



| Teaching Guide      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |       |            |                                                                                                   |
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| Identifying Data    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |       | 2019/20    |                                                                                                   |
| Subject (*)         | Inorganic Chemistry 4                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |       | Code       | 610G01024                                                                                         |
| Study programme     | Grao en Química                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |       |            |                                                                                                   |
| Descriptors         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |       |            |                                                                                                   |
| Cycle               | Period                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Year  | Type       | Credits                                                                                           |
| Graduate            | 2nd four-month period                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Third | Obligatory | 6                                                                                                 |
| Language            | SpanishGalicianEnglish                                                                                                                                                                                                                                                                                                                                                                                                                                                                |       |            |                                                                                                   |
| Teaching method     | Face-to-face                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       |            |                                                                                                   |
| Prerequisites       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |       |            |                                                                                                   |
| Department          | Química                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |       |            |                                                                                                   |
| Coordinador         | Rodriguez Blas, Maria Teresa                                                                                                                                                                                                                                                                                                                                                                                                                                                          |       | E-mail     | teresa.rodriguez.blas@udc.es                                                                      |
| Lecturers           | Avecilla Porto, Fernando Francisco<br>Bermúdez García, Juan Manuel<br>Rodriguez Blas, Maria Teresa<br>Sanchez Andujar, Manuel                                                                                                                                                                                                                                                                                                                                                         |       | E-mail     | fernando.avecilla@udc.es<br>j.bermudez@udc.es<br>teresa.rodriguez.blas@udc.es<br>m.andujar@udc.es |
| Web                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |       |            |                                                                                                   |
| General description | Preparation and characterization of inorganic compounds: Coordination compounds and non-molecular solids.<br>CONTEXT: The course is fitted in the sixth semester of the Degree in Chemistry (3rd year), and is closely related to the subject of the fifth semester "Inorganic Chemistry 3." The two fields set up the module "Advanced Inorganic Chemistry", which will provide an adequate education to students in the fields of Coordination Chemistry and Solid State Chemistry. |       |            |                                                                                                   |

| Study programme competences |                                                                                                                                         |
|-----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| Code                        | Study programme competences                                                                                                             |
| A1                          | Ability to use chemistry terminology, nomenclature, conventions and units                                                               |
| A3                          | Knowledge of characteristics of the different states of matter and theories used to describe them                                       |
| A4                          | Knowledge of main types of chemical reaction and characteristics of each                                                                |
| A6                          | Knowledge of chemical elements and their compounds, synthesis, structure, properties and reactivity                                     |
| A9                          | Knowledge of structural characteristics of chemical and stereochemical compounds, and basic methods of structural analysis and research |
| A14                         | Ability to demonstrate knowledge and understanding of concepts, principles and theories in chemistry                                    |
| A15                         | Ability to recognise and analyse new problems and develop solution strategies                                                           |
| A16                         | Ability to source, assess and apply technical bibliographical information and data relating to chemistry                                |
| A17                         | Ability to work safely in a chemistry laboratory (handling of materials, disposal of waste)                                             |
| A18                         | Risk management in relation to use of chemical substances and laboratory procedures                                                     |
| A19                         | Ability to follow standard procedures and handle scientific equipment                                                                   |
| A20                         | Ability to interpret data resulting from laboratory observation and measurement                                                         |
| A21                         | Understanding of qualitative and quantitative aspects of chemical problems                                                              |
| A22                         | Ability to plan, design and develop projects and experiments                                                                            |
| A23                         | Critical standards of excellence in experimental technique and analysis                                                                 |
| A24                         | Ability to explain chemical processes and phenomena clearly and simply                                                                  |
| A26                         | Ability to follow standard laboratory procedures in relation to analysis and synthesis of organic and inorganic systems                 |
| B1                          | Learning to learn                                                                                                                       |
| B2                          | Effective problem solving                                                                                                               |
| B3                          | Application of logical, critical, creative thinking                                                                                     |
| B4                          | Working independently on own initiative                                                                                                 |
| B5                          | Teamwork and collaboration                                                                                                              |
| B7                          | Effective workplace communication                                                                                                       |
| C1                          | Ability to express oneself accurately in the official languages of Galicia (oral and in written)                                        |
| C7                          | Acceptance as a professional and as a citizen of importance of lifelong learning                                                        |

|    |                                                                                                      |
|----|------------------------------------------------------------------------------------------------------|
| C8 | Understanding role of research, innovation and technology in socio-economic and cultural development |
|----|------------------------------------------------------------------------------------------------------|

| Learning outcomes                                                                                                                                                                     |                                              |                      |          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|----------------------|----------|
| Learning outcomes                                                                                                                                                                     | Study programme competences                  |                      |          |
| To identify problems associated with the synthesis and structural characterization of metal complexes and inorganic solids, and plan strategies to solve them.                        | A6<br>A15                                    |                      |          |
| To know and handle the literature on the structure, bonding, synthesis, reactivity, characterization, properties and applications of coordination compounds and non-molecular solids. | A16                                          | B1<br>B4             |          |
| To understand and to carry out standard procedures for the synthesis and characterization of inorganic compounds, and to use scientific instrumentation for their characterization.   | A17<br>A19<br>A26                            |                      |          |
| To plan, design and carry out the synthesis and characterization of coordination compounds and non-molecular solids.                                                                  | A15<br>A22                                   | B5                   |          |
| To understand and explain the processes observed in the Inorganic Chemistry Laboratory.                                                                                               | A1<br>A18<br>A20<br>A21<br>A23<br>A24        | B2<br>B3<br>B4<br>B7 | C1<br>C7 |
| To understand the important contribution that the research in Inorganic Chemistry has on the socio-economic and cultural progress of society.                                         |                                              |                      | C8       |
| To manage properly the waste generated in a laboratory devoted to the synthesis and characterization of inorganic compounds.                                                          | A17<br>A18<br>A23                            |                      |          |
| To prepare a laboratory notebook that gathers all relevant information making the necessary calculations.                                                                             | A1<br>A15<br>A18<br>A20<br>A21<br>A23<br>A24 | B3<br>B4<br>B7       | C1       |
| To know the structure of coordination compounds and molecular crystalline solids and to apply the techniques required for structure determination.                                    | A9                                           | B2<br>B4             |          |
| To prepare and present reports on the work and results obtained in a laboratory of inorganic chemistry .                                                                              | A1<br>A3<br>A4<br>A9<br>A14<br>A20           | B3<br>B4<br>B7       | C1       |

| Contents                                               |                                                                                                                                                 |
|--------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| Topic                                                  | Sub-topic                                                                                                                                       |
| Preparation of Coordination Compounds                  | Methods for the preparation of metal complexes. Solvent effects. Speciation diagrams.                                                           |
| Structural determination of coordination compounds (I) | Chemical analysis. Mass spectrometry. Molar conductivity. Dipolar moments. Vibrational spectroscopy. NMR spectroscopy. Questions and exercises. |



|                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
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| Structural determination of coordination compounds (II):<br>Electronic Absorption Spectroscopy | Introduction. Selection rules. Origin of the bands: Ligand-ligand bands, charge transfer bands and d-d bands. Spectroscopic terms and electronic states. Orgell diagrams and Tanabe-Sugano diagrams. Analysis of electronic spectra and applications in structure determination. Questions, problems and exercises.                                                                                                                                                       |
| Structural determination of coordination compounds (III):<br>magnetic properties               | Diamagnetism and paramagnetism. Effective magnetic moment. Spin and orbital contributions. Applications in structure determination. Questions, problems and exercises.                                                                                                                                                                                                                                                                                                    |
| Methods of preparation of non-molecular solids                                                 | Strategies for the preparation of crystalline non-molecular solids. Main synthesis methods: ceramic method, "soft" chemistry methods (co-precipitation, decomposition of nitrates, sol-gel method, intercalation reactions?), solvothermal method.                                                                                                                                                                                                                        |
| Methods for Characterization of non-molecular solids                                           | General overview of the different diffractometric techniques (X-ray, electron and neutron diffraction), with emphasis on crystal powder X-ray diffraction.<br>Spectroscopic techniques.<br>Thermal methods.<br>Electronic microscopy (scanning and transmission electron microscopies).                                                                                                                                                                                   |
| Preparation and Characterization of Coordination Compounds                                     | Selection of the synthesis conditions.<br>Selection of materials (reagents, solvents, instrumentation, glass equipment...).<br>Assessment of the risks associated with the experiment and its prevention.<br>Experimental procedure for the synthesis.<br>Use of instrumental techniques for structural elucidation.<br>Interpretation of the structural elucidation results.<br>Preparation of a laboratory notebook.<br>Preparation and presentation of a final report. |
| Preparation and Characterization of crystalline non-molecular solids                           | Selection of the synthesis conditions.<br>Selection of materials (reagents, solvents, instrumentation, glass equipment...).<br>Assessment of the risks associated with the experiment and its prevention.<br>Experimental procedure for the synthesis.<br>Use of auxiliary software for structural elucidation.<br>Interpretation of the structural elucidation results.<br>Preparation of a laboratory notebook.<br>Preparation and presentation of a final report.      |

| Planning                       |                                                                               |                      |                               |             |
|--------------------------------|-------------------------------------------------------------------------------|----------------------|-------------------------------|-------------|
| Methodologies / tests          | Competencies                                                                  | Ordinary class hours | Student's personal work hours | Total hours |
| Guest lecture / keynote speech | A1 A6 A9 A15 A20<br>A21 A24 B1 B2 B3 B7<br>C7 C8                              | 10                   | 30                            | 40          |
| Laboratory practice            | A1 A3 A4 A6 A15 A16<br>A17 A18 A19 A20<br>A22 A23 A26 B1 B3<br>B4 B5 B7 C1 C2 | 34                   | 0                             | 34          |
| Seminar                        | A1 A9 A12 A14 A15<br>A16 A20 A21 A24 B1<br>B2 B3 B4 B5 B7 C1<br>C2            | 4                    | 20                            | 24          |
| Supervised projects            | A1 A3 A4 A6 A9 A14<br>A15 A16 A20 A21<br>A22 A24 B3 B4 B7 C1<br>C2            | 2                    | 28                            | 30          |



|                                                                                                                                 |                                            |   |    |    |
|---------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|---|----|----|
| Oral presentation                                                                                                               | A1 A14 A16 A24 B3<br>B4 B7 C1 C2           | 2 | 8  | 10 |
| Mixed objective/subjective test                                                                                                 | A1 A6 A9 A14 A20<br>A21 A24 B2 B3 C1<br>C2 | 2 | 0  | 2  |
| Summary                                                                                                                         | A1 A20 A24 B4                              | 0 | 10 | 10 |
| Personalized attention                                                                                                          |                                            | 0 | 0  | 0  |
| (*)The information in the planning table is for guidance only and does not take into account the heterogeneity of the students. |                                            |   |    |    |

| Methodologies                   |                                                                                                                                                                                                                                        |
|---------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Methodologies                   | Description                                                                                                                                                                                                                            |
| Guest lecture / keynote speech  | Lectures: oral presentations of the topics 1-6 of ?Contents? section. These sessions involve also the active participation of the students and a continuous exchange of ideas between lecturer and students.                           |
| Laboratory practice             | Laboratory practices (topics 7-8 in &quot;Contents&quot;): student's work in the laboratory, under the tutoring of the teacher. Students will synthesize and characterize coordination compounds and crystalline non-molecular solids. |
| Seminar                         | Seminars: sessions in small groups to solve problems and exercises related with the topics of the lectures. They also serve as a &quot;feed-back&quot; to the lecturer to assess the progress of students.                             |
| Supervised projects             | The students must prepare the experiments, prior to start the work at the laboratory, using the literature. This process will be guided and supervised by the laboratory instructor.                                                   |
| Oral presentation               | Group sessions to present the work done during the laboratory practice. Each student must summarize his/her work in a short time (around 5 minutes) and discuss it with the audience.                                                  |
| Mixed objective/subjective test | Written test that will include questions and numerical problems related to the contents of the course.                                                                                                                                 |
| Summary                         | Each student must provide the laboratory notebook at the end of the laboratory practice, as well as brief report of each experiment, which will be evaluated and corrected by the laboratory instructor.                               |

| Personalized attention                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Methodologies                                                              | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Laboratory practice<br>Seminar<br>Supervised projects<br>Oral presentation | <p>During the "laboratory practice" students will be individually interviewed by the teacher at different stages:</p> <p>i) Interviews prior to the start of the experimental work, once the student completes the literature review and the preparation of the experiments. A positive assessment of this work is required for the student to be allowed to start the experimental work.</p> <p>ii) A personal interview at the end of the laboratory practice to assess the work carried out and to solve possible deficiencies in the training.</p> <p>Moreover, students can ask for additional tutoring sessions that will take place at the tutoring hours of the teacher (the timetables will be indicated at the beginig of the course).</p> |

| Assessment    |              |             |               |
|---------------|--------------|-------------|---------------|
| Methodologies | Competencies | Description | Qualification |



|                                 |                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |    |
|---------------------------------|-------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| Laboratory practice             | A1 A3 A4 A6 A15 A16<br>A17 A18 A19 A20<br>A22 A23 A26 B1 B3<br>B4 B5 B7 C1 C2 | The preparation and execution of the experimental part (laboratory practice) will represent 75% of the final mark. The approximate breakdown of this part is:<br>1. Instructor's assessment of lab skills (planning, time management, skill and confidence in practical work) and results of the synthesis and characterization (20%).<br>2. Preparation of each experiment, interpretation of the results and conclusions reached (assessed by personal interview) (35%).<br>3. Oral presentations of the work carried out in the laboratory (15%).<br>4. Laboratory notebook and reports on each experiment (30%). | 75 |
| Seminar                         | A1 A9 A12 A14 A15<br>A16 A20 A21 A24 B1<br>B2 B3 B4 B5 B7 C1<br>C2            | Instructor's assessment of the participation in seminars and lectures (quantity and quality of the participation: questions, resolution of problems and exercises...)                                                                                                                                                                                                                                                                                                                                                                                                                                                | 5  |
| Supervised projects             | A1 A3 A4 A6 A9 A14<br>A15 A16 A20 A21<br>A22 A24 B3 B4 B7 C1<br>C2            | The literatura review to prepare the experiments, the results of the experimental work and the conclusions reached will be assessed by personal interview.<br>(Its approximate contribution to the overall mark is described in the previous section).                                                                                                                                                                                                                                                                                                                                                               | 0  |
| Oral presentation               | A1 A14 A16 A24 B3<br>B4 B7 C1 C2                                              | In the oral presentation of the "Laboratory practice", the instructor will assess the analysis of the results and the conclusions, and the active participation of the students in the discussion after each presentation.<br>(Its approximate contribution to the overall mark is given above).                                                                                                                                                                                                                                                                                                                     | 0  |
| Summary                         | A1 A20 A24 B4                                                                 | The laboratory notebook and the reports will also be assessed.<br>(Its approximate contribution to the overall mark is given above).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 0  |
| Mixed objective/subjective test | A1 A6 A9 A14 A20<br>A21 A24 B2 B3 C1<br>C2                                    | A written text including questions and numerical problems related to the contents of the course. Those students attending to the course on a regular basis are allowed to make a preliminary test. Those obtaining four points (of a maximum of 10) in this text, with an average grade of the overall course of five points, may choose not to participate in the final test.                                                                                                                                                                                                                                       | 20 |

Assessment comments

This is a course with an important loading of experimental work. Therefore, attendance to all scheduled classes is mandatory.

First opportunity (June): The maximum score is 10 points, and passing the course requires a minimum of 5 points. In each of the assessed parts, it is required a minimum of 40% of the maximum score possible for that part. The assessment process will start when the student begins the work in the lab. Thus, every student that reaches this stage will obtain a mark even if the different activities of the course, including the laboratory practice, are not completed.

Second opportunity (July): The maximum score is 10 points, and passing the course requires obtaining 5 points. Students will be assessed by an objective test, from which students can obtain up to 2.5 points, and a laboratory practice test (which counts for a maximum of 7.5 points). The practical test will consist on the preparation and execution of a laboratory experiment using the same criteria detailed in the "methodology" section, with the exception that the preparation of the experiment will not be tutored. An inappropriate preparation of the experimental work will result in a negative assessment (failed course) before beginning the laboratory work. If the student obtained a minimum of 4 points in the Laboratory Practice in the first opportunity will not have to perform the laboratory practice test in the second opportunity.

From the time the student begins the preparation of the experiments, or the realization of the objective test, it is considered that accepted to be assessed, and therefore those students that reach these stages will obtain a mark even if the different activities of the course are not completed.

Those students assessed in the second opportunity (July) can be awarded with honors only if the maximum number of students that finish the course with honors is not reached after the first opportunity (June).

Those students that fail the course and wish to take the course in coming academic years will have to participate again in all the activities of the course, and will be assessed accordingly.

NOTA: "Students at partial time": First and second opportunities: Attendance to DE and TGR activities is not mandatory but the "mixed test" is required and they have to get a minimum of 5 points (of 10) to pass this activity. Laboratory practice is mandatory and follows the same requirements applied to students at full time.

#### Sources of information

|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Basic</b>         | -A. R. West, Basic Solid State Chemistry, John Wiley and Sons, Chichester, 1999, Libro, -D. F. Shriver, P. W. Atkins, C. H. Langford, Química Inorgánica, Editorial Reverté S. A., 1998, Libro, -J. Rivas Gispert, Química de Coordinación, Ediciones Omega S.A., 2000, Libro, -L. Smart, E. Moore, Una introducción a la química del estado sólido, Editorial Reverté, Barcelona, 1995, Libro, -L. Smart, E. Moore, Solid State Chemistry: an Introduction, Taylor & Francis, Third Edition, 2005, Libro, -M.T. Weller, Inorganic Materials Chemistry, Oxford University Press, Oxford, 1999, Libro, -S. F. A. Kettle, Physical Inorganic Chemistry. A Coordination Chemistry Approach, Oxford University Press, 1998, Libro, -D. F. Shriver, P. W. Atkins, C. H. Langford, Química Inorgánica, Editorial Reverté, Barcelona, 1998, Libro, -Dann, Reactions and Characterization of Solids, Royal Society of Chemistry. Cambridge, 2000, Libro,                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Complementary</b> | -A. R. West, Solid State Chemistry, John Wiley and Sons, Chichester, 1999, Libro, -A.F. Wells, Structural Inorganic Chemistry, 5th Ed., Oxford University Press, London, 1984, Libro, -D. Nicholls, Complexes and First-Row Transition Elements, McMillan Press, 1979, Libro, -D. Sutton, Espectros Electrónicos de los Complejos de los Metales de Transición, Reverté, Barcelona, 1975, Libro, -N.N. Greenwood, Cristales iónicos, defectos reticulares y no estequiometría, Alhambra, Madrid, 1970, Libro, -Angelici e outros, Synthesis and Techniques in Inorganic Chemistry?, 3ª Ed., University Science Books. Sausalito, 1999, Libro, -Brauer, Química Inorgánica Preparativa, Editorial Reverté, Barcelona, 1958, Libro, -Lever, Inorganic Electronic Spectroscopy. 2ª Ed., Elsevier. Ámsterdam, 1984, Capítulo de libro, -Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds, 5ª Ed., Wiley & Sons, New York, 1997, Libro, -Schlessinger, Preparación de Compuestos Inorgánicos en el Laboratorio, Continental, México, 1965, Libro, -W. McCleverty e outros, Comprehensive Coordination Chemistry II, Elsevier-Pergamon, Amsterdam, 2004, Libro, -Wilkinson e outros, Comprehensive Coordination Chemistry, Pergamon Press, Oxford, 1986, Libro, -Cotton e Wilkinson, Química Inorgánica Avanzada?, 4ª Ed., Limusa-Wiley. México, 1986, Libro, |

#### Recommendations

Subjects that it is recommended to have taken before



Physical Chemistry 1/610G01016

Physical Chemistry 2/610G01017

Inorganic Chemistry 1/610G01021

Inorganic Chemistry 2/610G01022

Inorganic Chemistry 3/610G01023

**Subjects that are recommended to be taken simultaneously**

**Subjects that continue the syllabus**

Advanced Inorganic Chemistry/610G01025

Materials Science/610G01035

**Other comments**

that those students who take the "Inorganic Chemistry 4" course have passed "Inorganic Chemistry 3", and have the knowledge and skills associated with "Inorganic Chemistry 1 and 2" and "Physical Chemistry 1 and 2."

(\*)The teaching guide is the document in which the URV publishes the information about all its courses. It is a public document and cannot be modified. Only in exceptional cases can it be revised by the competent agent or duly revised so that it is in line with current legislation.