Subject Guide

1. Information about the subject

SUBJECT	Chemistry of the Transition Elements	**CODE**	GQUIMI01-3-005
EDUCATIONAL OFFER	Bachelor´s Degree in Chemistry	**CENTER**	Facultad de Química
TYPE	Compulsory	**N° TOTAL CREDITS**	6.0
PERIOD	Second Semester	**LANGUAGE**	Spanish

COORDINATORS/ES	**EMAIL**
GARCIA DIAZ MARIA ESTHER	garciame@uniovi.es

LECTURERS	**EMAIL**	
GARCIA DIAZ MARIA ESTHER	garciame@uniovi.es	
PEREZ MARTINEZ JULIO ANTONIO	japm@uniovi.es	(English Group)

2. Context

A theoretical course belonging to the basic module of the Inorganic Chemistry subject, Chemistry of the Transition Elements (CTE) is offered in the second semester of the third academic year of the degree in Chemistry. It provides the students, by means of a descriptive approach, with an understanding of the structure, bonding, preparation and reactivity of the main types of compounds of the transition metals. It relies heavily on the background provided in *Concepts and Models in Inorganic Chemistry*, and it continues and complements the descriptive approach initiated in *Chemistry of the Main Group Elements*, both second year courses. Having passed CTE is a prerequisite for signing in for the fourth year experimental course *Experimentation in Inorganic Chemistry II*.

The course will be fully taught by Dr. Julio Pérez, who is on the Inorganic Chemistry area of the Department of Organic and Inorganic Chemistry of the University of Oviedo.

3. Requirements

Having passed the first year courses *General Chemistry* and *Basic Laboratory Operations and Information Technology Tools*, both within the basic module General Chemistry, is a compulsory prerequisite to enroll in CTE. The student must have taken the second year courses *Concepts and Models in Inorganic Chemistry*, and *Chemistry of the Main Group Elements* and should master their content, since many basic ideas and concepts taught in these courses are employed in CTE.

4. Competencies and learning results

General competencies:

CG1: Synthetic and analytical abilities

CG2: Effectively problem solving

CG8: Correct oral and written communication

CG12: Environmental awareness

CG17: Critical thinking

Specific competencies:

Knowledge:

CE 9: Knowledge of the chemical elements and their compounds, natural occurrence, production, structure and reactivity

CE 11: Deduce the properties of the inorganic and organometallic compounds

CE 2: Relate the macroscopic properties with those of the individual atoms and molecules

Skills:

CE 19: To show knowledge and understanding of the essential facts, concepts, principles and theories pertaining to Inorganic Chemistry

CE 20: To solve qualitative and quantitative problems applying previously developed models

CE 22: Acquire ability to evaluate, interpret and synthesize chemical information

CE 32: Employ correctly the inductive and deductive methods in the domain of Chemistry

CE7: To apply the foundations and applications of Thermodynamics to chemical problems

Learning outcomes:

To access and use chemical information efficiently

To know, understand and explain the stability of the different oxidation states of the transition elements and the types of compounds they form from their position in the periodic table

To know, understand and explain the structure, synthesis and reactivity of halides, oxides, sulfides and oxoanions of the transition elements

To know, understand and explain the procedures to obtain and purify the transition elements from their natural sources, and their reactivity

To know, understand and explain the electric and magnetic properties of the transition elements and their compounds, relating them to their structures

To know, understand and explain the structure, nature of the bond, methods of synthesis and reactivity of the main types of coordination and organometallic compounds

To know, understand and explain selected applications of the compounds of the transition metals in catalysis and biochemistry

5. Contents

The contents of the course are developed through the following eleven lessons, in which the study of the structure, reactivity, production, properties and applications are dealt with.

Lesson 1. **General characteristics of the transition elements and their compounds**. Electronic configurations. Types of elements: block d and block f. Elemental state: structure and properties. Bonding capability. Stability of the oxidation states. Types of compounds.

Lesson 2. **Halides of the transition elements**. Structures: molecules, chains, layers and tridimensional networks. Production: direct synthesis, reaction of the metal with hydrogen halide, and synthesis from another compound. Reactivity: acid-base reactions and thermal decomposition.

Lesson 3. **Oxides and sulfides of the transition elements**. Oxides. Structures: molecules, chains, layers and 3D networks. Mixed valence oxides: spinels, ilmenites and perovskites. Non-stoichiometric oxides. Tungsten bronzes. Production procedures: from the metal, from another oxide, from oxosalts and by precipitation of metallic cations.

Lesson 4. **Electric and magnetic properties of the transition elements and their compounds**. Ionic and electric conduction. Dielectrics: Ferroelectricity. Ferromagnetic and antiferromagnetic materials. Superconductors.

Lesson 5. **Oxoanions of the transition elements**. Classification. Mononuclear and dinuclear oxoanions: synthesis and structure. Acid-base reactions and reductions. Isopolyanions: structural aspects. Heteropolyanions: Anderson, Keggin and Dawson types. Iso- and heteropolyanions: synthesis and applications.

Lesson 6. **Production and reactivity of the transition metals**. Natural occurrence. Pyrometallurgy and hydrometallurgy. Production from oxides, oxoanions and sulfides. Iron and steel. Metallothermic reductions. Purification methods: Van Arkel-de-Boer and electrolysis. Extraction and purification of native metals. Reactivity of the metal: stability in air and reactions with acids. Oxosalts of the transition elements.

Lesson 7. **Coordination compounds of the transition elements**. General aspects: oxidation states, coordination numbers and geometries. Halocomplexes. Aquocomplexes. Oxo- and peroxocomplexes. Aminocomplexes. Cyanocomplexes. Complexes with chelate and macrocyclic ligands. Complex formation reactions. Addition and substitution in metal halides. Substitution and redox reactions in other complexes. Template effect reactions. Reduction of oxoanions. Metal oxidation.

Lesson 8. **Compounds with metal-metal bond**. Distribution on the transition series and types of compounds. Dinuclear compounds: structure and bonding. Clusters: structure and bonding. Cluster halides and Chevrel phases.

Lesson 9. **Organometallic complexes of the transition elements**. Definition and history. Classification. Types of ligands. The Effective Atomic Number rule. Metal carbonyls. Bonding and coordination number. Homoleptic carbonyls. Carbonyl clusters. Preparation procedures: direct synthesis and reductive carbonylation. Reactivity: substitution, thermal decomposition, redox and nucleophilic attack reactions. Complexes with alkyl, carbene, olefin, polyolefin, allyl and cyclopentadienyl ligands: study of bonding, synthetic methods and reactivity.

Lesson 10. **The transition elements in catalysis**. Homogeneous catalysis: olefin hydrogenation and hydroformylation. Synthesis of acetic acid. Heterogeneous catalysis: olefin polymerization. Supported metal catalysts.

Lesson 11. **Biochemistry of the transition elements**. Biochemistry of iron: hemoglobin, myoglobin and cytochromes. Biochemistry of cobalt: vitamin B12. Nitrogen fixation. Other metalloproteins.

6. Methodology and working plan

The course will be taught during the second semester using lectures, seminars and group tutorials as indicated in the table below.

In lectures, the instructor will present and explain in detail the different lessons of the course, making use of both the blackboard and the projector.

Seminar classes will be used to solve problems and questions related to the contents of the course. These problems and questions will be made available to the students well in advance. In the group tutorials, the students will solve some of these problems, and deliver solved exercises, which would have been made available to them in advance.

Group tutorials will also be used to answer questions and resolve doubts that may have arisen, and as part of the evaluation.

Problems and exercises for seminars and group tutorials, as well as the support information to follow the lectures will be available in advance through the e-campus.

		ON-SITE INSTRUCTION								**INDEPENDENT WORK**		
Lessons	***Total hours***	*Lectures*	*Seminars*	*Laboratory*	*Clinical/hospital*	*Group tutorials*	*External activities*	*Exams*	***Total***	*Team work*	*Individual work*	**Total**
Lesson1		4				1			5		9	9
Lesson 2		4	1						4		9	9
Lesson 3		4	1			1			6		10	10
Lesson 4		3							3		5	5
Lesson 5		3	1						4		7	7
Lesson 6		5							6		10	10
Lesson 7		4	1			1			6		10	10
Lesson 8		3	1						4		7	7
Lesson 9		6	2			1			9		15	15
Lesson 10		4							4		7	7
Lesson 11		2							2		3	3
Total	**150**	**42**	**7**			**4**	**4**	**3**	**60**		**90**	**90**

INSTRUCTION MODE		Hours	%	Total
On-site instruction	Lectures	42	70	60
	Seminars	7	11,66	
	Laboratory			
	Clinical/hospital			
	Group tutorials	4	6,66	
	External activities	4	6,66	
	Exams	3	5	
Independent work	Team work			90
	Individual work	90	100	
	Total	150		

7. Evaluation of the student's learning results

The assessment will be carried out by a combination of a written exam given at the end of the semester, and the group tutorials. In the ordinary call, the exam will contribute a 80% of the final grade, and the group tutorials will contribute a 20%. To pass the course the final grade must be equal or higher than 5 on a 0-10 scale. In the extraordinary (June and January) calls, the final grade will be entirely that of a written exam, in which a 5 must also be attained to pass the course.

8. Resources, bibliography and complementary documentation

Specific bibliography will be indicated for each lesson. The following, general textbooks are recommended for the course:

- *Chemistry of the Elements*, N. N. Greenwood and A. Earnshaw, 2nd edition, Butterworth-Heinemann, Oxford, 1997
- *Inorganic Chemistry*, N. Wiberg, A. F. Holleman and E. Wiberg, Academic Press, New York, 2001
- *Advanced Inorganic Chemistry*, F. A. Cotton, G. Wilkinson, C. A. Murillo and M. Bochmann, 6th edition, Wiley, New York, 1999
- *Química Inorgánica*: volumen II, Elementos de Transición, G. A. Carriedo, Síntesis, Madrid 2015
- *Inorganic Chemistry*, C. E. Housecroft, A. G. Sharpe, 4th edition, Pearson, 2012

- *Inorganic Chemistry*, D. Shriver, M. Weller, T. Overton, J. Rourke, F. Armstrong, 6th edition, W. H. Freeman and Company, New York, 2014