Course Guide

INORGANIC CHEMISTRY II

FACULTAD DE CIENCIAS QUÍMICAS
UNIVERSIDAD COMPLUTENSE DE MADRID
ACADEMIC YEAR 2022-2023

I.- COURSE IDENTIFICACIÓN

COURSE NAME:	**Inorganic Chemistry II**
CREDITS:	**12**
CHARACTER:	**Mandatory**
SUBJECT:	**Inorganic Chemistry**
MODULE:	**Fundamental**
DEGREE:	**Degree in Chemistry**
SEMESTER/COURSE:	**Annual (3rd year)**
DEPARTAMENT:	**Inorganic Chemistry**

PROFESSORS:

Course Coordinator	**Professor:**	JOSEFA ISASI MARÍN
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Laboratory Coordinator	**Professor:**	JOSEFA ISASI MARÍN
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Group E		
Theory Seminars Tutorials	**Professor:**	Mª JOSE MAYORAL MUÑOZ
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Theory Seminars Tutorials	**Professor:**	ELENA ARROYO Y DE DOMPABLO
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Laboratory QA141

Group	Semester	Professor	e-mail	Office	Depar.
E1	1º	Miguel Cortijo	miguelcortijomontes@ucm.es	QA-210	QI
	2º	Inmaculada Álvarez	ias@ucm.es	QA-108	QI
E2	1º	Cristián Cuerva	c.cuerva@ucm.es	QA-211	QI
	2º	Elena Arroyo	e.arroyo@ucm.es	QA-137	QI

II.- OBJECTIVES

GENERAL OBJECTIVE

It is intended that the student acquires the appropriate knowledge that will allow her/him to know and relate the structure, properties, reactivity and applications of the compounds of metallic elements.

Students must learn specific synthesis procedures with the use of the appropriate material and assemblies, as well as be introduced to the basic aspects and the use of different characterization methods to the synthesized inorganic compounds.

SPECIFIC OBJECTIVES

- To develop the fundamental aspects of Coordination and Organometallic Chemistry.
- To develop the fundamental aspects of Solid State Chemistry.
- To establish structure-property relationships in elements as well as in their corresponding compounds.
- To use specific synthesis procedures to obtain inorganic compounds.
- To know the fundamentals of the most frequent techniques for characterizing inorganic compounds.
- To understand the importance of inorganic compounds of metallic elements within Science, and their significance as advanced materials.

III.- BACKGROUND KNOWLEDGE AND RECOMMENDATIONS

PRIOR KNOWLEDGE:

Characteristics of the elements and the general trends of their physical-chemical properties based on the periodic table. Basic structural aspects of molecular and non-molecular species. General characteristics of the electronic structure of a metal, a semiconductor and an insulator. General procedures for the synthesis of inorganic compounds.

RECOMMENDATIONS:

It is recommended that students enrolling in this course have previously taken and passed the *General Chemistry* and *Inorganic Chemistry I* courses.

IV.- CONTENTS

BRIEF DESCRIPTION:

Theoretical contents

Coordination compounds: bond, stereochemistry, spectroscopic and magnetic properties, reactivity. Organometallic compounds: basic aspects. Metal-metal bond in coordination and organometallic compounds. Structure, bond, properties and reactivity of non-

molecular inorganic solids. Oxides and sulfides of the transition elements. Silicates and phosphates.

Practical contents

Synthesis and characterization of non-molecular inorganic solids and coordination and organometallic compounds. Instrumental characterization techniques.

SYLLABUS:

THEORY. FIRST SEMESTER.

Coordination Compounds

Unit 1: Bonding in coordination compounds
- Molecular orbital theory: octahedral, tetrahedral and square-plane compounds

Unit 2: **Thermodynamic aspects of coordination compounds**
- Equilibrium constants
- The chelate, cryptate and macrocyclic effects
- Hard-soft interaction

Unit 3: Stereochemistry
- Factors influencing the stereochemistry of coordination compounds
  Low coordination numbers
  High coordination numbers

Unit 4: **Spectroscopic properties**
- Adjusted crystal field theory
- Electronic transitions: d-d transitions and charge transfer transitions. Color
- Tanabe-Sugano diagrams
- Analysis of electronic spectra

Unit 5: **Magnetic Properties**
- Magnetic behavior of transition metal coordination compounds
- Spin moment and orbital contribution. Spin-orbital coupling

Unit 6: **Reactivity of coordination compounds**
- Types of reactions
- Substitution reactions
- Electronic transfer reactions. Outer sphere and inner sphere mechanisms

Unit 7: Basic concepts in organometallic compounds
- Classification of organometallic compounds
- Metal-carbon bonds
- Transition metal compounds. 18 electron-rule

Unit 8: Metal-metal bonding in coordination and organometallic compounds
- Dinuclear compounds with metal-metal bond
- Metal carbonyl clusters. Effective atomic number (EAN) rule. Wade's rules
- Metal halide clusters

THEORY. SECOND SEMESTER.

Non- molecular inorganic solids

Unit 9: Reactivity of solids. Types of reactions.
- Solid-solid reactions: mechanisms

- Solid-liquid reactions
  - Intercalation reactions
  - Ionic-Exchange reactions
- Solid-gas reactions
  - Transport reactions
- Crystal growth

Unit 10: Introduction to the electronic structure of solids

- Information provided by spectroscopy methods
- Band models for inorganic solids. Overlapping of the orbitals in the crystal. The effect of the periodic potential of the network. Properties depending on the density of states

Unit 11: Metal oxides

- Structure-property relations. Application of the Goodenough band model to the study of oxides with stoichiometries MO, M_2O_3, MO_2 and MO_3. Applications. Nonstoichiometry in binary oxides.
- Mixed oxides: structural characteristic of ABO_3 types (Ilmenites and perovskites) and AB_2O_4 (spinels).
- Structure-properties relations.: Electronic properties in perovskite and spinel - type oxides. Ferroelectric Perovskites. Ionic and mixed conductivity in spinel. Influence of particle size on the magnetic properties of spinels. Applications
- Homologous series related to ReO_3 structure. Bronzes A_xBO_3. Nonstoichiometric perovskites.

Unit 12: Metal sulphides

- Analogies and differences between oxides and sulphides
- Structure-properties relations: metal transition sulphides
- Nonstoichiometry in sulphides
- Applications

Unit 13: Other inorganic relevant compounds: Silicates.

- Introduction.General classification of silicates.
- Laminar silicates
- Silice and 3D-silicates
- Zeolites: Structural Characteristics. Synthesis Applications; catalysts, molecular sieves, ion exchangers.

LABORATORY SESSIONS. FIRST SEMESTER.

Characterization of coordination and organometallic compounds. Magnetic behavior.

1. Template effect: Synthesis of Ni(II) tetraazamacrocyclic complexes
2. Preparation of hexacoordinate chromium(III) complexes. Magnetic behavior. Determination of the spectrochemical series.

LABORATORY SESSIONS. SECOND SEMESTER.

Non-molecular solid synthesis methods. Thermal decomposition.

X-ray diffraction. Magnetic behavior of non-molecular solids.

1. Preparation of TiO_2 by different synthesis methods. Study of the transformation of anatase-rutile phase.

2. Preparation and characterization of solid solutions:
   - Al_2O_3/Cr_2O_3 system
   - Fe_2O_3/Cr_2O_3 system
3. Preparation, structural and magnetic characterization of $RCrO_4$ oxides (R = Rare Earth).
4. Preparation of Fe(III) spinels. Structural characterization and magnetic behavior.
5. Preparation and study of the properties of zeolite A.

V.- COMPETENCES

GENERAL COMPETENCES:

- **CG1-MF1:** Recognize chemical processes in daily life.
- **CG2-MF1:** Relate Chemistry to other disciplines.
- **CG3-MF1:** Continue her/his studies in multidisciplinary areas.
- **CG5-MF1:** Demonstrate knowledge and understanding of the essential facts, concepts, principles and theories related to the areas of Chemistry.
- **CG6-MF1:** Analyze and solve qualitative and quantitative problems.
- **CG7-MF1:** Recognize and analyze new problems and plan strategies to solve them.
- **CG8-MF1:** Consult and use scientific and technical information in an effective manner.
- **CG9-MF1:** Demonstrate knowledge of laboratory material and practical skills.
- **CG10-MF1:** Safe handling of chemical materials.
- **CG10-MF2:** Recognize and assess hazards in the use of chemicals and laboratory procedures.
- **CG11-MF1:** Handle standard and specific chemical instrumentation.
- **CG12-MF1:** Interpret data from observations and laboratory measurements.
- **CG13-MF1:** Recognize and implement good scientific practices for measurement and experimentation.

SPECIFIC COMPETENCES:

- **CE8-MFQI1:** Describe and relate the bond, structure and properties of compounds of metallic elements.
- **CE9-MFQI1:** Develop the fundamental aspects of Coordination and Organometallic Chemistry.
- **CE9-MFQI2:** Develop the fundamental aspects of Solid State Chemistry.
- **CE10-MFQI1:** Use experimental methods for the synthesis of inorganic compounds.
- **CE10-MFQI2:** Explain the fundamentals and use the most frequent techniques for the characterization of inorganic compounds.

TRANSVERSAL COMPETENCES:

- **CT1-MF1:** Prepare and write scientific and technical reports.
- **CT2-MF1:** Cooperate with other students through teamwork.
- **CT3-MF1:** Apply critical and self-critical reasoning.

- **CT5-MF1:** Use chemical information, bibliography and specialized databases.
- **CT6-MF1:** Identify the importance of chemistry in the industrial, environmental and social context.
- **CT7-MF1:** Use computer tools and programs for the treatment of experimental data.
- **CT11-MF1:** Develop autonomous learning.
- **CT12-MF1:** Recognize the current energy problem and its importance.
- **CT12-MF2:** Develop sensitivity to environmental issues.

VI.- LEARNING OUTCOMES

Once the student has passed this course, he/she should be able to:

- Apply the Molecular Orbital Theory to coordination compounds.
- Discuss fundamental thermodynamic aspects of coordination compounds.
- Describe the chelate and macrocyclic effect.
- Predict the most favorable stereochemistry for a given coordination compound.
- Describe and apply the adjusted crystal field theory.
- Recognize and differentiate the different types of electronic transitions.
- Use the Tanabe-Sugano diagrams and calculate the corresponding parameters.
- Explain the color observed in coordination compounds.
- Explain the magnetic behavior of metal coordination compounds of the first transition series.
- Predict the existence of spin-orbital coupling.
- Analyze substitution reactions in coordination compounds and explain the reaction mechanism.
- Design synthetic procedures of square-plane compounds by ligand substitution.
- Analyze electron transfer reactions in coordination compounds and justify the most appropriate mechanism.
- Identify the different types of metal-carbon bond.
- Apply the 18 electron-rule.
- Explain the metal-carbon bond in representative examples.
- Determine the metal-metal bond order in clusters.
- Apply Wade's rules to determine the structure of clusters.
- Discuss the synthesized non-molecular solids by ceramic method, intercalation reactions, ion exchange, hydrothermal synthesis and transport reactions.
- Explain the characteristics of the electronic structure of non-molecular solids through different approaches that consider collective electrons and localized electrons.
- Analyze the conceptual bases and general characteristics of the Goodenough band model for non-molecular solids.
- Interpret the crystalline structure, the electronic structure and its relationship with the properties of binary oxides (MO, MO_2, MO_3 and M_2O_3) and mixed oxides (ABO_3 and AB_2O_4).
- Discuss the differences between a non-stoichiometric solid and the formation of a crystalline superstructure.
- Explain the analogies and differences between sulfides and oxides of transition elements.
- Explain some examples of non-stoichiometric sulfides.

- Explain the crystal and electronic structure of some 2D and 3D sulfides of transition elements.
- Explain the general characteristics of silicates.
- Discuss the crystal structure of layered and three-dimensional silicates.
- Discuss the applications of zeolites based on their properties.
- Properly use the specific synthesis methods depending on the nature of the inorganic compounds.
- Explain the fundamentals and use the most frequent techniques for characterizing inorganic compounds, and interpret the results obtained.

VII.– WORK TIME DISTRIBUTION AMONG ACTIVITY TYPES

Activity	Face-to-face (hours)	Personal work (hours)	Credits (hours)
Theory classes	56	54	4,4 (110)
Seminars	22	48	2,8 (70)
Tutorials/guided work	6	14	0,8 (20)
Laboratory	40	33	2,92 (73)
Classroom assignments and exams	6	21	1,08 (27)
Total	**130**	**170**	**12 (300)**

VIII.- METHODOLOGY

A mixed methodology based on cooperative learning, collaborative learning and self-learning will be followed. The face-to-face activities of the course are structured in **lectures or master classes of the principles, seminar classes, tutorials and guided activities, and practical classes.**

The **theory classes** (2 hours/week throughout the course) will be expositive and in them the professor will present in an orderly manner the theoretical concepts and experimental facts that allow the student to obtain a global and comprehensive vision of the subject. At the beginning of each topic, the content and main objectives will be presented. At the end of the topic, new proposals may be proposed that allow the interrelation of contents. As support for the theoretical explanations, students will be provided with the appropriate teaching material which will be available in the UCM **Virtual Campus**.

The **seminar sessions** (1 hour/week throughout the course) will aim to apply the knowledge acquired to a set of questions/exercises. For this purpose, students will be given a list of questions/exercises related to each topic of the course. Part of the exercises will be solved in class by the professor and in other cases the resolution will be carried out by the students as personal work. Some of the questions will be related to inorganic species not described in the theory classes, so that students can use the acquired knowledge in the answer to the questions.

Short exams and **questions** will be required to assess the evolution of the students and the degree of achievement of the knowledge they are acquiring.

In order to carry out a more personalized follow-up of the students, and promote autonomous group work, a series of **directed activities** will be proposed. The professor will schedule **tutorials** on issues raised by the students (or by the professor), related to the syllabus of the subject.

Laboratory practices will be developed with contents related to the theory to constitute a complement and support to the classes and seminars. The experimental laboratory sessions will take place over five days per semester (4 hours/day). In the sessions, selected experiments will be carried out among those proposed in the practical program of the subject and which are included in the practice script.

During the practical sessions, 2 hours of seminars per semester will be given, where the necessary knowledge to carry out the planned experiences will be explained. In parallel to each practice, they will develop a report of their work, which reflects in detail each of the operations and reactions carried out, as well as the results obtained. The professor will supervise and discuss with the student the proposed work and the outline of the laboratory report, resolving any doubts that may have arisen during its development. The laboratory report will be delivered to the professor at the end of the practices of each semester, on the date that will be indicated in due time.

IX.- BIBLIOGRAPHY

■ BASIC:

At the beginning of the course, the recommended bibliography will be discussed, indicating the most relevant aspects of each text. General recommended texts are listed below:

THEORY

- Huheey J. E., Keiter E. A., Keiter R. L., Medhi O. K., *Inorganic Chemistry: Principles of Structure and Reactivity*, 4th Ed. Pearson, 2006. Existe traducción al castellano de la 2ª ed. 1981.
- Ribas Gispert, J.: *Química de la Coordinación*, Ediciones Omega, 2000. Versión inglesa: *Coordination Chemistry*, Wiley-VCH, 2008.
- Smart, L.E.; Moore, E.A.: *Solid State Chemistry: An Introduction*, 4th ed., CRC Press, 2014.
- West A. R.: *Solid State Chemistry and its Applications*, Wiley, 2nd Edition, 2014.
- Pico, C.; López, M. L.; Veiga, M. L.: Química del Estado Sólido, Síntesis, 2017.

LABORATORY

- Dann, S. E.: *Reactions and Characterization of Solids*, The Royal Society of Chemistry, London, 2000.
- Nakamoto K., *Infrared and Raman Spectra of Inorganic and Coordination Compounds (parts A and B)*, John Wiley & Sons, 2008.
- Schubert, U.; Hüsing, N.: *Synthesis of Inorganic Materials*, 2nd ed. Wiley, 2005.

The laboratory scripts will be available in the UCM Virtual Campus.

COMPLEMENTARY:

- Astruc, D.: *Organometallic Chemistry and Catalysis*, Springer, 2007.
- Bochmann M.: "*Organometallics 1: Complexes with Transition Metal-Carbon σ-bonds"*, Oxford Univ. Press, 1994.
- Bochmann M.: *Organometallics 2: Complexes with Transition Metal-Carbon π-bonds*, Oxford Univ. Press, 1994.
- Cotton, F. A.; Wilkinson, G.; Murillo, C. A.; Bochmann, M.: *Advanced Inorganic Chemistry,* 6th ed., Wiley, 1995.
- Cotton, F. A., Murillo C.A., Walton R. A., *Multiple Bonds between Metal Atoms,* 3rd ed., Springer, 2005.
- Greenwood, N.; Earnshaw, A.: *Chemistry of the Elements,* 2nd ed., Pergamon Press, 1997.
- Housecroft, C.E.; Sharpe, A.G.: *Inorganic Chemistry.* 4th ed., Pearson 2012. (Traducción de la 2ed., 2006).
- Hyde G. G., Anderson S., *Inorganic Crystal Structures*, Wiley, 1989.
- Miessler, G. L.; Fischer P. J., Tarr, D. A.: *Inorganic Chemistry*, 5th ed., Pearson 2013.
- Müller, H.: *Inorganic Structural Chemistry*, 2nd ed., Wiley, 2007.
- Porterfield, W. W.: *Inorganic Chemistry: An Unified Approach*, 2nd ed., Academic Press, 1999.
- Rao, C. N. R.; Raveau, B.: *Transition Metal Oxides: Structure, Properties and Synthesis of Ceramic Oxides*, Wiley, 1998.
- Weller, M. T.; Overton, T L.; Rourke, J.P., Armstrong, F.A.: *Inorganic Chemistry*, 6th ed., Oxford University Press, 2014. Revised versión: Shriver et al. 2009.
- Wells A. F. *Structural Inorganic Chemistry*, 5th Ed. Oxford Univ. Press, 1985.
- Wold, A.; Dwight, K.: *Solid State Chemistry,* Chapman and Hall*,* 1993.

In addition to the basic and complementary texts, on time, students may be given a specific bibliography for each topic.

X.- EVALUATION

For the final evaluation, it is mandatory for the student to participate in the proposed activities. It is also mandatory to attend all laboratory sessions. In order to access the final evaluation, the student must have participated in at least 70 % of the face-to-face activities.

The student's academic performance and the final grade will be computed according to the weights shown in each of the items listed below. All grades will be based on the absolute 10- points score and according to the scale established in the RD 1125/2003 law. This criterion will be maintained in all calls.

The **grades** of the activities foreseen for the evaluation of the course **will be communicated to the students sufficiently in advance before the completion of the final exam**. In particular, the grades of the **mid-term exams** ("partial") will be communicated within a maximum period of 20 days, except in the case of the **second partial exam**, in which the

period may be shorter to adapt to the final exam date. In any case, **a minimum period of 7 days** between the **publication of the grades and the date of the final exam** of the course will be respected.

Partial exams will be liberatory provided that the mark achieved is greater than or equal to 6, only for the ordinary call.

- **WRITTEN EXAMS (theory): 60%**

  The knowledge acquired by the student (CG1-MF1, CG2-MF1, CG3-MF1, CG5-MF1, CG6-MF1, CG7-MF1, CG8-MF1, CE8-MFQI1, CE9-MFQI1, CE9-MFQI2, CT3-MF1, CT5-MF1, CT6-MF1, CT11-MF1, CT12-MF1, CT12-MF2) will be evaluated by means of two mid-term ("partial") exams, one at the end of each semester, and a final exam. Students who pass the two mid-term exams will not be required to take the final exam. Those students who take the final exam will have to obtain a minimum grade of 4.0 in that exam to have access to the overall grade of the course, whether the exam includes one or both partial exams.

  This exam will assess the general competences CG1-MF1, CG2-MF1, CG5-MF1, CG6-MF1, CG7-MF1, CG8-MF1, the specific competences CE8-MFQI1, CE9-MFQI1 and CE9-MFQI2 and the transversal competences CT3-MF1, CT5-MF1 and CT6-MF1.

- **PERSONAL WORK: 5%**

  The evaluation of the personal work will be valued taking into account the following factors:

  • Student skill in solving the proposed problems and exercises, which will be collected periodically.

  • Evaluation of the student's work in the seminars.

  The evaluation of these aspects will allow knowing the degree of achievement of the general competences CG1-MF1, CG2-MF1, CG5-MF1, CG6-MF1, CG7-MF1, CG8-MF1, CG12-MF1, of the specific competences CE8-MFQI1, CE9-MFQI1, CE9-MFQI2, CE10-MFQI2 and transversal competences CT1-MF1, CT2-MF1, CT3-MF1, CT5-MF1, CT6-MF1, CT7-MF1, CT11-MF1, CT12-MF1, CT12 -MF2.

- **GUIDED ACTIVITIES: 5%**

  The work done by the students during the tutorials will be evaluated.

  The evaluation of these aspects will allow knowing the degree of achievement of the general competences CG1-MF1, CG2-MF1, CG5-MF1, CG6-MF1, CG7-MF1, CG8-MF1, of the specific competences CE8-MFQI1, CE9-MFQI1, CE9-MFQI2 and the transversal competences CT1-MF1, CT2-MF1, CT3-MF1, CT5-MF1, CT6-MF1, CT7-MF1, CT11-MF1, CT12-MF1, CT12-MF2.

- **LABORATORY: 30% (10% exam; 20% laboratory)**

  Attendance at all experimental sessions and laboratory seminars is **mandatory**. Group changes may only be made for justified reasons.

It will be necessary to globally pass the activities related to the laboratory practices in order to access the final grade for the course and which together constitute 30 % of the overall grade.

Participation in the laboratory will be evaluated through the professor's assessment of the theoretical knowledge acquired, the experimental procedures used, the aptitude and attitude of the student in the sessions and the progress observed in the student.

The presentation of the laboratory report made by each student during the laboratory sessions will be required. The professor will consider the preparation of this work, the way in which the student presents and interprets the results obtained and the ability to show the experimental results.

An exam will be held per semester upon completion of the corresponding block of laboratory sessions (ordinary call). There will be an extraordinary call for students who have not reached the minimum qualification.

This activity will reinforce the knowledge acquired by the student, both in the face-to-face theory classes and seminars, as well as in the other activities of the course, which will result in the consolidation of all the general, specific and transversal skills.

With this activity the general competences CG1-MF1, CG2-MF1, CG5-MF1, CG6-MF1, CG7-MF1, CG8-MF1, CG9-MF1, CG10-MF2, CG11-MF1, CG12-MF1, CG13-MF1, the specific competences CE8-MFQI1, CE9-MFQI1, CE9-MFQI2, CE10-MFQI1 and CE10-MFQI2, and all the transversal ones.

ACTIVITY PLANNING – CHRONOGRAM

SUBJECT	ACTIVITY	HOURS	GRUPS	START	END
1. Bonding in coordination compounds, Thermodynamic aspects and Stereochemistry (Units 1, 2 and 3)	Theory	6	1	1st week	3rd week
	Seminar	2	1		
2. Spectroscopic and Magnetic properties (Units 4 and 5)	Theory	8	1	3rd week	7th week
	Seminar	4	1		
	Tutorial	1	1	7th week	
3. Reactivity of coordination compounds (Unit 6)	Theory	6	1	8th week	10ª Semana
	Seminar	1	1		
	Tutorial	1	1	10ª Semana	
4. Basic concepts and Metal-metal bonding in coordination and organometallic compounds (Units 7 and 8)	Theory	8	1	10th week	14th week
	Seminar	4	1		
	Tutorial	1	1	13rd week	
5. Reactivity of solids. Types of reactions (Unit 9)	Theory	3	1	15th week	16th week
	Seminar	1	1		
	Tutorial	1	1	17th week	
6. Metal oxides and sulphides (Units 10, 11 and 12)	Theory	16	1	17th week	23rd week
	Seminar	5	1		
	Tutorial	1	1	24th week	
7. Other inorganic relevant compounds: Silicates (Unit 13)	Theory	8	1	24th week	28th week
	Seminar	3	1		
	Tutorial	1	1	28th week	
Laboratory	5 laboratory sessions	20	4	5 days of the first Semester	
	5 laboratory sessions	20	4	5 days of the second Semester	
Laboratory sessions are planning according to the established theory groups					

SUMMARY OF ACTIVITIES

Teaching activity	Associated competences	Professor activity	Student activity	Evaluation procedure	IP	NIP	Total	C (%)
Theory classes	CG1-MF1, CG2-MF1, CG3-MF1, CG5-MF1, CG6-MF1, CG7-MF1, CG8-MF1, CE8-MFQI1, CE9-MFQI1, CE9-MFQI2 CT3-MF1, CT5-MF1, CT6-MF1, CT7-MF1, CT12-MF1, CT12-MF2	• Preparation of the materials • Presentation of theoretical concepts	• Note taking • Completion of exercises • Development of new proposals • Formulation of questions and doubts	• Marking of the written answers to questions related to the theoretical concepts explained	56	54	110	5 %
Seminars	CG1-MF1, CG2-MF1, CG5-MF1, CG6-MF1, CG7-MF1, CG8-MF1, CG12-MF1 CE8-MFQI1, CE9-MFQI1, CE9-MFQI2, CE10-MFQI2 CT1-MF1, CT2-MF1, CT3-MF1, CT5-MF1, CT6-MF1, CT7-MF1, CT11-MF1, CT12-MF1, CT12-MF2	• Previous preparation of the classes • Application of theory to the resolution of exercises and problems	• Note taking • Completion of exercises • Formulation of questions and doubts	• Marking of the answers (approach and result) made in writing for the resolution of the given practical exercises	22	48	70	
Tutorials	CG1-MF1, CG2-MF1, CG5-MF1, CG6-MF1, CG7-MF1, CG8-MF1 CE8-MFQI1, CE9-MFQI1, CE9-MFQI2 CT1-MF1, CT2-MF1, CT3-MF1, CT5-MF1, CT6-MF1, CT7-MF1, CT11-MF1, CT12-MF1, CT12-MF2	• Direction and supervision of the student's study and activities. • Proposal of detailed resolution of exercises	• Consult the teacher about the conceptual and methodological difficulties encountered when studying the subject matter • Completion of exercises • Cooperación con los compañeros y análisis crítico de los trabajos	• Marking of the answers (approach and result) made in writing for the resolution of practical exercises	6	14	20	5 %

Teaching activity	Associated competences	Professor activity	Student activity	Evaluation procedure	IP	NIP	Total	C (%)
Examinations (theory)	CG1-MF1, CG2-MF1, CG5-MF1, CG6-MF1, CG7-MF1, CG8-MF1 CE8-MFQI1, CE9-MFQI1, CE9-MFQI2 CT3-MF1, CT5-MF1, CT6-MF1	• Proposal, proctoring and correction of the examinations • Student marking	• Preparation and completion of exams and other tests	• Assessment of written exams	4	11	15	60 %
Laboratories	All general, specific and transversal competences	• Explanation and supervision of the experimental procedures • Teach how to interpret and discuss the experiments carried out	• Conducting and analyzing experiments • Whrite a laboratory report	• Continuous evaluation of the student's attitude and aptitude (skills) in the laboratory • Laboratory report evaluation	40	33	73	20 %
Examinations (laboratory)	CG1-MF1, CG2-MF1, CG5-MF1, CG6-MF1, CG7-MF1, CG8-MF1, CG9-MF1, CG10-MF2, CG12-MF1 CE8-MFQI1, CE10-MFQI1, CE10-MFQI2 CT3-MF1, CT5-MF1, CT6-MF1	• Proposal, proctoring and correction of the examinations • Student marking	• Preparation for and completion of the exams	• Exams evaluation	2	10	12	10 %
IP: In-person; NIP: non in-person (autonomous work); C: rating								