influence of thermodynamic and physical parameters on molar mass control for free radical and step-growth polymers - Describe the main types of industrial polymerization processes, the major industry trends and explain the applicability range, advantages and disadvantages of the various options - Give major examples of industrial polymerization processes : polyolefins, styrenics, PVC, polyesters, polyamides and explain the key challenges in all cases - Understand the different advance separation techniques, when they are needed and the implications (energy requirements, environmental aspects, overall cost) involved with their use. - Describe mathematically the mass and energy transfer in the studied units. - Design the units. - Apply membrane technology as the substitution of conventional technology (distillation, absorption, extraction, etc). Transverse learning outcomes: At the end of this course the student will be able to: - Study independently the different aspects of a (petro)chemical and polymeric process as well as the separation techniques involved. - Present and explain the different aspects of a (petro)chemical process to a professional audience, in writing and orally. - Read, analyze and question a scientific paper. - Mobilize scientific and technical knowledge from various sources, including reference textbooks and the web to explain real life industrial examples of refining and petrochemical and polymerization processes, and advance separation processes. - To use a corpus of scientific and technical knowledge, allowing to solve given problems in the discipline studied. - To analyze, organize and develop an engineering approach for process development responding to specific needs or a given problem, the analysis of a given physical phenomenon or a system. - To contribute, as a team member, to the realization of a project with a given discipline or multiple disciplines according to a well described approach. - To efficiently communicate by writing and presentation, in English or French, the results of a well-defined project. - To show a rigorous behavior and critical thinking in carrying out scientific or technical tasks with respect for ethical issues. The contribution of this Teaching Unit to the development and command of the skills and learning outcomes of the programme(s) can be accessed at the end of this sheet, in the section entitled 'Programmes/courses offering this Teaching Unit'.
Evaluation methods	The students will be individually graded based on the objectives indicated above. The exam is an oral defense/discussion with or without a written preparation. Depending on the circumstances, the examination can be organized in presential or in remote mode. The parts taught by each teacher normally count for a third of the total mark, unless specified otherwise during the course. At the examination, the teachers have the right to reduce the weights of parts of the course if a deep deficiency (<=8/20) is found for another one.
Teaching methods	This course combines ex-cathedra teaching and projects/exercises with tutoring. Depending on the circumstances, the lectures and the practical sessions can be organized in presential and/or in remote mode. Processes for the production of (petro)chemicals and advanced reactor technologies: The theoretical courses are ex-cathedra. The students are encouraged to ask questions. During the course, the students are asked to read, analyze and question a number of scientific papers. Practical sessions are given in the form of exercise sessions. Advance Separation Processes: Theoretical classes are complemented with exercises sessions. If possible considering the current situation related to Covid, one practical session will be performed with the computer so that the student can control a distillation column (pilot plant) located in Toulouse. The student will be able to change the operation conditions of the column and watch on-live via several web-cam. After the session, the student will do the interpretation of results. This session is carried out in collaboration with the ENSIACET.
Content	Part A: - Introduction and overview of refining and the (petro)chemical industry. Three example processes are studied in detail, e.g.: • Hydrocracking;

	• Phtalic acid anhydride; • Fischer-Tropsch. Advanced reactor technologies for process intensification and their modeling. - Introduction to polymerization processes: • Suspension Polymerization • Emulsion Polymerization • Step-Growth Polymerization • Coordination Polymerization • Free-Radical Polymerization: Homogeneous Systems • Free-Radical Polymerization: Heterogeneous Systems • Control of Polymerization Reactors • Identification of emissions: water, air, waste Part B: - Advance Separation Techniques : Enhanced Distillation : • Extractive Distillation ; • Salt Distillation ; • Pressure-Swing Distillation ; • Homogeneous Azeotropic Distillation ; • Heterogeneous Azeotropic Distillation ; • Reactive Distillation Batch Distillation : • Differential Distillation ; • Binary Batch Rectification ; • Batch Stripping and Complex Batch Distillation Membrane Separations : • Gas Permeation and pervaporation ; • Membrane contactors (membrane-based absorption; membrane distillation; membrane crystallization)
Inline resources	https://moodleucl.uclouvain.be/course/view.php?id=10010
Bibliography	Les notes de cours sont fournies aux étudiants ou disponibles via Moodle. Reference books: - Separation Process Principles by Seader, J. D., Henley, Ernest J., Roper, D. Keith. Published by Wiley,2010, Binding: Hardcover 3rd Edition.
Other infos	This course requires basic knowledge in organic chemistry and chemical engineering (chemistry, thermodynamics, kinetics, reactor design and transport phenomena, polymer chemistry, fluid-fluid separation).
Faculty or entity in charge	FYKI

Programmes containing this learning unit (UE)

Program title	Acronym	Credits	Prerequisite	Learning outcomes
Master [120] in Chemical and Materials Engineering	KIMA2M	5		🔍