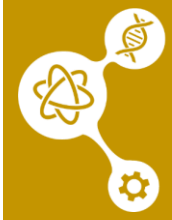
Academic Year 2026/2027

Coruse Guide:

THERMODYNAMICS AND CHEMICAL KINETICS



FACULTY OF CHEMICAL SCIENCES

1. IDENTIFICATION

Degree Program	Bachelor's Degree in Chemical Engineering			Code	801540
Corse	Thermodynamics and Chemical Kinetics			ECTS	9
Subject Area	Thermodynamics and Thermal Engineering				
Module	Industrial Engineering				
Course Type	Compulsory	Course	Second	Semester	First
Responsible Department	Physical Chemistry				

Teaching Staff

Activity	Lecturer	Email	Office
Course Coordinator	PAOLO NATALE	pnatale@ucm.es	QA-264
Laboratory Coordinator	FRANCISCO MONROY MUÑOZ	monroy@quim.ucm.es	QA-259

Group A1

Activity	Lecturer	Email	Office
Lectures Seminars Tutorials	PAOLO NATALE	pnatale@ucm.es	QA-264

Group A2

Activity	Lecturer	Email	Office
Lectures Seminars Tutorials.	GUILLERMO GONZÁLEZ RUBIO	ggrubio@ucm.es	QA-247B

Laboratory Teachers

Activity	Lecturer	Email	Office
Lab	Mauricio, Alcolea Palafox	alcolea@ucm.es	QA-247
Lab	Samuel, Blázquez Fernández	samuelbl@ucm.es	QB-231
Lab	Cosmin Alexandru, Dicu Gohoreanu	cdicu@ucm.es	QB-224
Lab	Fernando, Martínez Pedrero	fmpedrero@pdi.ucm.es	QB-209
Lab	Monica ,Muñoz Ubeda	monicamubeda@quim.ucm.es	QA-264

2. OBJECTIVES

General Objective

It is a subject in which some aspects of Physical Chemistry will be developed, and whose objective is for the student to come into contact with the basic concepts involved in this discipline, providing them with the appropriate chemical-physical tools to face the rest of the contents of the Industrial Engineering Module. In this subject, the basic theoretical concepts of thermodynamics and chemical kinetics necessary to understand chemical reactions and equilibria, as well as the thermodynamics involved in phase transitions and solutions, will be introduced. The most fundamental concepts of electrochemistry, surfaces and interfaces and adsorption phenomena on solids will be introduced.

Specific objectives

- Know the fundamentals of Chemical Thermodynamics and understand the conditions of equilibrium and spontaneity of a chemical system.
- Understand the application of thermodynamics to gases, gas mixtures, pure condensed-phase substances, and solutions, as well as to chemical equilibrium and phase transitions.
- Understand the concept of chemical activity and its applications.
- Know the fundamentals of Chemical Kinetics and its application to both simple and complex reactions and understand the variation of the rate of a chemical reaction with temperature in terms of the most elementary microscopic theories.
- To know the conductivity phenomena in electrolyte solutions and the fundamentals and applications of electrodicics.
- Understand the fundamentals of surface thermodynamics and, in particular, the concept of surface work. Understand the phenomena of nucleation, adhesion, wetting, and adsorption.
- Understand the processes of adsorption of gases on solids and relate these to adsorption isotherms.
- Develop the ability to perform quantitative calculations in all areas covered by the subject.

3. PRIOR KNOWLEDGE AND RECOMMENDATIONS

Prior knowledge

Following this course satisfactorily requires the student to have previously acquired the knowledge and competences corresponding to the following courses: "*Basic Chemistry*", "*Physics*" and "*Mathematics I*". Although enrolment is not formally conditioned on these prior knowledge, effective mastery of this knowledge is essential to follow this course with a reasonable prospect of success.

Recommendations

It is recommended that the student has a basic level of English that allows him or her to handle bibliography in English, search for information, and communicate in writing and orally in that language.

It is recommended that the student be familiar with tools and computer programs for solving complex problems.

4. CONTENTS

Brief description

First and second principles of thermodynamics. Mass as a thermodynamic variable: chemical potential. Third principle of thermodynamics. Change of phase. Ideal and real solutions. Kinetics and mechanisms of chemical reactions. Surface thermodynamics. Electrochemistry.

Course Syllabus

THEORY AND SEMINARS

TOPIC 1. Fundamentals of Thermodynamics

Chapter 1

Fundamental definitions - Zero principle - Properties of state functions - Temperature - Thermoelastic coefficients - Equations of state of gases.

Chapter 2

Warmth and work. • Work in hydrostatic systems • Work in other systems • Reversible and irreversible transformations • Internal energy function • First principle of thermodynamics • Enthalpy • Heat capacities • Joule's experiment • Adiabatic changes for an ideal gas. Open systems.

Chapter 3

Spontaneous processes - Transformation of work into heat - The Carnot cycle - Second principle of thermodynamics - Performance of thermal engines - Kelvin scale or thermodynamics of temperatures - Entropy - Consequences of the second principle.

Chapter 4

Calculation of entropies - Third principle of thermodynamics - Consequences of the third principle - Calculation of absolute entropies.

Chapter 5

Conditions for equilibrium and spontaneity - Helmholtz energy and Gibbs energy - Maxwell relations - Effect of temperature and volume or pressure on entropy - Thermodynamic equations of state - Gibbs-Helmholtz equations. Residual properties - Equilibrium between phases - Clapeyron and Clausius-Clapeyron equations - Higher-order phase transitions.

TOPIC 2. Chemical Thermodynamics

Chapter 6

Partial molar magnitudes - Chemical potential - Fugacity and activity - Standard states - Gas mixtures - Chemical potential of a gas in a mixture - Mixing functions - Fugacity in a mixture of real gases.

Chapter 7

Ideal solutions. Raoult's Law - Thermodynamic Magnitudes of the Mixing Process - Liquid-Vapor Equilibrium in Ideal Solutions - Bubble and Dew Points - Ideal Dilute Dissolution - Henry's Law - Colligative Properties.

Chapter 8

Real solutions - Activity and coefficients of activity - Variation of activity with temperature and pressure - Determination of activities in real solutions - Calculation of the activity of one component from that of another - Mixing functions and excess functions - Phase equilibrium in real systems.

Chapter 9

Electrolyte solutions - Activities and coefficients of activity - Ionic strength - Debye-Hückel theory - Determination of mean ionic activity coefficients.

Chapter 10

Chemical reaction - Degree of progress of the reaction - Chemical equilibrium - Van't Hoff equation - Le Chatelier's principle - Determination of equilibrium constants - Rule of phases in systems with multiple equilibria.

TOPIC 3. Chemical Kinetics

Chapter 11

Reaction rate - Rate equation - Determination of reaction order - Integrated speed equations - Effect of temperature - Arrhenius equation - Experimental methods for measuring reaction rate.

Chapter 12

Complex reactions: reversible, consecutive and competitive - Steady state - Chain reactions. Thermal decompositions - Catalysis

Chapter 13

Collision theory - Potential energy surfaces - Activated complex theory - Reactions in solution - Reactions between ions.

TOPIC 4. Electrochemistry, Surfaces and Interfaces

Chapter 14

Electrical conductivity and its measurement - Ionic mobilities - Transport indices and their measurement - Kohlrausch's Law - Applications of conductivity measurements.

Chapter 15

Galvanic and electrolytic cells - Electrode: definitions and types - Representation of a cell - Measurement of electromotive force - Thermodynamics of galvanic cells - Nernst's equation - Types of electrodes - Types of cells - Diffusion potential - Applications of emf measurements - Batteries and fuel cells.

Chapter 16

Surface tension - Young-Laplace equation - Kelvin equation - Capillarity - Nucleation - Solid-liquid interface - Contact angle and adhesion - Gibbs equation - Gibbs adsorption isotherm - Surfactants - Surface films - Colloids.

Chapter 17

Gas-surface interactions - Surface forces, bonds and surface structure - Physical adsorption - Scattering of atomic and molecular beams on surfaces - Physisorption isotherms - Brunauer-Emmett-Teller isotherm - Determination of surface areas - Comparison between chemisorption and physisorption - Langmuir isothermal - Chemisorbed surface structures - Mechanism of chemisorption - Heterogeneous catalysis.

DIRECTED TUTORIALS

Tutoring 1

Cooperative learning based on an advanced problem on thermodynamics of simple systems.

Tutoring 2

Cooperative learning based on an advanced problem on thermodynamics of mixtures, solutions and chemical equilibrium.

LABORATORY PRACTICES

Practice 1

Surface Tension: determination of the critical micellar concentration of a surfactant (1 day)

Practice 2

Calorimetry: Determination of the specific heat of a solid body (1 day)

Practice 3

Galvanic Cells: Thermodynamic Analysis of an Electrochemical Equilibrium (1 Day)

Practice 4

Chemical Kinetics: Study of the Reaction Rate of Hydrolysis of Fe(II) Complexes (1 day)

5. COMPETENCIES

General

The general competence of the CG1 degree is developed in the Industrial Engineering module in eight, CG1-MII1 to CG1-MII8; Among these, the following are applicable in the subject, with the particularities indicated:

CG1-MII1	Apply concepts of applied thermodynamics.
CG1-MII7	Use the principles of machines and mechanisms.

Specific

The specific competence of the CE7 degree is developed for the subject Thermodynamics and Chemical Engineering in a series of CE7-T competences, of which the following correspond to this subject:

CE7-T1	Apply the Principles of Thermodynamics to different types of systems
CE7-T2	Formulate the equilibrium and stability criteria of systems and apply them to phase equilibria and chemical equilibrium.
CE7-T3	Calculate the parameters and variables that define phase equilibrium and chemical equilibrium.
CE7-T4	Formulate the kinetic equations of a chemical reaction.
CE7-T5	Solve reaction mechanisms when their kinetics are known.
CE7-T6	Distinguish between galvanic and electrolytic cells.
CE7-T7	Study reaction kinetics in the laboratory.
CE7-T8	Assemble different galvanic cells.

Cross-cutting

The transversal competences of the degree, CT, which are developed in the Industrial Engineering module, CT-II, and which are applied in this subject are the following:

CT4-II1	Communicate in Spanish using standard audiovisual media.
CT5-II1	Consult, use and analyse bibliographic sources.
CT5-II2	Use bibliography, specialised databases and resources accessible through the Internet.
CT6-II1	Use computer programs to calculate, design, simulate, approximate, and predict.
CT7-II1	Work in a team.
CT9-II1	Demonstrate professional ethical commitment.
CT11-II	Learn autonomously.
CT13-II1	Demonstrate initiative and creativity in solving new situations.

6. WORKLOAD DISTRIBUTION BY ACTIVITY

Activity	Face-to-face (hours)	Freelance work (hours)	Credits
Theoretical classes	45	82	5,1
Seminars	15	20,5	1,4
Tutorials/Directed Work	2	3	0,2
Laboratories	16	11,5	1,0
Preparation of papers and exams	6	24	1,2
Total	**84**	**141**	**9**

7. METHODOLOGY

The teaching practice will follow a mixed methodology based on cooperative learning, collaborative learning and self-learning, which involves theoretical classes, seminars in groups with resolution and discussion of questions and problems and practical laboratory sessions. In addition to this, student activities directed and supervised by the teacher are added, including the corresponding bibliographic work, for which the Virtual Campus will be very useful.

The lessons will be taught in the corresponding theoretical classes, supported by seminar classes where numerical problems and questions will be solved in smaller groups and in the directed tutorials indicated.

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

In addition, a laboratory will be held in which the knowledge acquired in the theoretical classes will be put into practice, with emphasis on the development of skills in the handling of experimental equipment, in obtaining experimental data and in the analysis of these using the appropriate mathematical tools.

Before the completion of the first laboratory of the subject, the student must confirm in writing that he or she has read, understood and accepted the safety rules of the laboratory.

8. BIBLIOGRAPHY

Basic

- Rodríguez Renuncio, J.A.; Ruiz Sánchez, J.J.; Urieta, J.S.: "*Termodinámica Química*", 2nd ed., Síntesis, Madrid, 2000.
- Smith, J.M., Van Ness, H.C., Abbott, M.M.: "*Introduction to Thermodynamics in Chemical Engineering*", 7th ed., McGraw Hill, Mexico, 2007.
- González Ureña, A.: "*Kinética Química*", Síntesis, Madrid, 2001.
- Logan, S.R.: "*Fundamentals of Chemical Kinetics*", Addison Wesley, 2000.

Complementary

- Atkins, P.W.: "*Physical Chemistry*", 8ª ed., Freeman, 2008. www.whfreeman.com/pchem8
- Sonntag, R.E., Borgnakke, C.: "*Introduction to Thermodynamics for Engineering*", Limusa-Wiley, Mexico, 2006
- Keeler, J.; Wothers, P.: "*Chemical Structure and Reactivity*", Oxford U.P., 2008.
- Rodríguez Resigned J.A.; Ruiz Sánchez, J.J.; Urieta, J.S.: "*Solved Problems of Chemical Thermodynamics*", Síntesis, Madrid, 2000.
- Pellicer, J.; Manzanares, J.A.: "*100 problems of Thermodynamics*", Alianza, 1996.

The scripts of the internships and the auxiliary material that is considered necessary will be available to the student on the Virtual Campus of the subject. In addition to the basic and complementary texts, students may be given specific bibliography for each topic.

9. ASSESSMENT

Both directed tutorials and laboratory practices are mandatory. In order to carry out the overall assessment of the subject, it will be necessary for the student to have participated in at least 70% of the face-to-face activities. The final grade will consider the criteria indicated below. These criteria will be maintained in all calls.

The final grade will be the weighted average of the assessable activities, provided that the minimum grade of 4 out of 10 is achieved in each of them. If this requirement is not met, the maximum final grade will be 4.5, regardless of whether the weighted average is higher.

❖ WRITTEN EXAMS: 70%

A written exam will be held on the theoretical contents, seminars and practices of the subject that will account for 70% of the final grade, both in the ordinary and extraordinary call. In the written exam, it will be an essential requirement to be able to pass the subject to obtain a minimum grade of 4 out of 10.

Competencies CG1-MII1, CG1-MII7, CE7-T1, CE7-T2, CE7-T3, CE7-T4, CE7-T5, CE7-T6, CT11-II and CT13-II1 will be assessed.

❖ PERSONAL WORK: 5%

Personal work evaluated through self-assessment exercises carried out by the student using the virtual campus will account for 5% of the final grade. In order to pass the subject, it is essential to obtain a minimum grade of 4 out of 10.

Competencies CG1-MII1, CG1-MII7, CE7-T1, CE7-T2, CE7-T3, CE7-T4, CE7-T5, CE7-T6, CT4-II1, CT11-II and CT13-II1 will be assessed.

❖ DIRECTED ACTIVITIES (WORK): 5%

The work carried out in the guided tutorials will be valued, as well as active participation in them with 5% of the final grade. In order to pass the subject, it is essential to obtain a minimum grade of 4 out of 10.

❖ LABORATORY: 20%

Active participation in the activities of the laboratory, as well as the degree of understanding of the practices carried out and the skills acquired in the laboratory, together with the report presented at the end of the laboratory, will account for 20% of the final grade.

Attendance at the laboratory is mandatory. In order to pass the subject, it is essential to obtain a minimum grade of 4 out of 10. Those students who, having completed and passed the laboratory, do not pass the subject, will be exempt from repeating the laboratory in the academic year following the one in which they have passed it, maintaining the corresponding grade.

Students who have carried out the internship in previous years will have the option of requesting the non-repetition of these as long as no more than 3 years have elapsed since they carried out these internships.

Competencies CG1-MII1, CG1-MII7, CE7-T2, CE7-T3, CE7-T4, CE7-T6, CE7-T7, CE7-T8, CT4-II1, CT5-II1, CT5-II2, CT6-II1, CT7-II1, CT9-II1, CT11-II y CT13-II1 will be assessed.

The grades of the activities planned for the evaluation of the subject (laboratories, tutorials, delivery of problems, ...) will be communicated to students sufficiently in advance before the final exam, so that they can properly plan the study of this or other subjects.

In any case, the minimum period of seven days between the publication of the grades and the date of the final exam of the subject will be respected.

ACTIVITY PLANNING - SCHEDULE

UNIT	ACTIVITY	HOURS	GROUPS	START	END
1. Fundamentals of Thermodynamics	Theory Classes	15	1	1st Week	5th Week
	Classes Problems	5	1		
	Scheduled Tutoring*	1	4	6th Week	
2. Thermotechnics	Theory Classes	15	1	6th Week	10th Week
	Classes Problems	5	1		
3. Chemical Kinetics	Theory Classes	8	1	11th Week	13th Week
	Classes Problems	3	1		
	Scheduled Tutoring*	1	4	Week 12	
4. Electrochemistry. Surfaces and Interfaces	Theory Classes	7	1	Week 13	Week 15
	Classes Problems	2	1		
Laboratory	Practical Sessions	16	3	4th Week	7th Week

* The scheduled tutorials are subject to possible modifications according to the joint planning of the course.

SUMMARY OF THE ACTIVITIES

ACTIVITY	ASSOCIATED COMPETENCIES	TEACHING ACTIVITY	STUDENT ACTIVITY	ASSESSMENT	P	NP	TOTAL	C
Theory classes	CG1-MII1, CG1-MII7; CE7-T1, CE7-T2, CE7-T3, CE7-T4, CE7-T5, CE7-T6, CE7-T7, CE7-T8; CT5-II1, CT5-II2, CT9-II1, CT11-II1	Presentation of theoretical concepts, posing of questions for the student to solve and bibliographic recommendations.	Active participation in class activities, taking notes and studying them, as well as the bibliographic recommendations made by the teacher.	Assessment of participation in class activities and grading of oral or written answers to questions related to the theoretical concepts explained.	45	82	127	
Seminars	CG1-MII1, CG1-MII7; CE7-T1, CE7-T2, CE7-T3, CE7-T4, CE7-T5, CE7-T6, CE7-T7, CE7-T8; CT5-II1, CT5-II2, CT9-II1, CT11-II1	Application of theory to the resolution of exercises and problems. Proposal of practical exercises and numerical problems for the student to solve	Active participation in class activities, taking notes and studying them. Resolution of the exercises and problems proposed by the teacher.	Assessment of participation in class activities and grading of the answers (approach and result) made orally or in writing to the resolution of practical exercises and proposed numerical problems.	15	20,5	35,5	**5%**
Tutorials	CT4-II1, CT5-II1, CT5-II2, CT9-II1, CT11-II1, CT13-II1	It helps the student to direct their study. Didactic recommendations. Resolution of doubts. Bibliographic recommendations.	Consult the teacher about the conceptual and methodological difficulties encountered when studying the subject.					
Directed tutorials	CE7-T1, CE7-T2, CE7-T3, CT4-II1, CT5-II1, CT5-II2, CT6-II1, CT7-II1, CT9-II1, CT11-II1, CT13-II1	Preparation and proposal of works	Active participation in the proposed activities. Written preparation of individual works and presentation of them	Assessment of participation in the directed activities and grading of the work proposed in writing and its oral presentation.	2	3	5	**5%**

ACTIVITY	ASSOCIATED COMPETENCIES	TEACHING ACTIVITY	STUDENT ACTIVITY	ASSESSMENT	P	NP	TOTAL	C
Laboratories	CG1-MII1, CG1-MII7 CE7-T1, CE7-T2, CE7-T3, CE7-T4, CE7-T5, CE7-T6, CE7-T7, CE7-T8 CT5-II1, CT5-II2, CT6-II1, CT7-II1, CT9-II1, CT11-II1, CT13-II1	Organization and planning of laboratory practices, explanations to the student of their contents and the procedures and practical protocols necessary for their development. Explanation to the student of the interrelationship with the contents of the subject.	Realization of the laboratory and active participation in its development. Study of the theoretical and practical contents of the laboratory. Preparation of the results obtained, and a report of the practices carried out.	Assessment of participation in the laboratory activities and grading of the report submitted by the student. Through small questions asked to the student, assessment of the degree of understanding achieved by the student about the contents and the practical skills developed.	16	11,5	27,5	**20%**
Exams	CG1-MII1, CG1-MII7 CE7-T1, CE7-T2, CE7-T3, CE7-T4, CE7-T5, CE7-T6, CE7-T7, CE7-T8 CT13-II1	Proposal, monitoring and correction of the exam.	Preparation and completion of the proposed exams.	Exam grading.	6	24	30	**70%**

P: Contact activities

NP: Non-contact activities (independent study)

C: Grade