

Guía docente / *Course Syllabus*

2019-20

1. Descripción de la Asignatura / *Course Description*

Asignatura <i>Course</i>	TERMODINÁMICA Y CINÉTICA QUÍMICA (docencia en inglés)
Códigos <i>Code</i>	202104
Facultad <i>Faculty</i>	Facultad de Ciencias Experimentales
Grados donde se imparte <i>Degrees it is part of</i>	Grado en Biotecnología
Módulo al que pertenece <i>Module it belongs to</i>	Química para las biociencias moleculares
Materia a la que pertenece <i>Subject it belongs to</i>	Termodinámica y cinética química
Departamento responsable <i>Department</i>	Sistemas Físicos, Químicos y Naturales
Curso <i>Year</i>	2º
Semestre <i>Term</i>	1º
Créditos totales <i>Total credits</i>	6
Carácter <i>Type of course</i>	Obligatoria
Idioma de impartición <i>Course language</i>	Inglés
Modelo de docencia <i>Teaching model</i>	A1

Clases presenciales del modelo de docencia A1 para cada estudiante: 31 horas de enseñanzas básicas (EB), 14 horas de enseñanzas prácticas y de desarrollo (EPD) y 0 horas de actividades dirigidas (AD). Hasta un 10% de la enseñanza presencial puede sustituirse por docencia a distancia (también presencial, pero posiblemente asíncrona), de acuerdo con la programación de la Asignatura publicada antes del comienzo del curso.

Number of classroom teaching hours of A1 teaching model for each student: 31 hours of general teaching (background), 14 hours of theory-into-practice (practical group tutoring and skill development) and 0 hours of guided academic activities. Up to 10% of face-to-face sessions can be substituted by online teaching, in accordance with the course schedule published before it begins.

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2. Responsable de la Asignatura / Course Coordinator

Nombre <i>Name</i>	Juan Antonio Anta Montalvo
Departamento <i>Department</i>	Sistemas Físicos, Químicos y Naturales
Área de conocimiento <i>Field of knowledge</i>	Química Física
Categoría <i>Category</i>	Catedrático de Universidad
Número de despacho <i>Office number</i>	22.3.13
Teléfono <i>Phone</i>	954349314
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3. Ubicación en el plan formativo / Academic Context

Breve descripción de la asignatura <i>Course description</i>	<p>Biotechnology deals with the use of living organisms or chemicals of biological origin to obtain products which involve an economical, health or social added value. For this reason, learning Biotechnology at an undergraduate degree level brings about acquiring basic knowledge in Chemistry and Biology, so that students can understand technological processes which are used in living organisms.</p> <p>In the Academic Memo for undergraduate studies in Biotechnology of the School of Experimental Science of the Universidad Pablo de Olavide, the following general skills are explicitly indicated (among others):</p> <ul style="list-style-type: none">To understand the Scientific Method.To get insight and to apply tools, techniques and protocols for experimental work in the laboratory, and to gain the capability to observe and interpret the results obtained.To develop basic experimental skills for every course, by means of the description, quantification, analysis and critical evaluation of experimental results obtained in an autonomous way.To be able to work adequately in biological, chemical or biochemical laboratory, including and adequate knowledge of the required safety and hygienic procedures, as well as waste disposal and animal test handling.To show a correct and integrated vision of the R&D procedures and to be able to connect and interrelate all fields of Biotechnology, from basic physicochemical and biological principles to new scientific findings, in order to develop novel applications and new biotechnological products of commercial interest. <p>On the other hand, the Memo includes the following specific skills:</p> <ol style="list-style-type: none">To know the Laws of Thermodynamics and their practical application to study a chemical reaction from the thermochemical and thermodynamic point of view. To understand the concept of
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	<p>Chemical Equilibrium and Equilibrium Constant as well as to be able to identify the factors on which they depend.</p> <p>2.To know the basic features which are characteristic of typical physicochemical transport processes like diffusion, osmosis and, electroforesis, among others.</p> <p>3.To master the concepts of reaction rate and rate constant, as well as to know how to identify the factors that influence these magnitudes. To be able to describe proton-transfer and electron-transfer chemical reactions, applying thermodynamic concepts.</p> <p>4.To know the basic principles of Surface Chemistry and Adsorption phenomena, applying thermodynamic and kinetic concepts.</p> <p>The main goal of the CHEMICAL THERMODYNAMICS AND KINETICS course is to help develop all these skills and give the students a more solid theoretical background to understand concepts from more advanced courses in their Biotechnology studies</p>
<p>Objetivos (en términos de resultados del aprendizaje) <i>Learning objectives</i></p>	<p>this course aims at developing a number of general and specific skills which are explicitly indicated in the Biotechnology Memo of the School and that are important for their education. The concrete goal of this course is that students master the following points:</p> <ol style="list-style-type: none"> 1. To know the origin, contents and implications of the Laws of Thermodynamics 2. The know the concept of Chemical Potential 3. To be able to describe Phase Equilibrium and interpret Phase Diagrams 4. To understand the Thermodynamics of Chemical Reactions and to be able to calculate equilibrium constants starting from thermodynamic concepts 5. To know the basic features of the Thermodynamics of solutions of Biomolecules 6. To know the basic features of Transport Phenomena: diffusion, viscosity and heat and charge transport 7. To understand and use correctly formal Chemical Kinetics: Rate equation and integrated Rate equations 8. To understand a chemical mechanism and to know how to derive the Rate equation from it: Steady state approximation and rate-limiting step approximation. 9. To understand the principles of Catalysis and its classification: homogeneous, heterogeneous and enzymatic. 10. To know the main interfacial and adsorption processes. 11. To know the determining factors for stability and aggregation of colloids and macromolecules.
<p>Prerrequisitos <i>Prerequisites</i></p>	<p>Good knowledge of Maths, Physics and Chemistry from first year</p>
<p>Recomendaciones <i>Recommendations</i></p>	<p>constancy and continual study</p>
<p>Aportaciones al plan formativo <i>Contributions to the educational plan</i></p>	<p>Together with the mastering of the concepts mentioned above, this course will help students to gain an improved knowledge of the understanding and use of the scientific English</p>

4. Competencias / Skills

<p>Competencias básicas de la Titulación que se desarrollan en</p>	<p>CB1 - Que los estudiantes hayan demostrado poseer y comprender conocimientos en un área de estudio que parte de la base de la</p>
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<p>la Asignatura <i>Basic skills of the Degree that are developed in this Course</i></p>	<p>educación secundaria general, y se suele encontrar a un nivel que, si bien se apoya en libros de texto avanzados, incluye también algunos aspectos que implican conocimientos procedentes de la vanguardia de su campo de estudio</p> <p>CB2 - Que los estudiantes sepan aplicar sus conocimientos a su trabajo o vocación de una forma profesional y posean las competencias que suelen demostrarse por medio de la elaboración y defensa de argumentos y la resolución de problemas dentro de su área de estudio</p> <p>CB3 - Que los estudiantes tengan la capacidad de reunir e interpretar datos relevantes (normalmente dentro de su área de estudio) para emitir juicios que incluyan una reflexión sobre temas relevantes de índole social, científica o ética</p> <p>CB4 - Que los estudiantes puedan transmitir información, ideas, problemas y soluciones a un público tanto especializado como no especializado</p> <p>CB5 - Que los estudiantes hayan desarrollado aquellas habilidades de aprendizaje necesarias para emprender estudios posteriores con un alto grado de autonomía</p>
<p>Competencias generales de la Titulación que se desarrollan en la Asignatura <i>General skills of the Degree that are developed in this Course</i></p>	<p>CG1 - Conocer y comprender los procesos biológicos generales desde un punto de vista molecular, celular, fisiológico y, en su caso, de comunidades, de los seres vivos.</p> <p>CG4 - Comprender el método científico. Conocer, entender y aplicar las herramientas, técnicas y protocolos de experimentación en el laboratorio y adquirir las capacidades de observación e interpretación de los resultados obtenidos.</p> <p>CG5 - Adquirir las habilidades adecuadas a cada una de las materias impartidas, mediante la descripción, cuantificación, análisis y evaluación crítica de los resultados experimentales obtenidos de forma autónoma.</p> <p>CG6 - Trabajar de forma adecuada en un laboratorio biológico, químico o bioquímico, conociendo y aplicando las normativas y técnicas relacionadas con seguridad e higiene, manipulación de animales de laboratorio y gestión de residuos.</p> <p>CG9 - Desarrollar los métodos de adquisición, interpretación y análisis de la información biológica junto con una comprensión crítica de los contextos apropiados para sus uso, mediante el estudio de manuales, monografías, ensayos, artículos originales, etc.</p> <p>CG10 - Utilizar la literatura científica y técnica de vanguardia, adquiriendo la capacidad de percibir claramente los avances actuales y los posibles desarrollos futuros</p> <p>CG23 - Saber analizar, sintetizar y utilizar el razonamiento crítico en ciencia.</p> <p>CG27 - Demostrar una correcta visión integrada del proceso de I+D+i y ser capaz de interrelacionar y conectar los ámbitos del conocimientos que engloba la biotecnología, desde los principios biológicos y fisicoquímicos a los nuevos conocimientos científicos, para el desarrollo de aplicaciones concretas y la introducción en el mercado de nuevos productos biotecnológicos de interés.</p>
<p>Competencias transversales de la Titulación que se desarrollan en la Asignatura <i>Transversal skills of the Degree that are developed in this Course</i></p>	
<p>Competencias específicas de la</p>	<p>CE1 - Conocer el origen atómico-molecular de las propiedades de</p>

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<p>Titulación que se desarrollan en la Asignatura <i>Specific competences of the Degree that are developed in the Course</i></p>	<p>la materia, incluyendo las sustancias puras, las mezclas y las disoluciones. CE2 - Conocer los Principios de la Termodinámica y su aplicación práctica al estudio termoquímico y termodinámico de una reacción y dominar el concepto termodinámico de equilibrio químico y de constante equilibrio, así como saber identificar los factores de los que depende. CE3 - Conocer las características comunes de los procesos fisicoquímicos de transporte: difusión, osmosis, electroforesis, etc. CE4 - Dominar el concepto de velocidad de reacción y constante de velocidad, así como saber identificar los factores de los que depende y saber describir las reacciones de transferencia protónica y electrónica y aplicar los conceptos termodinámicos a su comportamiento. CE5 - Conocer los principios básicos de la química de superficies y de los fenómenos de adsorción y aplicar los conceptos termodinámicos y cinéticos a su descripción. CE6 - Conocer los principales grupos funcionales orgánicos y las principales reacciones de síntesis orgánica. CE7 - Conocer los principales tipos de isomería en compuestos orgánicos y las principales técnicas de separación. CE8 - Saber que es un polímero, sus tipos y las principales reacciones de polimerización. CE10 - Conocer las bases de los métodos espectroscópicos para análisis químico cuantitativo y elucidación estructural de compuestos orgánicos. CE11 - Conocer los fundamentos de la Química Combinatoria.</p>
<p>Competencias particulares de la asignatura, no incluidas en la memoria del título <i>Specific skills of the Course, not included in the Degree's skills</i></p>	

5. Contenidos de la Asignatura: temario / *Course Content: Topics*

PARTE I	INTRODUCTION AND CHEMICAL THERMODYNAMICS
TEMA 1	INTRODUCTION
TEMA 2	BASIC DEFINITIONS AND THE FIRST LAW
TEMA 3	THE SECOND AND THE THIRD LAWS
TEMA 4	PHASE EQUILIBRIA
TEMA 5	CHEMICAL EQUILIBRIUM
PARTE II	KINETICS AND COMPLEX SYSTEMS
TEMA 6	TRANSPORT PROCESSES
TEMA 7	PHYSICAL CHEMISTRY OF ELECTROLYTIC SOLUTIONS AND ELECTRON-TRANSFER REACTIONS
TEMA 8	FORMAL CHEMICAL KINETICS
TEMA 9	MOLECULAR CHEMICAL KINETICS

6. Metodología y recursos / *Methodology and Resources*

Metodología general	Thermodynamics and Chemical Kinetics is taught in the first
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<p><i>Methodology</i></p>	<p>semester of the second year. It contains a total academic burden of 6 ECTS (European Credits Transfer System). According to the university regulations, 1 ECTS is equivalent to 7.5 hours of in-class/ teaching (time coincidence of teacher and student). Furthermore, this course falls within the A1 category, which implies that 70% of its academic contents correspond to “Basic Education” (EB, 31 hours), whereas 30% is “Practical and Development Education (EPD, 14 hours).</p> <p>In-class work will be carried in groups of 20 students, for both the EB and the EPD.</p> <p>The time distribution for the students per ECTS (25 hours) is as follows :</p> <ul style="list-style-type: none"> •7.5 hours of in-class work: 4.5 hours EB and 3 hours EPD •15 hours of individual work •2.5 hours of evaluation and examination. <p>Therefore: 6 ECTS are equivalent to 45 hours of class attendance for EB, 14 hours for laboratory exercises and seminars, 90 hours of individual work and 15 hours for evaluation.</p>
<p>Enseñanzas básicas (EB) <i>General teaching</i></p>	<p>Chemical Thermodynamics and Kinetics is a “tool” discipline and its scope and applicability is very broad. Besides, we only have 45 hours of in-class teaching. Therefore:</p> <ol style="list-style-type: none"> 1. Theoretical notes comprising the main concepts will be available in the virtual space of the course (aula virtual). A bibliography of recommended textbooks will also be given 2. A collection of proposed problems for EB will also be available 3. EB hours will be devoted to the solution of numerical problems on the blackboard 4. The solution of each problem will be preceded by a short theoretical introduction to help tackle the problem 5. An EPD seminar will be devoted to the solution of selected numerical problems. Student participation will be requested.
<p>Enseñanzas prácticas y de desarrollo (EPD) <i>Theory-into-practice</i></p>	<p>EPD lab exercises will be carried out in the lab following a script, also available in advance in the virtual space</p>
<p>Actividades académicas dirigidas (AD) <i>Guided academic activities</i></p>	<p>there are none</p>

7. Criterios generales de evaluación / Assessment

<p>Primera convocatoria ordinaria (convocatoria de curso) <i>First session</i></p>	<p>El 35% de la calificación procede de la evaluación continua. El 65% de la calificación procede del examen o prueba final. a one-hour exam containing 2-3 problems on the topics taught so far in the course will be presented. Students will be allowed to choose any one of these problems for their answer. Next day in the EB class the problems will be solved and discussed. Some of the students may be required to solve the problems on the blackboard for public discussion.</p> <p>1.The Final EB exam will be composed of 3 or 4 numerical problems from Parts A and B</p>
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	2. The Final EPD-laboratory exam will be composed of one question for each of the practical exercise done in the laboratory. The students may bring their laboratory notes to the exam to help them answer the questions. It is then important to carry out the laboratory exercises properly and correctly annotate the main results and conclusions
Segunda convocatoria ordinaria (convocatoria de recuperación) <i>Second session (to re-sit the exam)</i>	Same as before
Convocatoria extraordinaria de noviembre <i>Extraordinary November session</i>	Se activa a petición del alumno siempre y cuando éste esté matriculado en todas las asignaturas que le resten para finalizar sus estudios de grado, tal y como establece la Normativa de Progreso y Permanencia de la Universidad. Se evaluará del total de los conocimientos y competencias que figuren en la guía docente del curso anterior, mediante el sistema de prueba única. Same as before
Criterios de evaluación de las enseñanzas básicas (EB) <i>General teaching assessment criteria</i>	<p>Durante la evaluación continua: The final mark of the course will be the largest of either of these two mathematical formulae: $MARK\ 1 = 0.5 \times Final\ EB + 0.25 \times mid\text{-}term\ exams + 0.15 \times Final\ EPD\text{-}laboratory + 0.1 \times Problem\text{-}Paper$ $MARK\ 2 = 0.75 \times Final\ EB + 0.15 \times Final\ EPD\text{-}laboratory + 0.1 \times Problem\text{-}Paper$</p> <p>To pass the course, a minimum of 5 points out of 10 will be required, provided a minimum of 4 points in each of the Final Exams of EB and EPD-laboratory is achieved. This means that realization of the EB and EPD Final Exams is mandatory to pass the course, whereas the rest of the elements in the evaluation are facultative.</p> <p>Once the retake exams for both EB and EPD-lab (July call) are held, the marks obtained from the mid-term exams and the Poster-Paper during the normal teaching period will be kept and considered to calculate the final mark of the course. However, upon student request, and after renouncing to the marks previously obtained (by written and signed permission), a special exam covering a 100% of the total mark of the course will be presented to the students. This exam will include the examination of all skills taught during the course. In case the student does not pass the course, partial marks (EPD, Seminars, etc.) will not be kept for subsequent years.</p> <p>Attendance to the lab sessions is mandatory, although the students can miss one and only one session if their absence is properly justified (medical certificate). According to the article 8.2.d of the Evaluation Regulations of the University, the attendance to the lab sessions is not required when the course is evaluated by a single exam covering the 100% of the total mark.</p> <p>Durante el examen o prueba final (1ª convocatoria): The final mark of the course will be the largest of either of these two mathematical formulae: $MARK\ 1 = 0.5 \times Final\ EB + 0.25 \times mid\text{-}term\ exams + 0.15 \times Final\ EPD\text{-}laboratory + 0.1 \times Problem\text{-}Paper$ $MARK\ 2 = 0.75 \times Final\ EB + 0.15 \times Final\ EPD\text{-}laboratory + 0.1 \times Poster\text{-}Paper$</p> <p>To pass the course, a minimum of 5 points out of 10 will be required, provided a minimum of 4 points in each of the Final Exams of EB and EPD-laboratory is achieved. This means that</p>

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	<p>realization of the EB and EPD Final Exams is mandatory to pass the course, whereas the rest of the elements in the evaluation are facultative.</p> <p>Once the retake exams for both EB and EPD-lab (July call) are held, the marks obtained from the mid-term exams and the Poster-Paper during the normal teaching period will be kept and considered to calculate the final mark of the course. However, upon student request, and after renouncing to the marks previously obtained (by written and signed permission), a special exam covering a 100% of the total mark of the course will be presented to the students. This exam will include the examination of all skills taught during the course. In case the student does not pass the course, partial marks (EPD, Seminars, etc.) will not be kept for subsequent years.</p> <p>Attendance to the lab sessions is mandatory, although the students can miss one and only one session if their absence is properly justified (medical certificate). According to the article 8.2.d of the Evaluation Regulations of the University, the attendance to the lab sessions is not required when the course is evaluated by a single exam covering the 100% of the total mark.</p> <p>Durante el examen o prueba final (2ª convocatoria): same as before</p>
<p>Crterios de evaluaci3n de las ensefanzas pr3cticas y de desarrollo (EPD) <i>Theory-into-practice assessment criteria</i></p>	<p>Durante la evaluaci3n continua: The final mark of the course will be the largest of either of these two mathematical formulae: $MARK\ 1 = 0.5 \times Final\ EB + 0.25 \times mid\text{-}term\ exams + 0.15 \times Final\ EPD\text{-}laboratory + 0.1 \times Problem\text{-}Paper$ $MARK\ 2 = 0.75 \times Final\ EB + 0.15 \times Final\ EPD\text{-}laboratory + 0.1 \times Problem\text{-}Paper$</p> <p>To pass the course, a minimum of 5 points out of 10 will be required, provided a minimum of 4 points in each of the Final Exams of EB and EPD-laboratory is achieved. This means that realization of the EB and EPD Final Exams is mandatory to pass the course, whereas the rest of the elements in the evaluation are facultative.</p> <p>Once the retake exams for both EB and EPD-lab (July call) are held, the marks obtained from the mid-term exams and the Poster-Paper during the normal teaching period will be kept and considered to calculate the final mark of the course. However, upon student request, and after renouncing to the marks previously obtained (by written and signed permission), a special exam covering a 100% of the total mark of the course will be presented to the students. This exam will include the examination of all skills taught during the course. In case the student does not pass the course, partial marks (EPD, Seminars, etc.) will not be kept for subsequent years.</p> <p>Attendance to the lab sessions is mandatory, although the students can miss one and only one session if their absence is properly justified (medical certificate). According to the article 8.2.d of the Evaluation Regulations of the University, the attendance to the lab sessions is not required when the course is evaluated by a single exam covering the 100% of the total mark.</p> <p>Durante el examen o prueba final (1ª convocatoria): The final mark of the course will be the largest of either of these two mathematical formulae: $MARK\ 1 = 0.5 \times Final\ EB + 0.25 \times mid\text{-}term\ exams + 0.15 \times Final\ EPD\text{-}laboratory + 0.1 \times Problem\text{-}Paper$ $MARK\ 2 = 0.75 \times Final\ EB + 0.15 \times Final\ EPD\text{-}laboratory + 0.1 \times Problem\text{-}Paper$</p> <p>To pass the course, a minimum of 5 points out of 10 will be</p>

	<p>required, provided a minimum of 4 points in each of the Final Exams of EB and EPD-laboratory is achieved. This means that realization of the EB and EPD Final Exams is mandatory to pass the course, whereas the rest of the elements in the evaluation are facultative.</p> <p>Once the retake exams for both EB and EPD-lab (July call) are held, the marks obtained from the mid-term exams and the Poster-Paper during the normal teaching period will be kept and considered to calculate the final mark of the course. However, upon student request, and after renouncing to the marks previously obtained (by written and signed permission), a special exam covering a 100% of the total mark of the course will be presented to the students. This exam will include the examination of all skills taught during the course. In case the student does not pass the course, partial marks (EPD, Seminars, etc.) will not be kept for subsequent years.</p> <p>Attendance to the lab sessions is mandatory, although the students can miss one and only one session if their absence is properly justified (medical certificate). According to the article 8.2.d of the Evaluation Regulations of the University, the attendance to the lab sessions is not required when the course is evaluated by a single exam covering the 100% of the total mark.</p> <p>Durante el examen o prueba final (2ª convocatoria): same as before</p>
<p>Crterios de evaluación de las actividades académicas dirigidas (AD) <i>Criteria of assessment of guided academic activities</i></p>	<p>Durante la evaluación continua: there are none Durante el examen o prueba final (1ª convocatoria): Durante el examen o prueba final (2ª convocatoria):</p>
<p>Puntuaciones mínimas necesarias para aprobar la Asignatura <i>Minimum passing grade</i></p>	<p>1ª convocatoria: To pass the course, a minimum of 5 points out of 10 will be required, provided a minimum of 4 points in each of the Final Exams of EB and EPD-laboratory is achieved. This means that realization of the EB and EPD Final Exams is mandatory to pass the course, whereas the rest of the elements in the evaluation are facultative.</p> <p>2ª convocatoria: To pass the course, a minimum of 5 points out of 10 will be required, provided a minimum of 4 points in each of the Final Exams of EB and EPD-laboratory is achieved. This means that realization of the EB and EPD Final Exams is mandatory to pass the course, whereas the rest of the elements in the evaluation are facultative.</p>
<p>Material permitido <i>Materials allowed</i></p>	<p>ball pen and calculator</p>
<p>Identificación en los exámenes <i>Identification during exams</i></p>	<p>En cualquier momento de la realización de una prueba de evaluación los profesores podrán requerir la acreditación de la identidad de cualquier estudiante, mediante la exhibición de su carnet de estudiante, documento nacional de identidad, pasaporte u otro documento válido a juicio del examinador. Si no lo hiciese, el estudiante podrá continuar la prueba, que será calificada solo si la documentación es presentada en el plazo que el examinador establezca.</p>
<p>Observaciones adicionales <i>Additional remarks</i></p>	

Los estudiantes inmersos en un programa de movilidad o en un programa de deportistas de alto nivel, así como los afectados por razones laborales, de salud graves o por causas de fuerza mayor debidamente acreditadas, tendrán derecho a que en la convocatoria de curso se les evalúe mediante un sistema de evaluación de prueba

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única. Para ello, deberán comunicar la circunstancia al profesor responsable de la asignatura antes del fin del periodo docencia presencial.

Students enrolled in a mobility program or a program for high-level athletes, as well as students affected by work or serious health problems or reasons of force majeure duly accredited, will have the right to be evaluated during the first session through a single test evaluation system. To do this, they must report changes in their circumstances to the program coordinator before the end of the teaching period.

8. Bibliografía / Bibliography

	<ul style="list-style-type: none">• P.W. Atkins y J. De Paula (2003) “Fisicoquímica”, <i>Oxford University Press</i>• P.W. Atkins y J. De Paula (2006) “Physical chemistry for the Life Sciences”, <i>Oxford University Press</i>• J. Bertrán Rusca y Javier Núñez Delgado (2002) “Química Física I y II”, <i>Ariel</i>• Gordon G. Hammes (2007) “Physical chemistry for the Biological Sciences”, <i>John Wiley, cop</i>• Ken A. Dill y Sarina Bromberg (2011) “Molecular Driving Forces (2nd Edition)”, <i>Garland Science</i>• S. R. Logan (2000) “Fundamentos de Cinética Química”, <i>Addison Wesley Publishing Company</i>• M.W. Zemansky y R.H. Dittman (1990) “Calor y termodinámica”, <i>McGraw-Hill</i>• del Barrio Casado y col. (2005) “Problemas resueltos de termodinámica”, <i>Paraninfo</i>
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