Academic year 2026/2027

Course Guide:

ADVANCED SEPARATION OPERATIONS

FACULTY OF CHEMICAL SCIENCES

1. IDENTIFICATION

Degree Programme	Bachelor's Degree in Chemical Engineering			Course Code	801559
Course Name	Advanced Separation Operations			ECTS	6
Subject Area	Operations in the Chemical Industry				
Module	Chemical Technology				
Course Type	Optional	Year	Fourth Year	Semester	Second Semester
Department	Chemical and Materials Engineering				

Teaching Staff

Activity	Lecturer	Email	Office
Lectures/Seminars/Tutorials	MARCOS LARRIBA MARTÍNEZ	marcoslarriba@ucm.es	QP-B07
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Computer Laboratory

Group	Lecturer	Email	Office
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2. OBJECTIVES

General objective

The main aim of the course “Advanced Separation Operations” is to study operations governed by mass transfer or by simultaneous mass and heat transfer that have been developed or enhanced to address specific separation problems or represent more recent technologies. Specifically, the course covers enhanced distillation techniques for separating azeotropic mixtures and selective extraction with supercritical fluids. It also studies membrane-based separations in detail, whose commercial applications have grown exponentially over the last 60 years, and introduces freeze-drying, given the increasing use of this technology for the preservation of food, medicines, vaccines and related products.

Specific objectives

- Describe improved and/or advanced separation operations.
- Understand the principles that govern these separation operations.
- Apply the fundamentals of mass and heat transfer for the design/simulation of equipment in which these processes take place.
- Describe the main applications, mainly those that are on a commercial scale.
- Improve skills in solving separation problems.

3. PRIOR KNOWLEDGE AND RECOMMENDATIONS

Prior knowledge

To follow this course properly, students must have previously acquired the knowledge and skills covered in to following courses: Fundamentals of Chemical Engineering, Applied Thermodynamics, Thermal Engineering, Fluid Mechanics, Separation Operations, Mathematics, Simulation and Control. Although enrolment is not formally conditional upon this prior learning, effective mastery of these prior knowledge is essential to take this course with reasonable prospects of success.

Recommendations

Students are recommended to have a basic level of English enabling them to consult bibliographic sources in English, search for information, and communicate in writing and orally in that language. They are also recommended to be familiar with computer tools and software packages used to solve complex problems, as well as with applications for writing, editing, and presenting technical reports. Furthermore, for better use of the subject, it is recommended to have knowledge of how to use the ASPEN PLUS programme, Excel sheets, Power Point, etc.

4. CONTENTS

Brief description

Improved distillation: Extractive distillation, Azeotropic distillation, Reactive distillation. Optimisation of distillation column sequences. Supercritical extraction. Membrane separation processes: Types of membranes and modules. Dialysis and electrodialysis. Reverse osmosis. Microfiltration. Ultrafiltration. Separation processes governed jointly by mass transfer and heat transfer: freeze-drying..

The subject integrates the principles of green chemistry to design safer, more efficient and sustainable environmental processes.

Course syllabus

Improved distillation

Topic 1

Triangular diagrams for improved distillation resolution: residual curve maps. Distillation curve maps. Bow tie regions.

Topic 2.

Types of improved distillations. Extractive distillation. Distillation with addition of salt. Distillation with pressure changes. Homogeneous and heterogeneous azeotropic distillation. Reactive distillation. Fundamentals. Equipment sizing. Industrial examples.

Supercritical Extraction

Topic 3.

Supercritical extraction. Properties of supercritical solvents. Solvent-solute separation methods. Solvent cycle. Fundamentals. Adding modifiers. Continuous and countercurrent operation. Commercial applications. Teams. Costs.

Membrane Operations

Topic 4.

Basic concepts of membrane separations. General applications. Classification of membranes. Preparation of membranes. Membrane modules. Systems design. Types of flow. Transport models. Reduction of permeate flow. Transport of dissolved species. Polarization of concentration. Rejections.

Topic 5.

Membrane processes with pressure difference as driving force: microfiltration, ultrafiltration, reverse osmosis. Aspects of separation. Type and materials of membranes. Applications. Calculation of the flux through the membrane.

Topic 6.

Membrane processes with concentration difference as driving force: pervaporation, gas permeation and dialysis. Aspects of separation. Type and materials of membranes. Applications. Calculation of the flux through the membrane.

Topic 7.

Membrane processes with electric potential difference as driving force: electrodialysis. Aspects of separation. Type and materials of membranes. Applications. Calculation of the flux through the membrane.

Topic 8.

Membrane processes with temperature difference as driving force: membrane distillation. Aspects of separation. Type and materials of membranes. Applications. Calculation of the flux through the membrane.

Advanced drying operations

Topic 9.

Freeze drying. Introduction. Fundamentals: freezing, sublimation and secondary drying. Teams. Formulation and optimisation of the cycle. Leaks. Determination of the end point. Process costs. Mathematical models in freeze drying.

5. COMPETENCES

General competences

CG1-TQ1	Use concepts for the autonomous learning of new methods and theories.
CG1-TQ2	Design and manage applied experimentation procedures, especially for the determination of thermodynamic and transport properties, and for the modeling of phenomena and systems in the field of chemical engineering, systems involving fluid flow, heat transfer, mass-transfer operations, chemical reaction kinetics, and reactors.
CG4-TQ1	Apply concepts of biotechnology, mass transfer, separation operations, and chemical reaction engineering. Evaluate the transformation of raw materials and energy resources.
CG5-TQ1	Analyse, design, simulate and optimise processes and products.

Specific competences

CE20-OIQ1	Explain the principles on which the different separation operations are based.
CE20-OIQ2	Design the equipment in which to carry out the different separation operations.
CE22-OIQ1	Measure technical parameters in equipment and installations for separation operations based on mass transfer.

CE22-OIQ2	Propose their technical interpretation.

Cross-cutting competences

CT1-TQ1	Develop capacity for analysis and synthesis.
CT2-TQ1	Solve problems in the area of Chemical Technology.
CT5-TQ1	Consult, use and analyse bibliographic sources in the area of Chemical Technology.
CT6-TQ1	Use computer tools and programs to calculate, simulate, and approximate.
CT8-TQ1	Demonstrate capacity for critical and self-critical reasoning.

6. WORKLOAD DISTRIBUTION BY ACTIVITY.

Activity	In-class (hours)	Self-study (hours)	Credits
Lectures	30	45	3
Seminars	15	20	1,4
Tutorials/guided work	3	4,5	0,3
Laboratories	12	9	0,84
Preparation of Coursework and Exams	3	8,5	0,46
Total	**63**	**87**	**6**

7. METHODOLOGY

The teaching time of the course is divided into theoretical classes, seminars, tutorials and laboratory practices.

The **theory** will be taught in a single group, made up of all the students enrolled in the subject. It will be developed with master classes in which the fundamentals of operations will be explained.

The **seminars** will also be carried out in a single group. These classes will fundamentally address the resolution of practical cases and hypothetical problems whose statements the students will have previously available. Sometimes, students will be asked to solve some of these problems, which will then be solved in class, and which will be collected to be taken into account as an evaluation element. Examples of current processes using membrane and freeze-drying technology will also be presented.

The **tutorials** will take place in two groups, each of which will be made up of half of the students enrolled in the subject. In the tutorials, doubts will be resolved, both conceptual and regarding the resolution of the exercises that are requested to be delivered. Likewise, it will be used to monitor the learning progress of each student by posing problems that they will have to solve.

Simulation practices will be carried out using a commercial software such as Aspen Plus. In total, each student is expected to carry out at least three practices with a total of 12 contact hours. They are expected to be carried out after completing the theoretical contents and the seminars of the thematic block.

As teaching resources, transparencies, the blackboard, videos and support material will mainly be used: the basic books of the subject and/or review articles that will be previously delivered to students through the UCM Virtual Campus. This tool will also be used as a means of communication between the teacher and students.

Part of the recommended bibliography and part of the support material that is deposited in the virtual campus for the development of the teaching activities of this subject are in English.

8. BIBLIOGRAPHY

Basic bibliography

Improved distillation and membranes

- E.J. Henley, J.D. Seader, D.K. Roper: "*Separation Process Principles*", John Wiley & Sons, Asia, 2011.

Supercritical Extraction

- G. Brunner: "*Gas Extraction*", Springer, New York, 1994.

Freeze drying

- ACE. Mujumdar: "Handbook of industrial drying", 3rd ed., Taylor & Francis, 2006.

Complementary bibliography

- R. W. Baker: "Membrane Technology and Applications", 2nd ed., John Wiley & Sons, West Sussex, 2004.
- W.S.W. Ho, K.K. Sirkar: "Membrane Handbook", Van Nostrand Reinhold, New York, 1992.
- M. Mulder: "Basic Principles of Membrane Technology", Kluwer Academic Publishers, 1991.
- W.L. McCabe, J.C. Smith, P. Harriot: "Unit Operations in Chemical Engineering", 7th ed., McGraw-Hill, Mexico, 2007.
- P.C. Wankat: "Equilibrium Staged Separations", Prentice Hall, New Jersey, 1994.
- E. Goldberg: "Handbook of Downstream Processing", Blackie & Academic & Professional, London, 1997.
- M. Verrall: "Downstream Processing of Natural Products", Wiley & Sons, West Sussex, 1996.
- A. Casp; J. Abril: "Food Conservation Processes", 2nd ed., Mundi- Prensa, 2003.

9. EVALUATION

Both directed tutorials and laboratory practices are mandatory. In order to access the final evaluation, it will be necessary for the student to have participated in at least 70% of the face-to-face activities.

The evaluation of the student's performance and the skills acquired in the subject will be carried out through:

1) an exam that will be taken on the date assigned by the faculty, which will contribute 60% of the weight in the final grade.
2) the delivery of exercises/problems/work, which will count for 25%.
3) the completion of practices and delivery of a report, which will account for the remaining 15%.

It is essential to obtain a minimum grade of 5.0 in the Laboratory Practices evaluation to pass the subject.

It is essential to obtain a minimum grade of 5.0 points out of 10 in each part of the final exam to pass the subject (first part: Topics 1 to 3, second part: Topics 4 to 9). In this way, all the competencies of the subject will be evaluated. It is essential to make oral presentations of the work.

- **WRITTEN EXAMS: 60%**

  The exam will consist of multiple-choice questions (multi-choice) with conceptual questions, simple calculations and problem solving.

- **DELIVERY OF PROBLEMS AND PROPOSED WORK: 25%**

  The delivery of solved problems will be requested before their discussion and resolution in the seminar classes. Also the completion of works and/or oral presentations.

- **LABORATORY PRACTICES: 15%**

  After carrying out the practices, a brief report of each practice carried out will be requested that summarizes the results obtained and a critical discussion of them. The completion of the practices is mandatory when they are scheduled, but if the memory is suspended in the ordinary call, a test will be taken in the extraordinary call. Students who have completed internships in previous courses will have the option of requesting that they not be repeated as long as no more than 1 course has passed since they carried out those internships.

The final grade will result from the weighted average of the evaluable activities. However, to pass the subject it will be necessary to achieve the minimum grade established in each of them. If this requirement is not met, the final grade will be the weighted average obtained, with a maximum of 4.5 out of 10.

The grades of the activities planned for the evaluation of the subject will be communicated to the students sufficiently in advance before the final exam, so that they can adequately plan the study of this or other subjects. In any case, the minimum period of ten days will be respected between the publication of the grades and the date of the final exam of the subject.

The subject integrates the principles of green chemistry to design safer, more efficient and sustainable environmental processes.

ACTIVITY SCHEDULE

UNIT	ACTIVITY	HOURS	GROUPS	START	END
I. Improved distillation	Theory	12	1	1st Week	3rd Week
	Seminar	6	1	4th Week	5th Week
II. Supercritical extraction	Theory	2	1	5th Week	5th Week
	Seminar	2	1	6th Week	6th Week
III. Membranes	Theory	10	1	6th Week	8th Week
	Seminar	5	1	9th Week	10th Week
IV. Freeze drying	Theory	4	1	10th Week	11th Week
	Seminar	3	1	11th Week	11th Week

SUMMARY OF ACTIVITIES

TEACHING ACTIVITY	ASSOCIATED COMPETENCES	TEACHING ACTIVITY	STUDENT ACTIVITY	EVALUATION	P	NP	TOTAL	C
Lectures	CG1-TQ1, CG2-TQ2, CG4-TQ1, CG5-TQ1, CE20-OIQ1, CE20-OIQ2 CT1-TQ1, CT8-TQ1	Present fundamentals and applications. Develop equipment sizing/simulation methods.	Attend and actively participate in the development of the class	Exam	30	45	75	
Seminars	CT2-TQ1, CT5-TQ1, CT6-TQ1, CT8-TQ1, CE20-OIQ2	Pose and/or solve real cases and hypothetical problems.	Attend and actively participate in the resolution of real cases and problems or exposures.	Delivery of solved exercises and completion of the exam	15	20	35	**25%**
Tutorials	CT2-TQ1, CT5-TQ1, CT6-TQ1, CT8-TQ1, CE20-OIQ2	Resolve doubts. Direct student learning with explanations and bibliographic recommendations	Consult the teacher with theoretical or practical doubts regarding the subject.		3	4,5	7,5	
Laboratory	CE22-OIQ1, CE22-IQ2	Propose, develop and develop laboratory practices	Carry out the simulations, obtain the data, summarize and interpret them in a written report	Memory correction	12	9	21	**15%**
Exams	All of the subject	Propose, supervise and correct the exam. Grade the student	Prepare and take the exam		3	8,5	11,5	**60%**

P: In-class activities

NP: Non-classroom activities (self-study)

C: Assessment weighting