Academic Year 2026/2027

Course Guide:

CHEMICAL REACTION ENGINEERING

FACULTY OF
CHEMICAL SCIENCES

1. IDENTIFICATION

Degree Program	Bachelor's Degree in Chemical Engineering	Código	801550
Course Name	Chemical Reaction Engineering	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
Theory Seminars Tutorials.	AURORA SANTOS LÓPEZ	aursan@ucm.es	QA B57A
	SERGIO RODRÍGUEZ VEGA	sergioro@ucm.es	QA B71B
	CARMEN MARIA DOMINGUEZ TORRE	carmdomi@ucm.es	QA B57B
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	SALVADOR COTILLAS SORIANO	salvacot@ucm.es	QA B57B
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Laboratory Instructors

Activity	Lecturer	Email	Office
Lab	SERGIO RODRÍGUEZ VEGA	srvega@quim.ucm.es	QA B71B
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Lab	MERCEDES MARTÍNEZ RODRÍGUEZ	mmr1@quim.ucm.es	QA B58A

2. OBJECTIVES

General Objective

This course aims to introduce students to Chemical Reaction Engineering so that they acquire a clear understanding of the methodology used in the design of chemical reactors and can apply it to various situations encountered in the chemical industry and in facilities for the transformation of pollutants. The course seeks to ensure that students develop skills in identifying and quantitatively describing the phenomena that determine the behaviour of chemical reactors; in formulating kinetic models of reactions and reactors; in obtaining and interpreting kinetic data; in the numerical simulation of different types of reactors; and, finally, in applying clear criteria for selecting appropriate reactors and operating conditions to carry out manufacturing or transformation processes in industrial facilities.

Specific Objectives

- Formulate kinetic models for homogeneous and heterogeneous reactions.
- Obtain and interpret kinetic information for simple and multiple reactions.
- Understand the formulation, preparation, and characterisation of catalysts used in industrial catalytic processes.
- Analyse the influence of physical steps in multiphase reactions.
- Assess the effect of the main variables (temperature, composition, interfacial area, particle size, etc.) on the observed reaction rate.
- Know and classify the different types of chemical reactors according to flow-pattern and number-of-phase criteria.
- Model the behaviour of different types of chemical reactors as a function of input variables, process hydrodynamic conditions, and heat-exchange system.
- Select the most suitable reactor configuration for a given chemical process, according to its specific characteristics.
- Analyse the stability of different chemical reactors.

3. PRIOR KNOWLEDGE AND RECOMMENDATIONS

Satisfactory completion of this course requires the student to have previously acquired the knowledge and competences corresponding to the following courses: Mathematics I and Mathematics II, Fundamentals of Chemical Engineering, Basic Chemistry and Organic Chemistry, Thermodynamics and Chemical Kinetics, Applied Thermodynamics, and Fluid Mechanics.

It is useful to know how to use scientific calculation software. It is recommended that the student has a basic level of English that allows them to handle English-language references, conduct information searches, and communicate in writing and orally in that language. Furthermore, it is recommended that the student be familiar with computing tools and software for solving complex problems, as well as applications for drafting, editing, and presenting technical reports.

4. CONTENTS

Brief Description of the contents

Kinetics of chemical reactions. Methods for kinetic data analysis. Catalysis. Types of chemical reactors. Reactor operating modes in the chemical industry. Basic reactor design equations. Real reactors. Experimentation for determining kinetic equations. Experimentation with chemical reactors.

Course Syllabus

5. Concept of Chemical Reaction Engineering. Scientific foundations. Analysis and modelling of chemical reactors.
6. Chemical reactors. The most common reactors in industry. Ideal reactors. Innovative approaches in Chemical Reactors.
7. Material balances in ideal homogeneous reactors. Batch reactor, continuous stirred-tank reactor, and plug-flow tubular reactor. Non-ideal flow.
8. Applied Chemical Kinetics. Mechanistic and empirical models. Obtaining and interpreting kinetic data. Model discrimination and parameter estimation.
9. Thermal effects in ideal chemical reactors. Stable operation.
10. 6. Performance in multiple homogeneous reactions. Parallel, series, and series-parallel reactions.
11. Heterogeneous reactors. Types and applications.
12. Fixed-bed reactors. Heterogeneous catalysis. Phenomenology and extrapolation of laboratory data to real reactors.
13. Fluidized-bed reactors. Phenomenology and extrapolation of laboratory data to real reactors.
14. Non-catalytic gas-solid reactors. Phenomenology and extrapolation of laboratory data to real reactors.
15. Immiscible fluid-fluid reactors. Phenomenology and extrapolation of laboratory data to real reactors.

16. COMPETENCES

General

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

CE20-IP4	Recognise the fundamentals of unit operations and chemical reaction engineering.
CE20-IP5	Perform simple calculations involving unit operations, chemical kinetics, and ideal reactor design.
CE20-IP6	Calculate the basic reactor design parameters.
CE20-IP7	Analyse the behaviour of chemical reactors.
CE22-IP1	Apply methods that allow kinetic models to be formulated and kinetic parameters to be calculated.

Cross-cutting

CT1-TQ1	Develop capacity for analysis and synthesis.
CT2-TQ1	Solve problems in the area of Chemical Technology.
CT4-TQ1	Communicate in Spanish using standard audiovisual media.
CT5-TQ1	Consult, use and analyse bibliographic sources in the area of Chemical Technology.
CT5-TQ2	Consult, use and analyse specialised databases and resources accessible through the Internet.
CT6-TQ1	Use computer tools and programs to calculate, simulate, and approximate.
CT8-TQ1	Demonstrate capacity for critical and self-critical reasoning.
CT11-TQ1	Learn autonomously.
CT12-TQ1	Develop capacity for analysis and synthesis.

17. WORKLOAD DISTRIBUTION BY ACTIVITY

Activity	In-class (hours)	Self-study (hours)	Credits
Lectures	65	85	6
Seminars	26	31,5	2,3
Tutorials/guided work	6	9	0,6
Laboratory sessions	30	22,5	2,1
Preparation of Course work and Exams	6	19	1
Total	**133**	**167**	**12**

18. METHODOLOGY

The course content is presented to students in face-to-face classes and is divided into two main types.

Lectures will be delivered to the whole group and will introduce students to the course content. At the beginning of each topic, the content and main objectives will be clearly presented. At the end of the topic, a summary of the most relevant content will be provided, and new objectives will be proposed to interrelate previously studied content.

During the content presentation, questions will be posed to illustrate the concepts developed or to introduce new content. To facilitate student follow-up of the face-to-face classes, the necessary portion of the instructor's teaching material will be provided either as photocopies or through the Virtual Campus. Each topic will be presented using the board, presentations, simulations, numerical calculations, and related software. Bibliography and resources in English will be used.

Problem-solving classes will be held face-to-face. Students will periodically be provided with a set of problems/exercises. Some of these exercises will be solved in class by the instructor, while others will be assigned to students as personal work and submitted to the instructor. The results of these problems will subsequently be discussed in small groups. Part of these activities will be conducted in English. MATLAB, Excel, and Origin will be used for problem-solving.

Laboratory sessions will be held face-to-face. Throughout the course, three compulsory laboratory practical sessions will be carried out. Working in small groups, students will collect data from an experimental system and apply the concepts, abilities, and skills acquired in lectures and problem-solving classes to analyze and interpret the data. Students will prepare a laboratory report that presents the aim of the practical session, the experiments performed, the results obtained, and a reasoned discussion leading to the conclusions reached. After completing the practical sessions, students will take an examination on the principles and methodology applied in the laboratory sessions. The work carried out in the laboratory, the report submitted, and the examination will be graded. Part of these activities will be conducted in English. The necessary calculations will be performed using scientific software (Matlab, Excel, Origin). Before attending the first laboratory session of the course, students must confirm in writing that they have read, understood, and accepted the laboratory safety regulations.

In guided activities, students will complete work throughout the course on subject-related topics, which will be assessed as independent or non-contact learning activities. The general aim of this work is for students to learn how to carry out bibliographic searches in order to obtain the information needed to solve an open problem oriented towards industrial reality, and to analyse, evaluate, and apply that information. The assignments proposed to each student include bibliographic work, calculation methods, interpretation of results, and preparation of the corresponding report. Part of these activities will be conducted in English. If the number of students allows, it would be useful for students to present their work in class once it is completed, and to answer questions posed by the instructor and their classmates.

Tutorials will be scheduled individually or in small groups. During these sessions, students' questions will be answered, and problems and issues provided by the instructor, related to the course syllabus and specific case studies, will be discussed. Some of these activities will be conducted in English, and others may be supported by artificial intelligence. In tutorials and guided activities, the necessary calculations will be performed using scientific software (Matlab, Excel, Origin). Activities will be carried out in tutorials and guided activities to determine and assess students' project capacity using cutting-edge knowledge in the

Chemical Engineering discipline. Case studies related to safety in chemical plants will be analysed using good practice codes.

The UCM Virtual Learning Environment (Campus Virtual) will be used to ensure smooth communication between instructors and students and to make the materials considered necessary for lectures and problem-solving classes available to students. It may also serve as a forum to present complementary topics whose content, although important to the subject as a whole, is not considered appropriate for presentation in face-to-face classes. Part of the recommended bibliography and support materials deposited on the Virtual Campus to support the development of this course's teaching activities will be in English.

19. BIBLIOGRAPHY

Basic

- Levenspiel, O.: "*Ingeniería de las Reacciones Químicas*", 2ª Ed. Reverté. 1981; 3ª Ed., John Wiley, 1999.
- Fogler, H.S.: "*Elements of Chemical Reaction Engineering*", 3ª Ed., Prentice Hall, Englewood Cliffs, N.J., 1999.
- Froment, F.F. y Bischoff, K.B.: "*Chemical Reactor Analysis and Design*". 1ª Ed., John Wiley, 1979. 2ª Ed., 1990.
- Smith, J.M.: "*Ingeniería de la Cinética Química*", CECSA, 1981.
- Metcalfe, I.S.: “*Chemical Reaction Engineering. A first Course*”, Oxford Science Publications, 1999.

Complementary

- González Velasco, J.R.; González Marcos, M.A.; González Marcos, M.P., Gutiérrez Ortiz, J.I. y Gutiérrez Ortiz, M.A.: “*Cinética Química Aplicada*”, Ed. Síntesis, Madrid, 1999.
- Santamaría, J., Erguido, J., Menéndez, M.A. y Monzón, A.: “*Ingeniería de Reactores*”, Ed. Síntesis. Madrid, 1999.
- Villermaux, J.: "*Genie de la reaction chimique. Conception et fonctienement des reacteurs*", Lavoisier, 1982.
- Missen, R.W, Mins, C.A. y Saville, B.A.: “*Introduction to Chemical Reaction Engineering and Kinetics*”, Wiley, 1999.
- Westertep, K.R., van Swaaij, W.P.M. y Beenackers, A.A.C.C.: “*Chemical Reactor Design and Operation*”, Wiley, 2ª Ed., 1984.

20. EVALUATION

The student's academic performance and final course grade will be calculated as a weighted average using the following percentages, which will be applied across all examination periods.

To pass the course, students must obtain an overall grade of 5 or higher out of 10, taking into account the contribution of written examinations (70%) and the remaining training activities (30%).

The final course grade will be calculated as the weighted average of the different assessable activities. However, to pass the course, students must obtain the minimum grade established for each activity. If this requirement is not met, the final grade will be the weighted average, capped at 4.5 out of 10. This criterion shall apply to both the ordinary and extraordinary assessment periods.

❖ WRITTEN EXAMS: 70%

In addition to the ordinary and extraordinary examinations, two partial examinations will be held during the course: one at the end of the first semester and another at the end of the second semester, each corresponding to the syllabus taught during the respective period. To be eligible for continuous assessment during the course and not be required to sit the ordinary/extraordinary final examination, students must obtain in each of the two partial examinations:

- a minimum grade of 3 out of 10 in the theory part,
- a minimum grade of 3 out of 10 in the problem-solving part, and
- an average grade in the partial examination equal to or higher than 4 out of 10.

❖ SELF-WORK AND GUIDED ACTIVITIES: 30%

The assessment of the individual learning work carried out by the student will take into account the following factors:

- The student's skill in solving the proposed problems and exercises, which will be collected periodically in face-to-face classes.
- Assessment of work carried out in face-to-face problem-solving classes and tutorials.
- Assessment of work carried out in laboratory practical sessions (mandatory attendance).

The grade obtained in tutorials and guided work will contribute 10% of the final grade. The grade obtained in laboratory practical sessions will contribute 20% of the final grade. Some of these activities will be assessed in English.

❖ ATTENDANCE AND ACTIVE PARTICIPATION:

To be eligible for the overall assessment of the course, students must have participated in at least 70% of face-to-face classroom activities (lectures, seminars, and tutorials) and attended the laboratory sessions.

The grades for the activities planned to assess the course (course examinations, laboratory sessions, tutorials, problem submissions, etc.) will be communicated to students with sufficient notice before the final examination, so that they can adequately plan their study of this and other courses.

In particular, the grades for the course examinations will be communicated within a maximum of 20 working days, except for the final course examination, for which the period may be shorter to accommodate the final examination. In any case, a minimum period of seven days between the publication of grades and the date of the final examination of the course will be observed.

Students who have completed the laboratory practical sessions in previous academic years may request exemption from repeating laboratory attendance and preparation of the corresponding report, provided that no more than 2 years have elapsed since they completed those practical sessions and that they received a grade above five. In any case, all students must take the examination for each practical session, regardless of whether they have requested an exemption from repeating the experimental laboratory work.

In laboratory practical sessions, guided activities, and tutorials, in addition to the corresponding report, the scientific calculation programs/files developed by the student in the preparation of results must be submitted.

ACTIVITY SCHEDULE

UNIT	SEMESTER
1. Concept of Chemical Reaction Engineering	1
2. Chemical reactors	1
3. Material balances in ideal homogeneous reactors. Non-ideal flow	1
4. Applied Chemical Kinetics	1
5. Thermal effects in Ideal Chemical Reactors	2
6. Performance in multiple homogeneous reactions	2
7. Heterogeneous reactors. Heterogeneous catalysis	2
8. Fixed-bed reactors	2
9. Fluidised-bed reactors	2
10. Gas-solid reactors	2
11. Immiscible fluid-fluid reactors	2

Laboratory sessions and tutorials will be conducted in small groups.

SUMMARY OF ACTIVITIES

ACTIVITY	ASSOCIATED COMPETENCES	TEACHING ACTIVITY	STUDENT ACTIVITY	EVALUATION	P	NP	TOTAL	C
Lectures	CG1-TQ1, CG4-TQ1, CG5-TQ1, CE20-IP4, CE20-IP7, CE22-IP1, CT1-TQ1, CT5-TQ1, CT5-TQ2, CT11-TQ1, CT12-TQ1	Presentation of theoretical concepts. Assessment of the theoretical knowledge acquired by the student.	Attendance and note-taking, consultation of bibliographic sources, and personal study. Formulation of questions and doubts.	Attendance and participation in lectures.	65	85	150	
Seminars	CG1-TQ1, CG5-TQ1, CE20-IP5, CE20-IP6, CE22-IP1, CT1-TQ1, CT2-TQ2, CT5-TQ1, CT5-TQ2, CT11-TQ1, CT12-TQ1	Application of theoretical concepts to the solution of questions and problems. Assessment of the student's skills in solving problems and exercises.	Attendance and note-taking, consultation of bibliographic sources, and personal study. Completion of proposed exercises. Formulation of questions and doubts.	Attendance and participation in seminar classes and assessment of the exercises proposed by the instructor.	26	31,5	57,5	
Laboratory	CG1-TQ2, CE22-IP1, CT4-TQ1, CT5-TQ1, CT5-TQ2, CT6-TQ1, CT8-TQ1	Presentation of the theoretical foundations and methodology for carrying out practical sessions and interpreting the results obtained. Supervision and support during these stages. Grading of acquired knowledge and practical work.	Study of the theoretical/practical foundations required for the experimental task, completion of the experiment, and preparation of the technical report.	Assessment of the student's work during practical sessions and of the individual technical reports on the experimental work carried out. Written examinations on the knowledge acquired.	30	22,5	52,5	15%
Tutorials / Guided activities	CG1-TQ1, CG5-TQ1, CE20-IP7, CE22-IP1, CT4-TQ1, CT5-TQ1, CT6-TQ1, CT11-TQ1, CT8-TQ1, CT12-TQ1	Monitoring and support for the acquisition of knowledge and competences by the student through individual and/or group activities. Assessment of the work carried out in these activities.	Presentation of questions and issues to the instructor and self-assessment of acquired knowledge and competences. Preparation of the proposed assignments.	Assessment of the work carried out by the student.	6	9	15	**15%**

ACTIVITY	ASSOCIATED COMPETENCES	TEACHING ACTIVITY	STUDENT ACTIVITY	EVALUATION	P	NP	TOTAL	C
Examinations	CG4-TQ1, CG5-TQ1, CE20-IP5, CE20-IP6, CT1-TQ1, CT4-TQ1, CT8-TQ1	Preparation, supervision, correction, and grading of examinations.	Preparation and completion of tests for the assessment of knowledge and its application to solving theoretical/practical questions.	Grading of examinations.	6	19	25	**70%**

P: On-site activities **NP:** Independent activities (independent study) **C:** Grade