FACULTAD DE
CIENCIAS QUÍMICAS

CHEMICAL ENGINEERING

COURSE GUIDE

BSc Chemistry

Academic Year 2026-2027

UNIVERSIDAD
COMPLUTENSE
MADRID

I.- IDENTIFICATION

COURSE NAME:	**Chemical Engineering**
CREDITS (ECTS):	**9**
CHARACTER:	**Compulsory**
SUBJECT:	**Fundamental Complements of Chemistry**
MODULE:	**Fundamental**
DEGREE:	**Bachelor in Chemistry**
SEMESTER/TERM:	**Second (second year)**
DEPARTMENT/S:	**Chemical Engineering and Materials**

LECTURERS:

Coordinator	**Lecturer:** MARÍA ISABEL GUIJARRO GIL **Department:** Chemical Engineering and Materials **Office:** QA-B70A **e-mail:** migg@quim.ucm.es

Theory Group E	
Lectures **Seminars** **Tutorials**	**Lecturer:** JESÚS ESTEBAN SERRANO **Department:** Chemical Engineering and Materials **Office:** QP-115 **e-mail:** jeesteba@ucm.es
Lectures **Seminars** **Tutorials**	**Lecturer:** MARÍA MARTÍN MARTÍNEZ **Department:** Chemical Engineering and Materials **Office:** QA-154 **e-mail:** mariam74@ucm.es
Lectures **Seminars** **Tutorials**	**Lecturer:** VICTORIA RIGUAL HERNÁNDEZ **Department:** Chemical Engineering and Materials **Office:** QB-536 **e-mail:** vicrigua@ucm.es

Laboratory

Grupo	Cuatri.	Profesor/a	Correo	Despacho	Depar.
E	2	Jesús Esteban Serrano	jeesteba@ucm.es	QP-115	IQyM
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II.- OBJECTIVES

GENERAL OBJECTIVE

The general objective is to provide students with fundamental knowledges of the different areas in Chemical Engineering (unit operations, chemical reaction engineering and process engineering) that will allow them to understand the main operations and the fundamentals of the equipment that enable an industrial chemical plant to work. To provide the students the ability to assess the importance of chemistry in the industrial and environmental context.

SPECIFIC OBJECTIVES:

- To know the main milestones in the chemical industry, and the current situation of chemical industry in the world, Europe, and Spain.
- To understand the classic ways of exploitation in the chemical industry, the ways of operating and its objectives, as well as to understand what a raw material is and its main characteristics.
- To learn the underlying concepts of mass and energy balances, as well as the practical aspects for the resolution of problems based on the law of conservation of matter and energy.
- To be able to approach and solve steady state mass balance problems, both of isolated units and of several units connected to each other.
- To understand the concept of unit operation, as well as to know the main unit operations and the equipment in which they are carried out.
- To understand the nature of transport phenomena, and their relationship with unit operations. To know the different transport phenomena and their mechanisms.
- To know the objective of fluid dynamics, the concepts of fluid and flow and their types, and the proper use of Bernouilli's equation, or the principle of conservation of mechanical energy, for incompressible fluids.
- To know the main elements constituting a pipe network: pumps, flow meters, pipes, and valves.
- To understand the different mechanisms of heat transfer and to solve simple problems related to conduction and convection phenomena.
- To understand the design equation for concentric-tube heat exchangers and its difference with those for industrial shell and tube, and plate heat exchangers.
- To solve problems of heat exchangers and evaporators focused on calculating the exchange area.
- To know the main operations based on the momentum exchange: sedimentation, centrifugation, filtration, and agitation. To understand the purpose and basis of each operation, and to know the equipment in which they operate and the differences among them.
- To know the fundamentals and applications of stage distillation, as well as the equipment to carried it out. To understand and apply the McCabe-Thiele method for designing basic rectification columns, and the main design parameters of this type of equipment.

- To understand the aim of Chemical Reaction Engineering, and its main tools to study reaction systems.
- To understand the differences between homogeneous and heterogeneous systems where chemical reactions occur. To know, from rate equations, the time evolution of compounds in homogeneous systems both with elemental reactions and reaction networks: equilibrium reactions, series and parallel reactions.
- To apply these concepts in the resolution of standard problems focused on the application of the differential and integral methods for the study of the kinetics of the reaction system.
- To understand and know the main concepts of reactions catalysed by solids and their relevance: importance of the transport phenomena, the most representative kinetic models, and the most relevant applications.
- To know the differences and similarities of the different types of ideal reactors, as well as to know how to design ideal isothermal reactors.
- To understand the difference between homogeneous and heterogeneous reactors, as well as to know the importance of the latter in the Chemical Industry.
- To know the processes and raw materials for the manufacture of ammonia.
- To know the processes and raw materials for the manufacture of sulfuric acid.
- To know the ways of exploitation of crude oil and natural gas.
- To learn the measures for the control and remediation of pollution.

III.- PREVIOUS KNOWLEDGE AND RECOMMENDATIONS

PREVIOUS KNOWLEDGE:

Inorganic and organic nomenclature and formulation. Stoichiometry. Unit conversion. Thermodynamics. Basic knowledge of inorganic and organic chemistry. Basic concepts of chemical kinetics.

RECOMMENDATIONS:

Having passed the subjects General Chemistry and Mathematics (Basic Subjects).

IV.- CONTENTS

BRIEF DESCRIPTION:

General concepts: continuous and discontinuous operations. Process flow diagrams. Material and energy balances. Chemical processes of industrial interest. Energy and environment. Unit operations. Fluid dynamics. Heat transfer. Mass transfer. Separation processes. Chemical reaction engineering. Applied chemical kinetics. Chemical reactors.

■ SYLLABUS:

SECTION 1 INTRODUCTION AND GENERAL CONCEPTS

Unit 1: Chemical industry and chemical engineering

Historical development of chemical processes and chemical industry in Spain. Structure of the chemical industry. Use of raw materials of inorganic and organic nature. Products and applications.

Unit 2: Basic concepts in chemical engineering

Stoichiometry (concept of mole, limiting reagent, conversion, yield, selectivity, stream composition). Study of the main variables in a chemical process and their unit conversions.

Unit 3: Concepts of operation and transport phenomena

Continuous and discontinuous operations. Steady and non-steady state regimes. Types of phases contact. Fundamentals and classification of operations. Molecular and turbulent transport. Basic transport equations. Transport coefficients.

SECTION 2 MACROSCOPIC MATERIAL BALANCES

Unit 4: Macroscopic balances of extensive magnitudes

General conservation equation. Mass and enthalpy balances. Resolution of practical cases of mass balances.

SECTION 3 FLUID DYNAMICS

Unit 5: Fluid dynamics

Definitions and classification. Laminar and turbulent regime. Fluid transport by pipes. Bernouilli's equation. Pumps, flow-meters and other accidents in pipelines. Fluid dynamics operations: agitation, filtration, sedimentation, and centrifugation.

SECTION 4 HEAT TRANSFER

Unit 6: Heat transfer

Mechanisms: conduction, convection, and radiation. Basic transport equations. Heat exchangers. Evaporation.

SECTION 5 MASS TRANSFER

Unit 7: Mass transfer

Diffusion and convection. Basic transport equations. Mass transfer operations: simple distillation and rectification.

SECTION 6 REACTION ENGINEERING AND REACTORS

Unit 8: Chemical reaction engineering

Classification of chemical reactions. Kinetic models: reaction schemes and reaction rate. Homogeneous and simple reactions: determination of kinetic models. Catalytic heterogeneous reactions: solid catalysts and phenomenology.

Unit 9: Chemical reactors

Classification: number of phases, type of operation and degree of mixing. Ideal reactors for homogeneous reactions: discontinuous (batch) reactor and continuous reactors. Heterogeneous reactors: description and applications.

SECTION 7 INDUSTRIAL CHEMISTRY

Unit 10: Ammonia as the main product of the Inorganic Chemical Industry

Processes and raw materials for the manufacture of ammonia. Ammonia applications.

Unit 11: Manufacture of sulfuric acid

Raw materials and processes. Metal sulphides as chemical industry raw material. Composition and characteristics. Pyrite roasting.

Unit 12: Use of crude oil and sustainable alternatives

Origin, composition, and characterization. Treatment of crude oil and its fractions. Refinery products. Basic petrochemical industry. Derived Industries. Biorefinery

Unit 13: Chemical industry and the environment

Types, origin, and characterization of pollution? Internal and external corrective actions. Minimization of waste and emissions. Purification, management and use of waste.

V.- COMPETENCES

GENERAL:

- **CG1-MF1:** To recognize and value chemical processes in everyday life.
- **CG2-MF1:** To link Chemistry with other fields of study.
- **CG3-MF1:** To progress their studies in multidisciplinary areas.
- **CG5-MF1:** To demonstrate the knowledge and understanding of essential facts, concepts, principles and theories related to Chemistry.
- **CG6-MF1:** To analyse and solve qualitative and quantitative problems.
- **CG7-MF1:** To recognise and analyse new problems and to design new solving strategies.
- **CG8-MF1:** To be able to look up and apply efficiently scientific information.

SPECIFIC:

- **CE30-MFCQ1:** To describe the most relevant processes in the chemical industry.
- **CE30-MFCQ2:** To value the importance of the effective planning and the development of chemical processes developed in the area of Chemical Engineering.
- **CE31-MFCQ1:** To explain and understand in a streamlined manner process flow diagrams of industrial processes, identifying the operations and main equipment of a chemical plant.
- **CE31-MFCQ2:** To formulate and solve the properties balances that describes how a system changes due to a disruption produced by mass and heat transfer.

- **CE31-MFCQ3**: To classify separation processes according to physical-chemical and thermodynamic principles that compose the industrial chemical process.
- **CE31-MFCQ4:** To describe the operation of chemical reactors and to value the importance of chemical kinetics in their design.

- **CROSS DISCIPLINARY:**
  - **CT2-MF1**: To work as a team.
  - **CT3-MF1**: To demonstrate critical thinking and self-criticism.
  - **CT5-MF1**: To correctly use chemical-related information, bibliography, and specialised databases.
  - **CT6-MF1**: To identify the importance of chemistry within the industrial, environmental, and social framework.
  - **CT11-MF1**: To develop self-learning skills.
  - **CT12-MF1**: To identify the current energy concerns and their implications.
  - **CT12-MF2**: To develop sensitivity to environmental topics.

VI.- LEARNING OUTCOMES

Having passed this course, the student must be able to:

- Differentiate lab-scale processes from industrial processes regarding to operational volume, yields, raw material employed, resources valorisation, presence of rate determining steps, etc.
- Describe the concept and overall methodology followed in Chemical Engineering, and its links with other scientific and technical fields.
- Understand in a streamlined manner process flow diagrams of industrial processes, identifying the main operations and equipment involved in a chemical plant.
- Formulate and solve mass balance exercises, involving (or not) chemical reactions in isolated process units, and simple processes with limited number of recycling and purge streams.
- Explain the importance of a chemical-physical industrial process, properly ordered unit operations, operational requirements in every unit operation, and the nature of every operation.
- Define the core aspects of underlying phenomena of every unit operation process which will determine the specific design of the unit process. Relate physical laws and empirical equations that describe phenomena with the equations employed in the design of some selected unit operations.
- Describe differences and similarities of different fluids and their flows, as well as the concept of viscosity and its physical meaning.
- Deduction of the mechanical energy conservation, so called Bernouilli's equation, and explain every parameter involved. Apply the Bernouilli's equation to straightforward systems, estimating every parameter and the pump power.
- Explain heat transfer and the mechanisms involved in this phenomenon. Apply and know empirical equations and the main mechanisms that enable to deduce flow rates and energy flow rates in simple geometries, as well as the corresponding temperature profiles.
- Design industrial double pipe heat exchangers applied to simple cases of study.

- Explain mass transfer (concept and mechanisms) and phase equilibria, especially fluid phase equilibria.
- Explain distillation processes as an example of unit operation based on liquid-vapor equilibrium as well as Raoult's and Dalton's laws.
- Design simple rectification columns for ideal and real binary systems using different kind of feed and applying McCabe-Thiele plot method to total and partial condensers using operational and extreme conditions in the rectification column.
- Apply general mass balances and volatiles mass balances in different sections and trays of a rectification column for a better understanding of McCabe-Thiele method.
- Explain the concept of chemical reaction Engineering, tools employed in the topic, and its importance in scale-up of chemical reactors.
- Define main concepts of applied chemical kinetics: reaction rates, variables involved, equations (models). Relate the reaction rates related variables and equations involved.
- Solve simple problems of applied kinetics: relation between unit constants and kinetics order, calculation of kinetic constants using differential and/or integral methodologies and calculation of activation energies.
- Design ideal chemical reactors: batch and continuous reactor, differentiate them qualitatively and quantitatively.
- Apply the concepts of: reaction time, dead time, and residence time.
- Describe the importance of different operations and processes used in the manufacture of ammonia, sulfuric acid, and refinery products.
- Differentiate the main characteristics of raw materials employed in the above-mentioned examples of processes within the chemical industry.
- Describe the different reactors and technologies employed in the above-mentioned examples of processes within the chemical industry.
- Explain the current environmental management problems that emerge from the chemical industry and similar industries in the environment. Explain the main technological processes available to avoid pollution or limit the undesirable side-effects of pollutants in the atmosphere, hydrosphere, lithosphere, and biosphere.

VII.- WORKING HOURS DISTRIBUTED BY ACTIVITY

Activity	Attendance (hours)	Self-study (hours)	Credits/ hours
Lectures	42	88	5.2
Seminars / Problem classes	24	26	2.0
Tutorials / Guided work	4	6	0.4
Practical activities	6	9	0.6
Written assignments and exams preparation	6	14	0.8
Total	**82**	**143**	**9**

VIII.- METHODOLOGY

The contents of the course are presented to the students through lectures, seminars, scheduled evaluation tests (tutorials), and practical activities.

Lectures will be master lessons in which the complete syllabus will be exposed. Some topics will include problem resolution. Audio-visual content will be employed in the development of the lesson for an optimal understanding of every topic. Schemes, tables, figures, and any other kind of resource will be available for the students in paper/computer format through the Virtual Campus.

Seminars will be sessions to solve selected exercises. A list of exercises will be given in advance so the student may solve them by his/her own.

Scheduled evaluation tests (tutorials) are the framework in which the student will develop and solve theoretical questions, practical questions, and numerical exercises. Tutorials will cover in every session some of the topics of the subject. The students will be informed in advanced about the dates and topics that will be evaluated in every tutorial.

Practical activities will be developed in small groups. A complete session will be dedicated to show videos of industrial processes, explaining different kind of pumps, flow meters, and other basic equipment used in industrial facilities. Another session will be employed to show the students some of the most employed software tools in Chemical Engineering.

"Campus Virtual" (CV) will be used to create a responsive communication between lecturers and students, as a tool to facilitate the material that is going to be taught during lectures and seminars. "Campus Virtual" will also be employed to provide some supplementary material that can be relevant in the course but not necessarily be presented during a class.

IX.- BIBLIOGRAPHY

At the beginning of the course, the recommended bibliography will be explained, pointing out the most relevant aspects of each book and how the contents fit the subject's topics. A specific textbook will not be followed during the development of the subject.

BASIC:

- Aguado, J. y *col.*: "*Ingeniería de la Industria Alimentaria*", Ed. Síntesis, Madrid, 1999.
- Calleja, G. y *col.*: "*Introducción a la Ingeniería Química*", Volumen I: Conceptos básicos. Ed. Síntesis, Madrid, 1999.

COMPLEMENTARY:

- Himmelblau D.M. "*Basic Principles and Calculations in Chemical Engineering*". 5th ed. Englewood Cliffs, N.J.: Prentice-Hall; 1989.
- Felder R.M., Rousseau R.W. "*Elementary Principles of Chemical Processes*". 3rd ed. New York: John Wiley & Sons; 2000.
- Ruíz Palacín, J.: *"Problemas resueltos de balances de materia en estado estacionario"*, Ed. Prensas Universitarias de Zaragoza, 2009.

- Izquierdo, J.F., Costa, J., Martínez de la Ossa, E., Rodríguez, J., Izquierdo, M. *"Introducción a la Ingeniería Química: Problemas resueltos de balances de materia y energía"*, Ed. Reverté, 2011.
- Levenspiel O. "*Chemical Reaction Engineering*". 3rd ed. New York: John Wiley & Sons; 1999.
- Levenspiel O. "*Engineering Flow and Heat Exchange"*. New York: Plenum; 1986.
- MacCabe WL,y col. "U*nit Operations of Chemical Engineering*". New Yorketc.: McGraw-Hill; 1956.
- Vian Ortuño, Á.: "*Introducción a la Química Industrial", * 2ª ed., Ed. Reverté; Barcelona, 1994.

In addition to the basic and complementary bibliography, specific bibliography for each topic could be provided to the students.

X.- ASSESSMENT PROCEDURE

The academic performance and the competencies achieved by the students will be evaluated, considering two parts: the written exams accomplished and the student's personal work.

It is mandatory to attend all the programmed evaluation tests and practical activities (either individually or in small groups). In addition, the final evaluation will be dependent on the student's attendance of at least 70 % of lectures and seminars.

The student's academic performance and the final marks of the course will be computed in a weighted manner, considering the following percentages and aspects, which will be maintained in the ordinary and extraordinary calls.

- **WRITTEN EXAMS: 70%**

  The **exams** will consist of two parts: (i) theoretical questions (development or direct application of the theory) and (ii) resolution of numerical problems. Students must obtain a minimum score of 4 out of 10 in each part of the exam (theoretical questions and numerical problems).

  There will be two written midterm exams (**partial exams):** one around the middle of the term and another at the end. **To pass the course through the midterms (continuous assessment), students must obtain at least 4 out of 10 in each partial exam.**

  Midterm exams that are passed (with a grade of 5 or higher) **will exempt students from the corresponding part in the final exam** (only in the ordinary call). Students who pass both midterms are not required to take the final exam (ordinary call). Students who pass only one midterm with a grade of 5 or higher may take, in the final exam (ordinary call), only the midterm they failed. In this case, a minimum score of 4 out of 10 must be obtained in the failed midterm to calculate the arithmetic mean with the passed midterm.

Students who do not pass the ordinary call must be examined on the entire course syllabus in the extraordinary call.

The exam grade will account for 70% of the overall assessment. **To pass the course, the final weighted grade (including all assessment activities) must be at least 5 out of 10**.

The final grade will be calculated as the weighted average of all assessment activities. However, to pass the course, students must achieve the minimum required grade in each of them. If this requirement is not met, the final grade will be the calculated weighted average, with a maximum of 4.5 out of 10.

The written exam will evaluate the general competences, CG1-MF1, CG2-MF1, CG5-MF1, CG6-MF1, CG7-MF1; the specific competences CE30-MFCQ1, CE30-MFCQ2, CE31-MFCQ1, CE31-MFCQ2, CE31-MFCQ3, CE31-MFCQ4, and cross-disciplinary competences CT3-MF1, CT5-MF1, CT6-MF1, CT12-MF1, CT12-MF2.

- **SCHEDULED EVALUATION TESTS (TUTORIALS): 20%**

During the course, there will be **four individual scheduled evaluations tests (tutorials)** in which the student will develop self-work, which may include theoretical questions, open practical exercises, and numerical problems that must be handled and solved. These questions will fulfil a specific number of units in each tutorial. The units and dates will be previously informed to the students.

The students will keep the marks obtained in the evaluation exercises in both ordinary and extraordinary calls.

The marking of these exercises will serve to evaluate the achievement of the general competences CG1-MF1, CG2-MF1, CG3-MF1, CG6-MF1, CG7-MF1, CG8-MF1, specific competences CE30-MFCQ2, CE31-MFCQ1, CE31-MFCQ2, CE31-MFCQ3 and cross-disciplinary competences CT2-MF1, CT3-MF1, CT5-MF1, CT6-MF1, CT11-MF1, CT12-MF1, CT12-MF2.

- **PRACTICAL ACTIVITIES: 10%**

Attendance at all practical activities is **compulsory** and will be evaluated by a questionnaire where the concepts explained in these sessions will be asked. These activities will be beneficial to improve the knowledge acquired during the lectures, seminars, and other programmed activities. The latter will mean the achievement of the general, specific, and cross-disciplinary competences.

The students will keep the marks obtained in the evaluation exercises in both ordinary and extraordinary calls.

The marks obtained in the scheduled activities (scheduled evaluation tests, practical activities) will be communicated to the students soon enough before the final exam to let the students adequately plan the study of this or other subjects.

In any case, a minimum of seven days between the publication of the marks and the date of the final exam will be scheduled.

Students who completed the laboratory sessions in previous academic years may request their validation, provided that no more than one year has passed since they carried them out and that they were graded above five.

ACTIVITY SCHEDULE

UNIT	ACTIVITY	HOURS	GROUPS	START	END
1. Chemical industry and chemical engineering	Lectures	1	1	1st week	1st week
2. Basic concepts in chemical engineering	Lectures and Seminars	4	1	1st week	1st week
3. Concepts of operation and transport phenomena	Lectures	4	1	2nd week	2nd week
4. Macroscopic balances of extensive magnitudes	Lectures and Seminars	10	1	2nd week	6th week
5. Fluid flow	Lectures and Seminars	8	1	3th week	5th week
6. Heat transfer	Lectures and Seminars	7	1	5th week	7th week
7. Mass transfer	Lectures and Seminars	7	1	7th week	8th week
8. Chemical reaction engineering	Lectures and Seminars	8	1	9th week	10th week

UNIT	ACTIVITY	HOURS	GROUPS	START	END
9. Chemical reactors	Lectures and Seminars	7	1	10th week	12th week
10. Ammonia as the main product of the Inorganic Chemical Industry	Lectures	2	1	12th week	12th week
11. Manufacture of sulfuric acid	Lectures	2	1	12th week	13th week
12. Use of crude oil and sustainable alternatives	Lectures	4	1	13th week	14th week
13. Chemical industry and the environment	Lectures	2	1	14th week	14th week
TUTORIAL AND PRACTICAL ACTIVITIES					
Scheduled evaluation tests	Test 1	1	1	4th week	4th week
	Test 2	1	1	7th week	7th week
	Test 3	1	1	9th week	9th week
	Test 4	1	1	13th week	13th week
Practical activities	2 practical activities	6	2	14th week	14th week

SUMMARY OF ACTIVITIES

Teaching activity	Associated competences	Lecturer activity	Student activity	Assessment procedure	P	NP	Total	C
Lectures	CG1-MF1, CG2-MF1, CG3-MF1 CG5-MF1 CE30-MFCQ1 CE30-MFCQ2 CE31-MFCQ3 CE31-MFCQ4 CT6-MF1 CT12MF1 CT12-MF2	Presentation of theoretical concepts and approach of problems.	Attention and active participation in the development of the class.	Written exams.	42	88	130	
Problem-solving classes /Seminars	CG6-MF1, CG7-MF1 CE31-MFCQ1 CE31-MFCQ2 CE31-MFCQ4	Approach and resolution of exercises and problems.	Discussion and resolution of the proposed questions and problems.	Assessment of the answers (approach and result) given for the resolution of practical exercises and numerical problems.	24	26	50	20%
Programmed tutorial and guide activities.	CG1-MF1, CG2-MF1, CG6-MF1, CG7-MF1, CG8-MF1 CE30-MFCQ2 CE31-MFCQ1 CE31-MFCQ2 CE31-MFCQ3 CT2-MF1 CT3-MF1 CT5-MF1 CT6-MF1 CT11-MF1	Statement of numerical exercises in the tutorials. Direction and supervision of the study and activities of the students.		Assessment of active participation of the work carried out.	4	6	10	

Teaching activity	Associated competences	Lecturer activity	Student activity	Assessment procedure	P	NP	Total	C
Practical activities.	CG1-MF1, CG2-MF1, CG6-MF1, CG7-MF1, CG8-MF1 CE30-MFCQ2 CE31-MFCQ1 CE31-MFCQ2 CE31-MFCQ3 CT2-MF1 CT3-MF1 CT5-MF1 CT6-MF1 CT11-MF1	Activity approach. Direction and supervision of the study and activities of the students.	Attention and development of the proposed activities.	Questionary marking.	6	9	15	10%
Examinations	CG1-MF1, CG2-MF1, CG5-MF1, CG6-MF1, CG7-MF1 CE30-MFCQ1 CE30-MFCQ2 CE31-MFCQ1 CE31-MFCQ2 CE31-MFCQ3 CE31-MFCQ4 CT3-MF1 CT5-MF1 CT6-MF1 CT12-MF1 CT12-MF2	Exam design. Surveillance and correction. Evaluation of the student.	Exam preparation and examination	Exam marking.	6	14	20	70%
P : In-class; NP: Self-study; C: Evaluation								