UNIVERSIDAD DE CASTILLA - LA MANCHA

GUÍA DOCENTE

1. General information

Course: PHYSICAL-CHEMISTRY V: ELECTROCHEMISTRY AND MACROMO
Code: 57325
Type: CORE COURSE
ECTS credits: 6
Degree: 409 - CHEMISTRY
Academic year: 2022-23
Center: 1 - FACULTY OF SCIENCE AND CHEMICAL TECHNOLOGY
Group(s): 20 23
Year: 3
Duration: C2
Main language: Spanish
Second language: English
Use of additional languages:
English Friendly: Y
Web site:
Bilingual: N

Lecturer: **JOSE ALBALADEJO PEREZ** - Group(s): **20 23**

Building/Office	Department	Phone number	Email	Office hours
EDIFICIO MARIE CURIE, 2ª PLANTA	QUÍMICA FÍSICA	3451	jose.albaladejo@uclm.es	From Monday to Thursday from 13:00 h to 14:30 h.

Lecturer: **FRANCISCO JAVIER POBLETE MARTIN** - Group(s): **20 23**

Building/Office	Department	Phone number	Email	Office hours
EDIFICIO MARIE CURIE 2ª PLANTA, DESPACHOS 2.03	QUÍMICA FÍSICA	3457	fcojavier.poblete@uclm.es	Wednesday and Thursday 9.00h to 10.00h y 11.00h to 13.00 h, Monday from 17 to 18 h

2. Pre-Requisites

It is recommended to take this subject once the subjects of Physical Chemistry I and II of the second year have been passed. It is also considered important to take this subject simultaneously or later to the subject Physical Chemistry IV. It is considered very important for student learning process to respect the order of the subjects established in the curriculum.

3. Justification in the curriculum, relation to other subjects and to the profession

The subject of **Physical Chemistry V** is the last scheduled subject of the Physical Chemistry Matter and it shows the importance of surfaces in chemistry. Thus, we start by reviewing the superficial phenomena and studying the processes of adsorption and heterogeneous catalysis in topic 1, going on in topic 2 to make an introduction to the study of macromolecules and colloidal systems, whose properties are determined in large part by its high surface. The rest of the subject is devoted to reviewing the essential aspects of Electrochemistry, a branch of Physical Chemistry that studies the behavior of electrolyte solutions and the electrode processes that occur on a surface, both in equilibrium and its kinetic behavior. It has as fundamental fact the transport of charge from one phase to another, then it is, therefore, a branch of surface chemistry. Electrochemical kinetics and heterogeneous catalysis can also be considered part of the Chemical Kinetics that is studied in the subject of Physical Chemistry IV.

4. Degree competences achieved in this course

Course competences

Code	Description
CB01	Prove that they have acquired and understood knowledge in a subject area that derives from general secondary education and is appropriate to a level based on advanced course books, and includes updated and cutting-edge aspects of their field of knowledge.
CB05	Have developed the necessary learning abilities to carry on studying autonomously
E09	Know the kinetics of chemical change, including catalysis and reaction mechanisms
E14	Know and know how to apply the metrology of chemical processes, including quality management
E15	Know how to handle the standard chemical instrumentation and be able to elaborate and manage standardized procedures of work in the laboratory and chemical industry
E16	Plan, design and develop projects and experiments
E17	Develop the ability to relate to each other the different specialties of Chemistry, as well as this one with other disciplines (interdisciplinary character)
G01	Know the principles and theories of Chemistry, as well as the methodologies and applications characteristic of analytical chemistry, physical chemistry, inorganic chemistry and organic chemistry, understanding the physical and mathematical bases that require
G02	Be able to gather and interpret data, information and relevant results, obtain conclusions and issue reasoned reports on scientific, technological or other problems that require the use of chemical tools
G03	Know how to apply the theoretical-practical knowledge acquired in the different professional contexts of Chemistry
G04	Know how to communicate, orally and in writing, the knowledge, procedures and results of chemistry, both specialized and non-specialized
T03	Proper oral and written communication
T07	Ability to work as a team and, where appropriate, exercise leadership functions, fostering the entrepreneurial character
T09	Motivation for quality, job security and awareness of environmental issues, with knowledge of internationally recognized systems for the correct management of these aspects
T11	Ability to obtain bibliographic information, including Internet resources

5. Objectives or Learning Outcomes

Course learning outcomes

Description

Have a basic knowledge of electrochemical phenomena and their technological applications.

Ability to correctly use scientific language.

Dexterity in the analysis of errors of the magnitudes measured in the laboratory and in the use of computer programs for the treatment of experimental data.

Ability to search, understand and use relevant bibliographic and technical information.

Know the foundation and applications of transport phenomena, surface phenomena and macromolecular and colloidal systems.

Additional outcomes

Ability to determine thermodynamic properties of electrolyte solutions by potentiometry.

Ability to interpret the equilibrium properties of electrolyte solutions.

6. Units / Contents

Unit 1: Topic 1 SURFACE CHEMISTRY: HETEROGENEOUS CATALYSIS. The interface: surface tension. Curved interfaces. Capillarity. Thermodynamics of surfaces: Gibbs equation. Adsorption of gases on solids: physisorption and chemisorption. Adsorption isotherms: Langmuir isotherm. Heterogeneous catalysis. Mechanisms of Langmuir-Hinshelwood and Eley-Rideal.

Unit 2: Topic 2 MACROMOLECULES AND AGGREGATES. Classification of macromolecules. Polymerization mechanisms. Distribution and average values of molar masses. Conformation of macromolecules: models. Characterization techniques of macromolecules in solution. Colloids: classification, structure and stability.

Unit 3: Topic 3 ELECTROLYTE SOLUTIONS. Classification of electrolytes. Ion-solvent interactions. Enthalpy and entropy of solvation. Chemical potential of electrolyte solutions. Average ionic activity coefficients. Ion-ion interactions: Debye-Hückel theory. Concentrated solutions. Ionic association.

Unit 4: Topic 4 CONDUCTIVITY OF ELECTROLYTE SOLUTIONS. Law of Faraday. Measurement of conductivity and ways of expressing it. Law of Kohlrausch. Ionic mobility and its relationship with conductivity. Walden's Rule. Transportation numbers and their measurement. Arrhenius theory. Dilution law of Ostwald. Influence of ion-ion interactions on conductivity: Debye-Hückel-Onsager theory. Applications of conductivity measurements.

Unit 5: Topic 5 ELECTROCHEMICAL EQUILIBRIUM: ELECTRODES AND BATTERIES. Function of the electrodes: anode and cathode. Galvanic and electrolytic cells. Nernst equation. Formal potential Types of reversible electrodes. Notation of the galvanic cells. Cells with liquid union. Salt bridge. Electromotive Force of a cell (EMF). Standard electrode potentials. Electrochemical series. Secondary reference electrodes. Types of galvanic cells. Obtaining thermodynamic data from the measurement of the EMF of a cell.

Unit 6: Topic 6 KINETICS OF ELECTRODIC REACTIONS. Models of the electrode-electrolyte interface. Ideally polarizable and ideally non-polarizable electrodes. The rate of charge transfer: Butler-Volmer equation. Overpotential. Kinetics of rapid charge transfer: reversible behavior. Approximations of the Butler-Volmer equation.

Unit 7: Topic 7 INFLUENCE OF TRANSPORT: ELECTROCHEMICAL TECHNIQUES. APPLICATIONS. Processes governed by diffusion. Types of diffusion. Stationary processes: diffusion layer and diffusion limit current density. Overpotential concentration. Non-stationary processes. Potentiostatic method: Voltametric techniques. Galvanostatic method: Chronopotentiometric techniques. Determination of kinetic parameters. Applications of electrode kinetics. Corrosion. Potential and current of corrosion. Protection against cathodic and anodic corrosion.

Unit 8: Topic 8 PRACTICE 1. SURFACE TENSION AND SUPERFICIAL EXCESS. The surface tension of several solutions of a non-electrolyte is measured by a stalagmometer. The results of the variation of the surface tension with the solute concentration are interpreted in terms of the surface excess according to the Gibbs isotherm.

Unit 9: Topic 9 PRACTICE 2. DETERMINATION OF THE AVERAGE MOLECULAR WEIGHT OF A POLYMER BY VISCOSITY MEASUREMENTS. The viscosity of different solutions of a polymer (cellulose acetate) is determined using an Ostwald viscometer. From the viscosities measured, the specific viscosity of each solution is obtained. The intrinsic viscosity is determined from the appropriate representation of a function of the specific viscosity against the concentration of the polymer. From it and using the Mark-Houwkin-Sakurada equation, the average molecular weight of the polymer is calculated.

Unit 10: Topic 10 PRACTICE 3. DETERMINATION OF THE DISSOCIATION CONSTANT OF A WEAK ACID BY CONDUCTIMETRY. The dissociation constant of acetic acid is determined from measurements of the specific conductivity of several solutions of different concentrations. The molar conductivities of the different solutions are calculated and, given the molar conductivity at infinite dilution, the degree of dissociation of the acid is determined by applying the Arrhenius equation. From the appropriate representation of the Ostwald dilution law we obtain, from the ordinate at the origin, the molar conductivity to infinite dilution and from the slope, the dissociation constant. The goodness of the Arrhenius equation is verified using an iterative procedure to calculate the degree of dissociation.

Unit 11: Topic 11 PRACTICE 4. GALVANIC BATTERIES: ASSEMBLY AND DETERMINATION OF THERMODYNAMIC PROPERTIES FROM MEASUREMENTS OF THE ELECTROMOTIVE FORCE. In this practice three types of galvanic batteries are built: a concentration battery in the electrolyte (with silver electrodes, silver nitrate electrolyte and salt bridge of ammonium nitrate), a battery without transport with different electrodes and electrolytes and a standard or Clark battery. The measurement of electromotive force (EMF) of these cells is used to verify the Nernst equation (first cell) and determine the solubility product of the AgCl (second cell). In the case of the Clark battery, the measurement of the EMF at different temperatures between 25 and 45 ºC allows us to determine the variation of enthalpy, entropy and free energy of the chemical reaction of the battery.

7. Activities, Units/Modules and Methodology

Training Activity	Methodology	Related Competences	ECTS	Hours	As	Com	Description
Class Attendance (theory) [ON-SITE]	Lectures	E09 E17 G01 G03	1	25	N	-	Theoreticas lectures dedicated to explaining the contents of the syllabus. The Powerpoint presentations used will be available in the Virtual Campus.
Problem solving and/or case studies [ON-SITE]	Problem solving and exercises	E17 G02 G03 G04 T11	0.6	15	Y	N	Questions, seminars and problems previously raised and worked on autonomously by students will be resolved and clarified.
Class Attendance (practical) [ON-SITE]	Practical or hands-on activities	E14 E15 E16 E17 G02 G04 T11	0.64	16	Y	Y	The concepts of the syllabus and working methodology of the Physical Chemistry are put into practice in the laboratory. The student learn to handle the basic instrumentation necessary to perform the experiments.

Practicum and practical activities report writing or preparation [OFF-SITE]	Self-study	G02 G04 T11	0.48	12	Y	N	Autonomous resolution of the problems or seminars raised.
Writing of reports or projects [OFF-SITE]	Self-study	G02 G04 T11	0.9	22.5	Y	N	Study of demostration guide notes and lectures notes for the realization of the required measurements and calculations and the elaboration of the memory or each practice in the laboratory.
Study and Exam Preparation [OFF-SITE]	Self-study	E09 E17 G01	2.22	55.5	Y	N	Autonomous study of the theoretical contents of the program and its application to solving problems and seminars.
Mid-term test [ON-SITE]	Assessment tests	E09 E17 G01 G03 G04	0.16	4	Y	N	Two written partial exams. The first of the topics 1-4 and the second of the topics 5-7.
Final test [ON-SITE]	Assessment tests		0	0	Y	N	The final test will be carried out if the two partial evaluation tests have not been carried out and passed. The hours dedicated to this activity are computed in the hours dedicated to the partial tests (4h).
		Total:	**6**	**150**			
		Total credits of in-class work: 2.4					**Total class time hours: 60**
		Total credits of out of class work: 3.6					**Total hours of out of class work: 90**

As: Assessable training activity
Com: Training activity of compulsory overcoming (It will be essential to overcome both continuous and non-continuous assessment).

8. Evaluation criteria and Grading System

Evaluation System	Continuous assessment	Non-continuous evaluation*	Description
Assessment of active participation	10.00%	0.00%	At the end of the last theory lecture of each topic, a test will be carried out to assess the use of the theoretical classes,
Final test	0.00%	80.00%	Comprehensive exam of the subject
Mid-term tests	60.00%	0.00%	30% each of the 2 progress tests.
Assessment of problem solving and/or case studies	10.00%	0.00%	The student will perform an exercise proposed by the teacher in a seminar class (1/2 hour). As part of the continuous evaluation, two exercises will be carried out throughout the semester, one of the topics 1-3 and another of the topics 4-7.
Laboratory sessions	20.00%	20.00%	Attendance at all practical laboratory sessions is mandatory. The previous preparation of the practices (5%), the work in the laboratory and the corresponding report presented (5%) will be evaluated. There will also be a written test (10%) on the date established for the ordinary / extraordinary call of the subject.
Total:	**100.00%**	**100.00%**	

According to art. 6 of the UCLM Student Evaluation Regulations, it must be provided to students who cannot regularly attend face-to-face training activities the passing of the subject, having the right (art. 13.2) to be globally graded, in 2 annual calls per subject , an ordinary and an extraordinary one (evaluating 100% of the competences).

Evaluation criteria for the final exam:

Continuous assessment:

To pass the course it will be mandatory to have completed and passed the laboratory practices with a minimum of 5 points and obtain a minimum average grade of 5 points out of 10 in the overall evaluation of the course. To average, a minimum of 4 points is required in the progress tests (partial exams) and in the laboratory practice exam.

Students who have not passed the continuous assessment have the possibility of taking the progress tests again on the date established for the ordinary call.

Non-continuous evaluation:

Students that opt for the non-continuous assessment will be evaluated only with the final test (80%) and the laboratory sesions (20%), To pass the non-continuous evaluation, it will be necessary to obtain a minimum grade of 5 points in the global evaluation and that of the laboratory practices. To average, a minimum mark of 4 points is required in the laboratory exam and in the final test.

Specifications for the resit/retake exam:

The same criteria will be applied as in the ordinary non-continuous evaluation. The student who in the ordinary call has passed the evaluation of the laboratory practices will not have to re-examine this part in this call.

Specifications for the second resit / retake exam:

Same particularities as the non-continuous evaluation of the ordinary call.

9. Assignments, course calendar and important dates

Not related to the syllabus/contents

Hours	hours
Unit 1 (de 11): Topic 1 SURFACE CHEMISTRY: HETEROGENEOUS CATALYSIS. The interface: surface tension. Curved interfaces. Capillarity. Thermodynamics of surfaces: Gibbs equation. Adsorption of gases on solids: physisorption and chemisorption. Adsorption isotherms: Langmuir isotherm. Heterogeneous catalysis. Mechanisms of Langmuir-Hinshelwood and Eley-Rideal.	

Activities	Hours
Class Attendance (theory) [PRESENCIAL][Lectures]	4
Problem solving and/or case studies [PRESENCIAL][Problem solving and exercises]	2
Writing of reports or projects [AUTÓNOMA][Self-study]	3
Study and Exam Preparation [AUTÓNOMA][Self-study]	8
Mid-term test [PRESENCIAL][Assessment tests]	.6

Group 20:

Initial date: **End date:** 02/01/1970

Unit 2 (de 11): Topic 2 MACROMOLECULES AND AGGREGATES. Classification of macromolecules. Polymerization mechanisms. Distribution and average values of molar masses. Conformation of macromolecules: models. Characterization techniques of macromolecules in solution. Colloids: classification, structure and stability.

Activities	Hours
Class Attendance (theory) [PRESENCIAL][Lectures]	4
Problem solving and/or case studies [PRESENCIAL][Problem solving and exercises]	2
Writing of reports or projects [AUTÓNOMA][Self-study]	3
Study and Exam Preparation [AUTÓNOMA][Self-study]	8
Mid-term test [PRESENCIAL][Assessment tests]	.6

Unit 3 (de 11): Topic 3 ELECTROLYTE SOLUTIONS. Classification of electrolytes. Ion-solvent interactions. Enthalpy and entropy of solvation. Chemical potential of electrolyte solutions. Average ionic activity coefficients. Ion-ion interactions: Debye-Hückel theory. Concentrated solutions. Ionic association.

Activities	Hours
Class Attendance (theory) [PRESENCIAL][Lectures]	3
Problem solving and/or case studies [PRESENCIAL][Problem solving and exercises]	2
Writing of reports or projects [AUTÓNOMA][Self-study]	3
Study and Exam Preparation [AUTÓNOMA][Self-study]	6.5
Mid-term test [PRESENCIAL][Assessment tests]	.55

Unit 4 (de 11): Topic 4 CONDUCTIVITY OF ELECTROLYTE SOLUTIONS. Law of Faraday. Measurement of conductivity and ways of expressing it. Law of Kohlrausch. Ionic mobility and its relationship with conductivity. Walden's Rule. Transportation numbers and their measurement. Arrhenius theory. Dilution law of Ostwald. Influence of ion-ion interactions on conductivity: Debye-Hückel-Onsager theory. Applications of conductivity measurements.

Activities	Hours
Class Attendance (theory) [PRESENCIAL][Lectures]	3
Problem solving and/or case studies [PRESENCIAL][Problem solving and exercises]	2
Writing of reports or projects [AUTÓNOMA][Self-study]	3
Study and Exam Preparation [AUTÓNOMA][Self-study]	6.5
Mid-term test [PRESENCIAL][Assessment tests]	.55

Unit 5 (de 11): Topic 5 ELECTROCHEMICAL EQUILIBRIUM: ELECTRODES AND BATTERIES. Function of the electrodes: anode and cathode. Galvanic and electrolytic cells. Nernst equation. Formal potential Types of reversible electrodes. Notation of the galvanic cells. Cells with liquid union. Salt bridge. Electromotive Force of a cell (EMF). Standard electrode potentials. Electrochemical series. Secondary reference electrodes. Types of galvanic cells. Obtaining thermodynamic data from the measurement of the EMF of a cell.

Activities	Hours
Class Attendance (theory) [PRESENCIAL][Lectures]	4
Problem solving and/or case studies [PRESENCIAL][Problem solving and exercises]	2
Writing of reports or projects [AUTÓNOMA][Self-study]	3
Study and Exam Preparation [AUTÓNOMA][Self-study]	8
Mid-term test [PRESENCIAL][Assessment tests]	.6

Unit 6 (de 11): Topic 6 KINETICS OF ELECTRODIC REACTIONS. Models of the electrode-electrolyte interface. Ideally polarizable and ideally non-polarizable electrodes. The rate of charge transfer: Butler-Volmer equation. Overpotential. Kinetics of rapid charge transfer: reversible behavior. Approximations of the Butler-Volmer equation.

Activities	Hours
Class Attendance (theory) [PRESENCIAL][Lectures]	3
Problem solving and/or case studies [PRESENCIAL][Problem solving and exercises]	2
Writing of reports or projects [AUTÓNOMA][Self-study]	3
Study and Exam Preparation [AUTÓNOMA][Self-study]	6.5
Mid-term test [PRESENCIAL][Assessment tests]	.5

Unit 7 (de 11): Topic 7 INFLUENCE OF TRANSPORT: ELECTROCHEMICAL TECHNIQUES. APPLICATIONS. Processes governed by diffusion. Types of diffusion. Stationary processes: diffusion layer and diffusion limit current density. Overpotential concentration. Non-stationary processes. Potentiostatic method: Voltametric techniques. Galvanostatic method: Chronopotentiometric techniques. Determination of kinetic parameters. Applications of electrode kinetics. Corrosion. Potential and current of corrosion. Protection against cathodic and anodic corrosion.

Activities	Hours
Class Attendance (theory) [PRESENCIAL][Lectures]	4
Problem solving and/or case studies [PRESENCIAL][Problem solving and exercises]	3
Writing of reports or projects [AUTÓNOMA][Self-study]	4.5
Study and Exam Preparation [AUTÓNOMA][Self-study]	8
Mid-term test [PRESENCIAL][Assessment tests]	.6

Unit 8 (de 11): Topic 8 PRACTICE 1. SURFACE TENSION AND SUPERFICIAL EXCESS. The surface tension of several solutions of a non-electrolyte is measured by a stalagmometer. The results of the variation of the surface tension with the solute concentration are interpreted in terms of the surface excess according to the Gibbs isotherm.

Activities	Hours
Class Attendance (practical) [PRESENCIAL][Practical or hands-on activities]	4
Practicum and practical activities report writing or preparation [AUTÓNOMA][Self-study]	1
Writing of reports or projects [AUTÓNOMA][Self-study]	3

Unit 9 (de 11): Topic 9 PRACTICE 2. DETERMINATION OF THE AVERAGE MOLECULAR WEIGHT OF A POLYMER BY VISCOSITY MEASUREMENTS. The viscosity of different solutions of a polymer (cellulose acetate) is determined using an Ostwald viscometer. From the viscosities measured, the specific

viscosity of each solution is obtained. The intrinsic viscosity is determined from the appropriate representation of a function of the specific viscosity against the concentration of the polymer. From it and using the Mark-Houwkin-Sakurada equation, the average molecular weight of the polymer is calculated.	
Activities	**Hours**
Class Attendance (practical) [PRESENCIAL][Practical or hands-on activities]	4
Practicum and practical activities report writing or preparation [AUTÓNOMA][Self-study]	1
Writing of reports or projects [AUTÓNOMA][Self-study]	3
Unit 10 (de 11): Topic 10 PRACTICE 3. DETERMINATION OF THE DISSOCIATION CONSTANT OF A WEAK ACID BY CONDUCTIMETRY. The dissociation constant of acetic acid is determined from measurements of the specific conductivity of several solutions of different concentrations. The molar conductivities of the different solutions are calculated and, given the molar conductivity at infinite dilution, the degree of dissociation of the acid is determined by applying the Arrhenius equation. From the appropriate representation of the Ostwald dilution law we obtain, from the ordinate at the origin, the molar conductivity to infinite dilution and from the slope, the dissociation constant. The goodness of the Arrhenius equation is verified using an iterative procedure to calculate the degree of dissociation.	
Activities	**Hours**
Class Attendance (practical) [PRESENCIAL][Practical or hands-on activities]	4
Practicum and practical activities report writing or preparation [AUTÓNOMA][Self-study]	1
Writing of reports or projects [AUTÓNOMA][Self-study]	3
Unit 11 (de 11): Topic 11 PRACTICE 4. GALVANIC BATTERIES: ASSEMBLY AND DETERMINATION OF THERMODYNAMIC PROPERTIES FROM MEASUREMENTS OF THE ELECTROMOTIVE FORCE. In this practice three types of galvanic batteries are built: a concentration battery in the electrolyte (with silver electrodes, silver nitrate electrolyte and salt bridge of ammonium nitrate), a battery without transport with different electrodes and electrolytes and a standard or Clark battery. The measurement of electromotive force (EMF) of these cells is used to verify the Nernst equation (first cell) and determine the solubility product of the AgCl (second cell). In the case of the Clark battery, the measurement of the EMF at different temperatures between 25 and 45 ºC allows us to determine the variation of enthalpy, entropy and free energy of the chemical reaction of the battery.	
Activities	**Hours**
Class Attendance (practical) [PRESENCIAL][Practical or hands-on activities]	4
Practicum and practical activities report writing or preparation [AUTÓNOMA][Self-study]	1
Writing of reports or projects [AUTÓNOMA][Self-study]	3
Global activity	
Activities	**hours**
Class Attendance (theory) [PRESENCIAL][Lectures]	25
Problem solving and/or case studies [PRESENCIAL][Problem solving and exercises]	15
Class Attendance (practical) [PRESENCIAL][Practical or hands-on activities]	16
Practicum and practical activities report writing or preparation [AUTÓNOMA][Self-study]	4
Writing of reports or projects [AUTÓNOMA][Self-study]	34.5
Mid-term test [PRESENCIAL][Assessment tests]	4
Study and Exam Preparation [AUTÓNOMA][Self-study]	51.5
Total horas:	150

10. Bibliography and Sources

Author(s)	Title/Link	Publishing house	Citv	ISBN	Year	Description
Bertrán Rusca y J. Núñez Delgado (coord.).	Problemas de Química Física	Delta Publicaciones			2007	
Bockris, J. y A.K. Reddy	ELECTROQUÍMICA MODERNA (Volumen 1 y 2)	Reverté			1980	1ªEd.
Bockris, J.O y A.K. Reddy	ELECTROQUÍMICA MODERNA (Volumen 1 y 2)	Reverté			2000	2ª Ed. en inglés
Díaz Peña y A. Roig Muntaner.	Química Física	Alhambra, Madrid			1980	
Engel, T.; Reid, P.	Química Física	Pearson Addison Wesley, Madrid			2006	
Levine, I. N.	FISICOQUÍMICA	McGraw-Hill,			2004	5ª Edición
Mc.Quarrie, D.A. and Simon, J.D.	Physical Chemistry. A molecular approach.	University Science Books			1997	
Atkins, P. W.; De Paula	Química Física	Editorial Médica Panamericana			2008	8ª Edición
Levine, I. N.	Physical Chemistry	McGraw Hill			2008	6th Edition
Albaladejo, José	Apuntes proporcionados por el profesor				2020	Disponible en la Plataforma Campus Virtual
Atkins, P. W.; De Paula, J.; Keeler, J.	Physical Chemistry	Oxford University Press			2017	