FACULTAD DE
CIENCIAS QUÍMICAS

BIOINORGANIC CHEMISTRY

COURSE GUIDE

BSc Chemistry

Academic Year 2023-2024

UNIVERSIDAD
COMPLUTENSE
MADRID

I.- IDENTIFICATION

COURSE NAME:	**Bioinorganic Chemistry**
CREDITS:	**6**
CHARACTER:	**Optional**
SUBJECT:	**Advanced Inorganic Chemistry**
MODULE:	**Advanced**
DREGREE:	**Bachelor's in chemistry**
SEMESTER/TERM:	**First semester (fourth year)**
DEPARTMENT:	**Inorganic Chemistry**

PROFESSORS:

Group A		
Theory **Seminars** **Tutorials**	**Professor:** **Department:** **Office:** **e-mail:**	M CARMEN MARTIN GANDUL Inorganic Chemistry QA-117A mariad80@ucm.es

Group B		
Theory **Seminars** **Tutorials**	**Professor:** **Department:** **Office:** **e-mail:**	JULIO RAMÍREZ CASTELLANOS Inorganic Chemistry QA-132 jrcastel@ucm.es

II.- OBJETIVES

GENERAL OBJETIVES

It is intended that the student acquires the appropriate knowledge that will allow him/her to know the essential elements for life and the importance of inorganic species in biological systems.

SPECIFIC OBJETIVES

- To identify the essential chemical elements for life.
- To describe the main functions performed by metallic and non-metallic elements in biological systems.
- To apply the methodological bases of inorganic chemistry, more particularly around coordination chemistry, to study metallobiomolecules and their functions.
- To explain the biomedical and pharmacological applications of inorganics species.
- To recognize the bioinorganic chemistry importance within Science and Technology.

III.- BACKGROUND KNOWLEDGE AND RECOMMENDATIONS

PRIOR KNOWLEDGE:

Previous knowledge in inorganic chemistry: structure, bond, properties and reactivity of inorganic elements and compounds. Previous knowledge in biology: metabolic processes of living beings and main biomolecules (proteins and nucleic acids).

RECOMMENDATIONS:

It is recommended to have successfully completed the following subjects: Inorganic Chemistry and Biology.

IV.- CONTENTS

BRIEF DESCRIPTIOS:

Theoretical contents

Bioinorganic chemistry overview. The chemical elements of life. Bioavailability. Biological ligands. Metal-biomolecule complexes. Metallic elements of **s**-block (Na, K, Ca, Mg) in living beings. Metallic elements of **d**-block (Fe, Cu, Mn, Mo, Co, Zn) in living beings. Biological role of non-metals. Biominerals. Biomedical and Pharmacological applications of inorganic species.

PROGRAMME:

***THEORETICAL*:**

Unit 1: Introduction

- Bioinorganic chemistry overview.
- Chemical elements in living beings. Role and functions of metallic and non-metallic elements.

- Bioavailability and uptake of chemical elements.

Unit 2: Formation of metallobiomolecules

- Classification. Biological ligands. Mononuclear and polynuclear active centers.
- Energy sources in biochemical processes.
- Models.

Unit 3: Function of alkali and alkaline earth metal ions

- Active and passive transport across the membrane.
- Biological role of calcium.
- Biological role of magnesium.

Unit 4: Functions of transition metals

- Metalloenzymes not-involved in electron transfer processes. Zn Metalloenzymes.
- Electronic transfer. Cytochromes. Fe-S centers. "Blue" copper proteins. Cellular respiration. Nitrogenases. Photosynthetic process.
- Transportation and storage of iron.
- Proteins responsible for the transport of molecular oxygen. Hemoglobin and myoglobin. Hemerythrin. Hemocyanin.
- Metalloenzymes that catalyze oxygen atom transfer reactions. Mono- and dioxygenases. Molybdenum oxotransferases. Hydrogenases. Transfer reactions of other groups: coenzymes B_{12}.
- Metalloenzymes involved in the cellular defense mechanism. Superoxide dismutase. Catalases and peroxidases.

Unit 5: Introduction to metallic toxicology.

- Toxicity of metals and other inorganic species.
- Detoxification mechanisms.

Unit 6: Metal compounds in therapies and diagnosis

- Therapeutic aspects. Chelating agents therapy.
- Radiopharmaceuticals.
- Platinum complexes with antitumor activity. Other interesting examples.

Unit 7: Biominerals

- Types and functions of biominerals.
- Chemical and structural features. Generation processes.

V.- COMPETENCES

GENERAL:

- **CG1-MA1:** To recognize chemical processes in daily life.
- **CG2-MA1:** To recognize the relevance of chemistry and its impact on industrial and technological society.

- **CG2-MA2:** To relate emerging interdisciplinary areas and be aware of the importance of interdisciplinary research in the advancement of science.
- **CG3-MA1:** To demonstrate knowledge and understanding of chemicals concepts to continue his/her studies in an advance area of chemistry or multidisciplinary areas.
- **CG4-MA1:** To express specific knowledge of each area in the universal scientific language, understood and interdisciplinary shared.
- **CG7-MA1:** to apply theoretical and practical knowledge to solve problems in chemistry and select the appropriate method to solve them.
- **CG8-MA1:** To appreciate research in the area of chemistry.

■ **EPECIFIC:**

- **CE9-MAQI1:** To describe the essential chemical elements for life and the different functions performed by inorganic species in biological systems.
- **CE9-MAQI2:** To use the methodological bases of inorganic chemistry, more particularly around coordination chemistry, to study metallobiomolecules and their functions.
- **CE9-MAQI3:** To describe the biomineral formation processes.
- **CE9-MAQI4:** To explain the biomedical and pharmaceutical applications of inorganic species.

■ **TRANSVERSAL:**

- **CT1-MA1:** To prepare and write scientific and technical reports.
- **CT2-MA1:** To cooperate with other students through teamwork.
- **CT3-MA1:** To learn to make decisions to face with real practical problems.
- **CT4-MA1:** To select the most appropriate method to solve a proposed problem.
- **CT5-MA1:** To consult, use and analyze bibliography.
- **CT5-MA2:** To use bibliography, specialized databases and resources accessible *via* the internet.
- **CT7-MA1:** To use computer tools and chemical programs for calculating, designing, simulating and predicting.
- **CT8-MA1:** To communicate using the most common audiovisual media.
- **CT11-MA1:** To develop autonomous learning.
- **CT12-MA1:** To develop sensitivity to environmental issues.

VI.- LEARNING OUTCOMES

At the end of the course the student should be able to:

- To recognize the essential chemical elements for life.
- To recognize the most important biomolecules.
- To describe functions performed by metallic ions in biological systems.
- To describe the metallobiosites features.

- To recognize the importance of model systems within the study of biological systems.
- To identify functions performed by non-metallic elements in living beings.
- To apply coordination Chemistry concepts to understand metallobiomolecules and their functions.
- To identify the most important biominerals in living beings and understand their formation processes.
- To identify toxic elements to biological systems and possible removal methods.
- To identify Inorganic species in biomedical and pharmacological applications.

VII. – WORKING HOURS DISTRIBUTED BY ACTIVITY

Activity	Attendance (hours)	Self-study (hours)	Credits (hours)
Lectures	37,5	52,5	3,6 (90)
Seminars (theoretical)	15	15	1,2 (30)
Tutorials	2	13	0,6 (15)
Works and exams preparation	8	7	0,6 (15)
Total	**62,5**	**87,5**	**6 (150)**

VIII.- METHODOLOGY

A mixed methodology based on self-learning, cooperative and collaborative learning will be followed. The subject is developed during the first semester of the Degree (4th year). The face-to face activities of the course are structured in **lectures, seminars, tutorials and guided activities**.

The **lectures** (2,5 hours/week) are expository in nature. The professor will present, in an orderly way, the theoretical concepts and experimental facts that allow the students to get a global and comprehensive overview of the subject. At the beginning of each unit, the content and the main objectives will be exposed. At the end of the unit, new proposals can be suggested allowing the interrelation of contents with other subject. To support the theoretical explanations, the appropriate teaching material will be provided to the students *via* **Virtual Campus**.

Seminars (1 hour/week) will aim to apply the acquired knowledge to a set of questions/exercises. Seminars will be also employed to explain the latest development of the topic.

Short **exams** and resolution of **questions** will be done to evaluate students and the acquired knowledge.

Guides activities will be proposed in order to carry out personalized monitoring of students and to promote autonomous group work.

The students will be organized in groups to carry out a **short work**. The work will be related to the contents of the subject: the biological role of non-metallic elements, the latest advances in this area, such as artificial photosynthesis or therapies and diagnosis based on inorganic species. Thus, students will be able to search for information using the appropriate bibliography or resources and develop his/her skills with information technologies. The student will exercise his/her explanation, outlining and communication abilities by the preparation and presentation of this work. The work will be delivered to the professor together with a representative figure of the most relevant points about the selected topic. Works performed by students will be available on the **Virtual Campus** to be analyzed.

The professor will program **small-group tutorials** (2 hours/semester) to solve questions raised by students or professor and related with the subject. Tutorials will allow the professor to know the student's capacity to acquire knowledge and competences of the subject, as well as to advice about the different proposed activities along the course. **Individual tutorials** can be also programed in order to solve doubts, questions, etc., or other aspects related to the subject.

IX.- BIBLIOGRAPHY

■ BASIC:

At the beginning of the course, the recommended bibliography will be discussed, specifying the most relevant aspects of each text and its adequacy to the subject. General recommended texts are listed below:

- J. S. Casas, V. Moreno, A. Sánchez, J. L. Sánchez y J. Sordo: *"Química Bioinorgánica"*. Editorial Síntesis, Madrid, 2003.
- W. Kaim, B. Schwederski, "*Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life. An Introduction and Guide*". Wiley, Chichester, 2006. 2ª Edición, Wiley, Chichester, 2013.
- E. Crabb y E. Moore: *"Metals and Life"*. Royal Society of Chemistry, Cambridge, 2010.
- M. Vallet, J. Faus, E. García-España y J. Moratal: *"Introducción a la Química Bioinorgánica"*. Editorial Síntesis, Madrid, 2003.

■ COMPLEMENTARY:

- J. J. R. Fraústo da Silva y R. J. P. Williams: *"The Biological Chemistry of the Elements"*. Oxford University Press, Oxford, 1991.
- D. E. Fenton: *"Biocoordination Chemistry"*. Oxford University Press, Oxford, 1995.
- P. C. Wilkins y R.G. Wilkins: *"Inorganic Chemistry in Biology"*. Oxford University Press, Oxford, 1997.
- S. J. Lippard y J. M. Beerg: *"Principles of Bioinorganic Chemistry"*. University Science Books. Mill Valley, California, 1994.
- I. Bertini (Ed.): *"Bioinorganic Chemistry"*. University Science Books. Mill Valley, California, 1994.
- J. A. Cowan: *"Bioinorganic Chemistry. An Introduction"*, VCH, 1993 (2ª Edición 1996).

Occasionally, the professor may recommend other specific bibliography.

X.- EVALUATION

In order to access to the final evaluation, it is mandatory to participate in at least 70 % of the different activities proposed.

The student's academic performance and the final grade will be computed, weighted, according to the percentages shown in each of the items listed below. All grades will be based on an 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 planned activities (partial exam, tutorials, delivery of questions …) will be communicated to the student will in advance before the final exam, so that they can properly plan the study of this or other subject.

Marks of the partial exams will be communicated within a maximum period of 20 days, except in the case of the second partial, where the term may be shorter to adapt to the final exam date.

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

■ EXAMS: 70%

The assessment of the acquired competences (CG1-MA1, CG2-MA1, CG2-MA2, CG3-MA1, CG4-MA1, CG7-MA1, CE9-MAQI1, CE9-MAQI2, CE9-MAQI3, CE9-MAQI4, CT3-MA1, CT4-MA1) will be carried out based on the evaluation of one partial exam (partial exam will be liberatory if the grade achieve is equal to or higher than 5) and a final exam. Students who pass partial exams with a minimum score of 5.0 in each of them will not be required to do the final exam. The extraordinary call will be based on a single final exam. Students who take the final exam will have to obtain a minimum score of 5.0 to have access to the overall grade of the course.

■ PERSONAL WORK: 20%

The evaluation of the personal work will be assessed considering the following factors:

- Student skill in solving proposed problems and exercises.
- Assessment of the student's work in seminars.
- Evaluation of scheduled group tutorials, compulsory attendance.
- Resolution of test-type questionnaires or short questions at the end of each content block of the subject.

The evaluation of these aspects will allow to know the degree of the achievement of the general competences CG1-MA1, CG2-MA1, CG2-MA2, CG3-MA1, CG4-MA1, CG7-MA1, CG8-MA1, of the specific competences CE9-MAQI1, CE9-MAQI2, CE9-MAQI3, CE9-MAQI4, and the transversal competences CT1-MA1, CT2-MA1, CT3-MA1, CT4-MA1, CT5-MA1, CT5-MA2, CT7-MA1, CT8-MA1, CT11-MA1, CT12-MA1.

GUIDED ACTIVITIES: 10%

Small groups of students will develop a selected work relate with the subject. Each group will be evaluated by the professor, as well as by the rest of the students through th exhibition of the work *via* the Virtual Campus. The professor will assess both the work and the graphic presentation, as well as the critical analysis performed by the rest ot the students.

The evaluation of these aspects will allow to know the degree of the achievement of the general competences CG1-MA1, CG2-MA1, CG2-MA2, CG4-MA1, CG7-MA1, CG8-MA1, of the specific competences CE9-MAQI1, CE9-MAQI2, CE9-MAQI3, CE9-MAQI4, and the transversal competences CT1-MA1, CT2-MA1, CT3-MA1, CT5-MA1, CT5-MA2, CT7-MA1, CT8-MA1, CT11-MA1, CT12-MA1.

ACTICITY PLANNING – CRONOGRAM

UNIT	ACTIVITY	HOURS	GROUPS	START	END
1. Introduction	Theory	2,5	1	1st week	1st week
	Seminar	1	1		
2. Formation of metallobiomolecules	Theory	4	1	2nd week	2nd week
	Seminar	2	1		
3. Function of alkali and alkaline earth metal ions	Theory	3,5		3rd week	4th week
	Seminar	1	1		
4. Functions of transition metals	Theory	21,5	1	5th week	13rd week
	Seminar	9	1		
	Scheduled tutorial session*	1	2	10th week	
5. Introduction to metallic toxicology	Theory	2	1	13rd week	14th week
6. Metal compounds in therapies and diagnosis	Theory	1,5	1	14th week	14th week
	Seminar	1	1		
7. Biominerals	Theory	2,5	1	14th week	15th week
	Seminar	1	1		
	Scheduled tutorial session *	1	2	14th week	
PLANING BY THEORY GROUP					

* Schedule tutorial sessions are subject to possible modifications.

SUMMARY OF ACTIVITIES

Teaching activity	Associated competences	Professor activities	Student activity	Assessment procedure	P	NP	Total	C
Theory	CG1-MA1, CG2-MA1, CG2-MA2, -MA1, CG7-MA1, CG8-MA1 CE9-MAQI1, CE9-MAQI2, CE9-MAQI3, CE9-MAQI4 CT3-MA1, CT4-MA1, CT5-MA1, CT5-MA2, CT11-MA1, CT12-MA1	• Presentation of the theoretical concepts. • Raising questions and new proposals.	• Taking notes. Resolution of questions. • Development of the aspect covered. Bibliographic consultation. • Development of new proposals. • Formulation of questions and doubts.	• Assessment of the written answers to questions related to the theoretical concepts explained.	37,5	52,5	90	20%
Seminars	CG1-MA1, CG2-MA1, CG3-MA1, CG2-MA2, CG7-MA1, CG8-MA1 CE9-MAQI1, CE9-MAQI2, CE9-MAQI3, CE9-MAQI4 CT3-MA1, CT4-MA1, CT5-MA1, CT5-MA2, CT7-MA1, CT8-MA1, CT11-MA1, CT12-MA1	• Application of theory to the resolution of experimental questions. • Raising new questions.	• Taking notes. • Resolution of questions. • Formulation of questions and doubts.	• Assessment of the answers (approach and result) made to solve questions and problems.	15	15	30	
Tutorials	CG1-MA1, CG2-MA1, CG2-MA2, -MA1, CG7-MA1, CG8-MA1 CE9-MAQI1, CE9-MAQI2, CE9-MAQI3, CE9-MAQI4 CT2-MA1, CT3-MA1, CT4-MA1, CT5-MA1, CT5-MA2, CT7-MA1, CT8-MA1, CT11-MA1, CT12-MA1	• Supervision of the student (study and activities). • Raising questions and problems.	• Consult the professor about conceptual and methodological difficulties encountered in the subject matter. • Resolution of questions.		2	13	15	

Teaching activity	Associated competences	Professor activities	Student activity	Assessment procedure	P	NP	Total	C
Guide work	CG1-MA1, CG2-MA1, CG2-MA2, CG4-MA1, CG7-MA1, CG8-MA1 CE9-MAQI1, CE9-MAQI2, CE9-MAQI3, CE9-MAQI4 CT1-MA1, CT2-MA1, CT3-MA1, CT5-MA1, CT5-MA2, CT7-MA1, CT8-MA1, CT11-MA1, CT12-MA1	• Proposal and critical evaluation of assignments.	• Cooperation with other students and critical analysis of the work of other groups.	• Assessment of the work and analysis performed by the student.	2	7	9	10 %
Exams	CG1-MA1, CG2-MA1, CG2-MA2, CG3-MA1, CG4-MA1, CG7-MA1 CE9-MAQI1, CE9-MAQI2, CE9-MAQI3, CE9-MAQI4, CT3-MA1, CT4-MA1	• Proposal, proctoring and correction of the exam. • Student's rating.	• Exam preparation and execution.	• Corrections and assessment of exams.	6	--	6	70 %
P : face-to-face; NP: self-study (autonomus work); C: rating								