2026/2027 Academic Year

Course Guide:

SEPARATION PROCESSES

FACULTY OF CHEMICAL SCIENCES

1. IDENTIFICATION

Degree Program	Bachelor's Degree in Chemical Engineering	Código	801549
Course Name	Separation Processes	ECTS	12
Subject Area	Chemical Production Engineering		
Module	Chemical Technology		
Course Type	Compulsory	Year	Third year
		Semester	Full-year
Department	Chemical Engineering and Materials		

Lecturers in Charge

Activity	Lecturer	Email	Office
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Activity	Lecturer	Email	Office
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2. OBJECTIVES

General Objective

The objective of this course is to study the most commonly used separation processes in the chemical industry and the design of the equipment used to carry them out.

The overall objective is to provide students with a comprehensive and in-depth understanding of the fundamentals of the main separation processes, including those based on interphase equilibrium and those designed based on interphase mass transfer rates. The course also reviews methods for designing and calculating the dimensions of the equipment used in these processes.

Specific Objectives

- Discuss the mechanisms of mass transfer, including the effect of overall mass flow.
- Calculate the mass transfer rates and composition gradients under conditions of equimolar countercurrent diffusion and unimolecular diffusion.
- Calculate the mass transfer rates due to molecular diffusion in a laminar flow.
- Understand the dimensionless groups used in correlations of mass transfer coefficients.
- Explain the role of separation processes in industrial chemical processes.
- Explain the use of an energy-driven separation agent and/or a material separation agent in a separation process.
- Calculate the number of design variables for a separation process or any component within a process, and select a set of specifications.
- Calculate the quantities and compositions of the fractions resulting from a flash distillation.
- Calculate the dimensions of the separator for the phases resulting from a flash distillation.
- Explain, in the context of distillation, the need for a condenser to produce the reflux and for a reboiler to produce the rising steam.
- Identify the five construction lines used in the McCabe-Thiele method for the distillation of a binary mixture.
- Distinguish between the five possible thermal states of the feed in a distillation column.
- Apply the simplified McCabe-Thiele method to calculate the minimum reflux ratio, the minimum number of equilibrium plates, the number of plates required for a specified reflux ratio greater than its minimum value, and the optimal feed tray position, in order to achieve a specific separation between the two components of the feed to a distillation column.
- Extend the application of the simplified McCabe-Thiele method to a distillation column with multiple feed streams, side streams, or direct steam injection.
- Understand the concept of the pole for each section of a distillation column.
- Apply the Ponchon-Savarit method to calculate the minimum reflux ratio, the minimum number of equilibrium plates, the number of plates required for a specified reflux ratio greater than its minimum value, and the optimal position of the feed plate, in order to achieve a specific separation between the two components of the feed.
- For a multicomponent distillation, select the two key components, the operating pressure, and the type of condenser.
- For a specified separation between the two key components in a multicomponent distillation column, calculate the minimum number of equilibrium plates and the distribution of components other than the key components using Fenske’s equation, the minimum reflux ratio using Underwood’s method, the number of equilibrium plates for a reflux ratio greater than its minimum value using the Gilliland correlation, and locate the position of the feed plate.
- Calculate the number of equilibrium plates required for a multicomponent distillation using Kremser's approximate method based on effective absorption and desorption factors.
- Discuss situations in which liquid-liquid extraction may be preferred over distillation.
- Calculate the minimum amount of solvent; for values greater than this, calculate the compositions and flow rates of the extract and refined streams obtained in a single-stage or multi-stage extraction system with serial extraction equilibrium.
- For a specified solute recovery, calculate the number of equilibrium stages required in a countercurrent equilibrium stage cascade, with and without reflux.
- Calculate the overall efficiency of a distillation column and determine the number of actual stages based on the number of theoretical equilibrium stages and the height of the distillation column.

- Determine the diameter of a multi-stage column and size the condensate separator tank.
- Determine the height and number of transfer units in a packed column for the absorption of dilute and concentrated binary mixtures.
- Calculate the height of a packing column for an absorption process.
- For a backfill column, determine the height equivalent to a theoretical equilibrium level.
- Explain the differences between the loading or drag point and the flooding point of a packed column.
- Estimate the diameter of a packing column and the pressure drop across the packing.
- Understand the most commonly used porous adsorbents and their most significant properties.
- Distinguish between chemisorption and physical adsorption.
- Compare the different adsorption isotherms used to correlate the adsorption equilibrium of a component.
- Estimate the overall adsorption rate based on transport across the different stages of the process.
- Explain the concepts of the transfer zone width and the breakthrough curve of a fixed-bed adsorption system.
- Calculate the height, diameter, and time cycle of a fixed-bed adsorption system.
- Explain how ion exchange resins work.
- Understand the definitions of the quantities used in psychrometry.
- Distinguish between adiabatic saturation temperature and wet-bulb temperature.
- Design of a humidifier.
- Explain the concepts of equilibrium moisture and free moisture, as well as bound and unbound water, in a solid.
- Describe the different stages of the drying process.
- Calculate the drying rates for the different periods.
- Design a continuous dryer for different drying conditions.
- Explain how crystals grow and how their size distribution can be measured.
- Distinguish between primary and secondary crystal nucleation.
- Apply the MSMPR model to design a continuous crystallizer.

3. PRIOR KNOWLEDGE AND RECOMMENDATIONS

Recommendations

It is recommended that students have taken the course "Applied Thermodynamics" in the second year, second semester (fourth semester).

It is recommended that students be familiar with software tools and programs for solving complex problems.

It is recommended that students have a basic level of English that allows them to work with English-language literature and conduct information searches.

4. CONTENTS

Brief description

Mass transfer mechanisms: transport coefficients. Separation processes governed by mass transfer: distillation, extraction, leaching, absorption, adsorption, and ion exchange. Separation processes governed by mass and heat transfer: air–water interaction processes, drying, and crystallization. Equipment for separation processes.

Program

Topic 1. Mass transfer mechanisms. Transport coefficients.

Topic 2. Introduction to separation processes. Definitions and classification. Design variables of a separation system.

Topic 3. Equipment for interphase contact. Multi-stage and packed columns. Other equipment.

Topic 4. Distillation of binary mixtures. Single-stage distillation. Multi-stage distillation. Simplified and rigorous calculation methods.

Topic 5. Batch distillation of binary mixtures. Simple batch distillation. Rayleigh equation. Multi-stage batch distillation.

Topic 6. Multicomponent distillation. Approximate and rigorous calculation methods.

Topic 7. Design of interphase contact columns. Hydrodynamic conditions. Contact efficiency.

Topic 8. Extraction of binary and multicomponent mixtures. Approximate calculation methods. Leaching.

Topic 9. Absorption. Absorption and desorption of one or more components.

Topic 10. Adsorption. Equilibrium and kinetics. Adsorbents. Fixed-bed adsorption. Ion exchange.

Topic 11. Air-water interaction processes. Properties of humid air. Air humidification and dehumidification. Water cooling. Equipment design.

Topic 12. Drying. Equilibrium and kinetics. Dryer design.

Topic 13. Crystallization. Equilibrium and kinetics. Crystallizer design.

These topics are grouped into the following thematic sections:

SECTION 1. MECHANISMS OF MASS TRANSFER

(Topic 1)

SECTION 2. SEPARATION PROCESSES CONTROLLED BY MASS TRANSFER

(Topics 2, 4, 5, 6, 8, 9, and 10)

SECTION 3. SEPARATION PROCESSES CONTROLLED BY MASS AND HEAT TRANSFER

(Topics 11, 12, and 13)

SECTION 4. EQUIPMENT FOR SEPARATION PROCESSES

(Topics 3 and 7)

5. SKILLS

General

CG1-TQ1	Use concepts for the autonomous learning of new methods and theories.
CG1-TQ2	Design and manage procedures for applied experimentation, particularly for mass transfer operations.
CG4-TQ1	Apply concepts of mass transfer and separation processes. Design mass transfer equipment.

Specific

CE20-IP8	Explain the mechanisms and basic laws governing mass transport.
CE20-IP9	Identify the principles underlying the various separation processes.
CE20-IP10	Design the equipment needed to perform the various separation processes.
CE22-IP2	Measure technical parameters in equipment and facilities used for separation processes based on mass transfer and interpret the results.
CE23-IP2	Use commercial simulation software in chemical engineering.

Transversal

CT1-TQ1	Develop analytical and synthesis skills.
CT2-TQ1	Solve problems in the field of chemical engineering
CT5-TQ1	Consult, use, and analyze bibliographic sources in the field of chemical engineering.
CT5-TQ2	Search, use, and analyze specialized databases and resources available online.
CT6-TQ1	Use software tools and programs to calculate, simulate, and estimate.
CT8-TQ1	Demonstrate the ability to think critically and self-critically.

6. WORK HOURS AND BREAKDOWN BY ACTIVITY

Activity	In-person (hours)	Autonomous work (hours)	Credits
Theory	68	82	6
Seminars	33	37	2.8
Tutorials	4	11	0.6
Laboratory	25	19	1.76
Exams	6	15	0.84
Total	**136**	**164**	**12**

7. METHODOLOGY

The course's class time is divided into lectures, seminars, and tutorials.

The **lecture** component will be conducted as a single class comprising all students enrolled in the course. Lectures will primarily consist of presentations in which the theoretical knowledge necessary to solve the practical examples covered during the course will be presented.

The **seminars** will be held in two groups, each consisting of half of the students enrolled in the course, or in a single group for seminars based on the use of graphs and individual calculations, with the assistance of several instructors. These classes will cover both the solution of previously assigned problems and certain complementary and highly practical topics. Calculations will be performed using programmable calculators and technical software such as Excel and Origin. The seminars introduce concepts related to the Sustainable Development Goals and green chemical engineering.

Tutorials will be held in a single group, consisting of all students enrolled in the course. During the tutorials, students' progress on their individual assignments will be monitored.

The **laboratory** sessions will consist of an initial session for collecting experimental data in the lab. The calculation of the various parameters involved in the experiment will be performed during a second session in the computer lab. The necessary calculations will be carried out using scientific software (Excel and Origin). The critical discussion and analysis of the results obtained in each session will form the core of the technical reports to be submitted for each session. Before participating in the first laboratory session of the course, students must confirm in writing that they have read, understood, and accepted the laboratory safety regulations.

The UCM Virtual Campus will be used to provide students with the materials to be used in the lectures and seminars, and as a means of communication between the instructor and the students.

Part of the recommended reading list and the supporting materials posted on the virtual campus for the course's teaching activities will be in English. These materials include databases and websites with equipment descriptions and information on the companies that sell them.

8. REFERENCES

Basic

- Henley, E. J.; Seader, J. D.; Roper, D. K. Separation Process Principles, 3rd ed. International Student Version; Wiley, 2011.
- Wankat, P. C. Separation Process Engineering: Includes Mass Transfer Analysis, 4th ed.; Prentice Hall, 2017.
- Wankat, P. C. Rate-Controlled Separations; Springer Netherlands, 2012.
- Ajay, K. R. Coulson and Richardson's Chemical Engineering: Volume 2B: Separation Processes, 6th ed.; 2023.

Supplementary

- Seader, J. D.; Henley, E. J.; Roper, D. K. Separation Process Principles: With Applications Using Process Simulators, 4th ed.; 2016.
- McCabe, W.; Smith, J.; Harriott, P. Unit Operations of Chemical Engineering, 7th Edition; McGraw-Hill Science/Engineering/Math, 2004.
- Treybal, R.E., Operaciones de transferencia de masa, McGraw-Hill, México, 1988.

9. EVALUATION

The student's academic performance, as well as the final grade for the course, will be calculated on a weighted basis according to the percentages listed below, which will remain consistent across all exam sessions.

- **WRITTEN EXAMS: 70%**

The assessment of the skills acquired in the course (CG1-TQ1, CG4-TQ1, CE20-IP8, CE20-IP9, CE20-IP10, CE23-IP2, CT1-TQ1, CT2-TQ1, CT5-TQ1, CT5-TQ2, CT6-TQ1, CT8-TQ1) will be conducted through two written midterm exams, primarily practical in nature, which account for 70% of the overall grade. One of the exams will be scheduled approximately halfway through the course, and the other at the end of the course. Students who pass both midterm exams, with a grade of at least 4.0 out of 10.0 on each and an average grade of at least 5.0 out of 10.0, will not be required to take the final written exam (regular and make-up sessions). Students who must take the final exam must obtain a minimum score of 5.0. This requirement applies to both the regular and make-up exam sessions.

- **PERSONAL WORK: 10%**

The student's individual work will be assessed based on their ability to solve model problems through written tests or individual assignments.

The assessment of the individual work will determine the extent to which the competencies CG4-TQ1, CE20-IP10, CT2-TQ1, and CT8-TQ1 have been achieved, and accounts for 10% of the overall grade.

- **LABORATORY: 20%**

Student attendance at the laboratory practical sessions is mandatory. Grading will be based on the quality of the technical report for each practical session, responses to specific questions posed by the instructor during the laboratory session, a test of prior knowledge (including laboratory safety regulations), and a written exam.

The laboratory assessment will determine the degree to which the competencies CG1-TQ2, CE22-IP2, CE23-IP2, and CT8-TQ1 have been achieved and accounts for 20% of the overall grade.

- **ATTENDANCE AND ACTIVE PARTICIPATION IN CLASS:**

In order to be eligible for the final grade for the course during the regular exam period, students must have participated in at least 70% of the in-person classroom activities (lectures, seminars, and tutorials). Attendance at the laboratory is mandatory.

Grades for the activities included in the course assessment (midterm exams, labs, tutorials, and problem sets) will be communicated to students well in advance of the final exam, so that they can properly plan their study for this or other courses.

In particular, midterm exam grades will be released within a maximum of 20 days, except in the case of the second midterm, for which the timeframe may be shorter to accommodate the final exam.

In any case, a minimum period of seven days will be observed between the release of grades and the date of the course's final exam.

Activities conducted in English will be evaluated.

The final grade will be the weighted average of the assessed activities. However, to pass the course, students must achieve the minimum grade established for each of these activities. If this requirement is not met, the final grade will be the weighted average obtained, with a maximum of 4.5 out of 10.

ACTIVITY PLANNING - TIMELINE

TOPIC	ACTIVITY	HOURS	GROUPS	START	END
Section 1. Mechanisms of Mass Transfer.	Theory	4	1	1st week	
	Seminars/Tutorials	2	2	2nd week	
Section 2. Separation processes controlled by mass transfer	Theory	43	1	Weeks 2, 4–10, 12, and 14–22	
	Seminars/Tutorials	19	2	Weeks 2, 4–10, 12, 14–22	
Section 3. Separation processes controlled by mass and heat transfer	Theory	12	1	Weeks 22–30	
	Seminars/Tutorials	13	2	Weeks 22–30	
Section 4. Equipment for Separation Operations	Theory	9	1	Weeks 3, 11, and 13	
	Seminars/Tutorials	3	2	Weeks 3, 11, and 13	
Sections 1 to 4	Laboratory	25	2	Weeks 17 and 26	

SUMMARY OF ACTIVITIES

ACTIVITY	SKILLS	LECTURER ACTIVITY	STUDENT ACTIVITY	EVALUATION	P	NP	TOTAL	C
Theory	CG1-TQ1, CG4-TQ1, CE20-IP8, CE20-IP9, CE20-IP10	Oral presentation of the main points of each topic on the program	Pay attention and actively participate in class.	Written exams	68	82	150	
Seminars	CG4-TQ1, CE20-IP10, CE23-IP2, CT1-TQ1, CT2-TQ1, CT5-TQ1, CT5-TQ2, CT6-TQ1, CT8-TQ1	Formulating and solving numerical problems	Discussion and solution of the proposed problems	Written exams	33	37	70	
Tutorials	CG4-TQ1, CE20-IP10, CT2-TQ1, CT8-TQ1	Monitoring student progress. Grading written tests	Completion of individual assignments and written exams	Written tests and submission of solved problems	4	11	15	**10%**
Laboratory	CG1-TQ2, CE22-IP2, CE23-IP2, CT8-TQ1	Design of laboratory exercises and grading of the written exam	Collecting and interpreting experimental data, and preparing a technical report for each lab session. Taking the written exam	Evaluation of the technical reports for each practicum, responses to the instructor's questions, and a written exam	25	19	44	**20%**
Exams	CG1-TQ1, CG4-TQ1, CE20-IP10, CT1-TQ1, CT2-TQ1, CT8-TQ1	Exam design and grading. Student evaluation	Taking the exam	Written exams	6	15	21	**70%**

P: In-person activities

NP: Distance learning activities (independent study)

C: Grade