FACULTAD DE
CIENCIAS QUÍMICAS

INORGANIC CHEMISTRY II

COURSE GUIDE

BSc Chemistry

Academic Year 2023-2024

UNIVERSIDAD
COMPLUTENSE
MADRID

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**

LECTURERS:

Course Coordinator	**Professor:**	Mª CARMEN TORRALBA MARTÍNEZ
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Laboratory Coordinator	**Professor:**	Mª CARMEN TORRALBA MARTÍNEZ
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Group E		
Theory Seminars Tutorials	**Lecturer:**	Mª JOSE MAYORAL MUÑOZ
	Departament:	Inorganic Chemistry
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Theory Seminars Tutorials	**Lecturer:**	DAVID AVILA BRANDE
	Departament:	Inorganic Chemistry
	Office:	QA-118
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Laboratory QA141

Group	Semester	Professor	e-mail	Office	Depar.
E1	1º	Ana Edilia Sánchez	aesanche@ucm.es	QA-229	QI
	2º	Miguel Cortijo	miguelcortijomontes@ucm.es	QA-210	QI
E2	1º	Elena Solana	elsolana@ucm.es	QA-119	QI
	2º	Daniel Muñoz	dmunozgi@ucm.es	QA-109A	QI

II.- OBJECTIVES

GENERAL OBJECTIVE

The aim is for the student to acquire the necessary knowledge to understand and establish connections between the structure, properties, reactivity, and applications of metallic compounds.

Students will be expected to learn precise synthesis techniques using suitable materials and apparatus. Additionally, they will be introduced to fundamental concepts and the utilization of various characterization methods for the inorganic compounds they synthesize.

SPECIFIC OBJECTIVES

- To delve into the foundational aspects of Coordination and Organometallic Chemistry, fostering a comprehensive understanding of these subfields.
- To develop a strong foundation in the fundamental aspects of Solid-State Chemistry, enabling students to gain a comprehensive understanding of this field.
- To establish and explore the relationships between the structure and properties of elements, as well as their corresponding compounds.
- To learn and apply specific synthesis procedures to successfully obtain inorganic compounds.
- To provide a comprehensive understanding of the fundamental principles behind the most used techniques for characterizing inorganic compounds.
- To foster an understanding of the significance and importance of inorganic compounds containing metallic elements in the field of Science, particularly their role 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: Electronic structure of solids

- Information provided by spectroscopic methods.
- Overlapping orbitals in the crystal: Band models

Unit 11: Metal oxides

- Binary oxides: relationship structure properties. Electrical and magnetic properties of the stoichiometry MO, M_2O_3, MO_2 and MO_3 oxides. Applications. Nonstoichiometry in binary oxides.
- Mixed oxides: structure-properties relationship. Electronic, dielectric and magnetic properties in oxides with stoichiometry ABO_3 (ilmenite and perovskite) and AB_2O_4, (spinel). No stoichiometry; homologous series, bronzes and perovskites

Unit 12: Metal sulphides

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

Unit 13: Other inorganic relevant compounds: silicates.

- Introduction
- General classification of silicates
- Structural description of silicates
- Zeolites: structural characteristics. Synthesis. Applications

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.

Methods of synthesis for non-molecular solids. 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 ionic exchange 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).
- Describe the structural and property modifications that ferrites present depending on their size.
- Discuss the accommodation of defects in non-stoichiometry.
- 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 and establish a classification based on the dimensionality of the silicate anion.
- Discuss the crystal structure of silicates.
- Describe the methods of synthesis, structure, and most relevant technological applications of zeolites.
- 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.

Practical sessions in the laboratory 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 laboratory practical guide.

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 practical guide 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.
- Housecroft, C.E.; Sharpe, A.G.: *Inorganic Chemistry.* 4th ed., Pearson 2012. (Traducción de la 2ed., 2006).
- 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.
- Wells A. F. *Structural Inorganic Chemistry*, 5th Ed. Oxford Univ. Press, 1985.
- Wold, A.; Dwight, K.: *Solid State Chemistry,* Chapman and Hall*,* 1993.
- Woodward, Solid State Materials Chemistry Cambridge Univ. Press. 2021
- David J Vaughan, *Sulfide Mineralogy and Geochemistry*, De Gruyter, Inc.,Geochemical Society Mineralogical Society of America 2018.
- F. Liebau; *Structural chemistry of silicates: structure, bonding and classification* Springer-Verlag, cop. 1985.
- Handbook on Synthesis Strategies for Advanced Materials, Volume-I: Techniques and Fundamentals. A. K. Tyagi y Raghumani S. Ningthoujam. Springer 2021

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

X.- EVALUATION

To access the final evaluation, participation in the different activities proposed and attendance at all laboratory sessions is mandatory. It will also be necessary for the student to have participated in at least 70% of the face-to-face activities.

The student's academic performance and the final grade for the subject 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.

The assessment of the general competences acquired in the theoretical part of the subject (CG1-MF1, CG2-MF1, CG5-MF1, CG6-MF1, CG7-MF1, CG8-MF1, of the specific competences CE8-MFQI1, CE9-MFQI1 and CE9-MFQI2 and of the transversal competences CT3-MF1, CT5-MF1 and CT6-MF1, will be carried out from the evaluation of two mid-term ("partial") exams that will be carried out one at the end of each semester, and a final exam.

Students who pass the two mid-term exams, having obtained a minimum grade of 5.0 in each of them, will not be required to sit the final exam in the ordinary call. Those who have only passed one of mid-term exam with a grade greater than or equal to 6, may take the final exam, taking only the part of the partial that they have failed. In these cases, to be able to do average with the mid-term exam that they had approved, it will be necessary to obtain a minimum score of 4.0. Students who must take the final exam, to access the overall grade for the subject must obtain a minimum score of 4.0. Students who have passed mid-term exam exams may also take the final exam if they want to raise their grade. In these cases, half an hour will be left for them to read the exam and, if they do not hand it in during that half hour, the final grade will be the one obtained from the average of the two mid-term exams. If they choose to take the final exam, their grade will be that obtained on that exam.

- **PERSONAL WORK AND GUIDED ACTIVITIES (5% + 5%)**

The evaluation of the individual learning work carried out by the student is carried out considering 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 work done by the students will be evaluated during the tutorials.

The evaluation of these parameters 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.

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

To access the final grade for the subject, it will be necessary to globally pass the activities related to laboratory practices which constitute 30% of the overall grade.

Attendance at all experimental sessions and laboratory seminars is mandatory and group changes can only be made for justified reasons.

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 skills acquired in the practical part of the subject by each student will be evaluated by the teaching staff who will assess the theoretical knowledge acquired in the laboratory sessions, the experimental procedures used, their aptitude and attitude, as well as the observed progress. The presentation of the laboratory report made will be a necessary requirement. The professor will analyze and assess the preparation of this work, the way in which the results obtained are presented and interpreted, and the capacity for synthesis.

In each semester there will be a laboratory exam that in sum constitutes a single exam and that is the one corresponding to the ordinary call. Students who do not reach the minimum grade of 4.0 in this single exam, may take another laboratory exam in the extraordinary call.

The activity of laboratory practices will reinforce the knowledge acquired by the student body, 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 CG1-MF1, CG2-MF1, CG5-MF1, CG6-MF1, CG7-MF1, CG8-MF1, CG9-MF1, CG10-MF2, CG11-MF1, CG12-MF1, CG13-MF1 competences, the CE8-MFQI1, CE9-MFQI1, CE9-MFQI2 , CE10-MFQI1 and CE10-MFQI2 specific competences and all transverse.

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								