| Teaching Guide | | | | | |
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| Identifying Data | | | | | 2023/24 |
| Subject (*) | Crystallography and Symmetry | | | Code | 610G04006 |
| Study programme | Grao en Nanociencia e Nanotecnoloxía | | | | |
| Descriptors | | | | | |
| Cycle | Period | Year | | Type | Credits |
| Graduate | 2nd four-month period | First | | Basic training | 6 |
| Language | SpanishGalician | | | | |
| Teaching method | Face-to-face | | | | |
| Prerequisites | | | | | |
| Department | Física e Ciencias da Terra | | | | |
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| Lecturers | Hernández Hernández, Armand<br>López Vicente, Manuel<br>Moncunill Solé, Blanca | | E-mail | armand.hernandez@udc.es<br>manuel.lopez.vicente@udc.es<br>blanca.moncunill@udc.es | |
| Web | | | | | |
| General description | "Cristallography and Symmetry" is a subject in the second semester of the first year of the Bachelor's Degree in Nanoscience and Nanotechnology, which belongs to the Basic Training Module. The aim of this subject is to introduce students to the fundamentals of point symmetry and spatial symmetry, familiarize them with the world of crystals and the most common structures of crystalline solids, explore X-ray diffraction as a tool for crystal characterization, and examine the relationship between crystallography and symmetry, and other disciplines. These knowledge and skills will provide the necessary theoretical and practical foundation for students to delve into the world of crystalline nanomaterials and their characterization through diffractometric and spectroscopic methods in subsequent subjects of the Nanoscience and Nanotechnology degree. | | | | |

| Study programme competences / results | |
|---|---|
| Code | Study programme competences / results |
| A3 | CE3 - Reconocer y analizar problemas físicos, químicos, matemáticos, biológicos en el ámbito de la Nanociencia y Nanotecnología, así como plantear respuestas o trabajos adecuados para su resolución, incluyendo el uso de fuentes bibliográficas. |
| A5 | CE5 - Conocer los rasgos estructurales de los nanomateriales, incluyendo las principales técnicas para su identificación y caracterización |
| A6 | CE6 - Manipular instrumentación y material propios de laboratorios para ensayos físicos, químicos y biológicos en el estudio y análisis de fenómenos en la nanoescala. |
| A7 | CE7 - Interpretar los datos obtenidos mediante medidas experimentales y simulaciones, incluyendo el uso de herramientas informáticas, identificar su significado y relacionarlos con las teorías químicas, físicas o biológicas apropiadas. |
| A8 | CE8 - Aplicar las normas generales de seguridad y funcionamiento de un laboratorio y las normativas específicas para la manipulación de la instrumentación y de los productos y nanomateriales. |
| B4 | CB4 - Que los estudiantes puedan transmitir información, ideas, problemas y soluciones a un público tanto especializado como no especializado |
| B6 | CG1 - Aprender a aprender |
| B7 | CG2 - Resolver problemas de forma efectiva. |
| B8 | CG3 - Aplicar un pensamiento crítico, lógico y creativo. |
| C3 | CT3 - Utilizar las herramientas básicas de las tecnologías de la información y las comunicaciones (TIC) necesarias para el ejercicio de su profesión y para el aprendizaje a lo largo de su vida |
| C7 | CT7 - Desarrollar la capacidad de trabajar en equipos interdisciplinares o transdisciplinares, para ofrecer propuestas que contribuyan a un desarrollo sostenible ambiental, económico, político y social. |
| C8 | CT8 - Valorar la importancia que tiene la investigación, la innovación y el desarrollo tecnológico en el avance socioeconómico y cultural de la sociedad |

| Learning outcomes |
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| Learning outcomes | Study programme competences / results | | |
|---|---|---|---|
| To identify the main crystalline forms, structures, growths, optics and systems. | A3<br>A5<br>A7 | B6<br>B7<br>B8 | C3<br>C8 |
| To describe and analyse the external shape of crystals, their structural patterns and their potential transformations | A3<br>A5<br>A7 | B6<br>B7<br>B8 | C3<br>C8 |
| To differentiate the main elements of symmetry and their nomenclature. | A5 | B4 | C3 |
| To recognise the fundamentals of diffraction. | A3<br>A6<br>A8 | | C3<br>C7<br>C8 |
| To solve basic crystallography problems. | A3<br>A5<br>A7 | B7<br>B8 | C3 |

| Contents | |
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| Topic | Sub-topic |
| Unit 1. Introduction. | Introduction to the world of crystals and symmetry. Its relevance in nanoscience and nanotechnology. |
| Unit 2. Cristal lattice theory. | Crystal lattices. Nodes, rows, lattice planes, and their notations. Unit cells. Reciprocal lattices. Lattice spacing. Exercises and problems. |
| Unit 3. Symmetry of crystals and molecules I: Point and spatial symmetry. | Concept of symmetry. Point symmetry operators. Applications of point symmetry. Bravais lattices. Introduction to spatial symmetry. Translations. Glide planes. Helical axes. Exercises and practical examples. |
| Unit 4. Symmetry of crystals II: Group theory. | Fundamentals of group theory. Description, nomenclature, and representation of Point Group of Symmetry. Molecular and crystal symmetry. Stereographic projection. Problems resolution. |
| Unit 5. Crystal Morphology and Properties of Crystals. | Shapes and habits. Mechanisms of crystal growth. Physical properties. Crystalline optics. Optical properties and structure of minerals. Problems resolution. |
| Unit 6. Crystal Chemistry. Introduction to X-ray diffraction. | Basic concepts of radiation-matter interaction. Bragg's law. X-ray powder diffraction and its utility in the study of crystalline solids. |

| Planning | | | | |
|---|---|---|---|---|
| Methodologies / tests | Competencies / Results | Teaching hours (in-person & virtual) | Student?s personal work hours | Total hours |
| Guest lecture / keynote speech | A3 A5 A7 B4 B7 B8 C8 | 28 | 42 | 70 |
| Laboratory practice | A5 A6 A7 A8 B6 B7 B8 C3 C7 | 12 | 12 | 24 |
| Workshop | A3 A5 B6 C7 C3 | 10 | 43 | 53 |
| Objective test | A3 A5 A7 B4 B7 B8 C8 | 2 | 0 | 2 |
| Personalized attention | | 1 | 0 | 1 |
| (*)The information in the planning table is for guidance only and does not take into account the heterogeneity of the students. | | | | |

| Methodologies | |
|---|---|
| Methodologies | Description |

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|---|---|
| Guest lecture / keynote speech | In the lectures, the content of the respective topics will be introduced, highlighting the most important aspects and focusing particularly on fundamental concepts or those that may be more challenging for students. These are interactive sessions where students are encouraged to ask questions and seek clarification of ideas or concepts. |
| Laboratory practice | Preparation and study of crystalline substances. Interpretation of results using PC software. Use of morphological and structural models of crystals, as well as an introduction to characterization through X-ray diffraction. Students will keep a laboratory notebook in which they will describe their work in the lab, analyze the results, and draw the main conclusions. |
| Workshop | An eminently practical training activity designed with the aim of focusing on those aspects of the subject that are more difficult to understand. The work will be carried out individually or in groups under the guidance of the teaching staff. |
| Objective test | Tests will be conducted, comprising both open-ended and multiple-choice questions, as well as problem-solving exercises that will be like those done throughout the course. The aim is to assess the level of knowledge and skills gained by students and their ability to relate them and get an overall understanding of the subject. |

| Personalized attention | |
|---|---|
| **Methodologies** | **Description** |
| Laboratory practice<br>Workshop<br>Objective test<br>Guest lecture / keynote speech | The proposed teaching method is based on the work of the student, who becomes the main responsible for his/her own educational process. In order to optimize the effort of the student and get guidance during the process, it is very important to achieve close and constant student-professor interaction. Through this interaction and the different evaluation activities, the teacher will determine to what extent the student is achieving the objectives proposed in each unit and guide them. This guidance will be carried out through individual interviews that will take place during the tutorial hours of the teacher and/or at the most convenient times for the students. Obviously, apart from these tutorials proposed by the teaching staff, students may attend tutorials at their own request as often as they wish and when it is convenient for both students and teaching staff. |

| Assessment | | | |
|---|---|---|---|
| **Methodologies** | **Competencies / Results** | **Description** | **Qualification** |
| Laboratory practice | A5 A6 A7 A8 B6 B7 B8 C3 C7 | We will evaluate the following aspects of laboratory work:<br>- Work organization and safety.<br>- Attitude, scientific curiosity, and degree of involvement in the work.<br>- Quality of results interpretation.<br>- Quality of the final report (laboratory notebook). | 20 |
| Workshop | A3 A5 B6 C7 C3 | Both student responses and individual or group participation in the corresponding face-to-face activities will be graded. Occasionally, at the request of the teacher, students may be required to submit problem sets, which will also be evaluated. | 10 |
| Objective test | A3 A5 A7 B4 B7 B8 C8 | Exams will be conducted to assess the content of the subject. | 70 |

| Assessment comments |
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The evaluation of the subject is divided as follows:
- First test: 25% (Units 1, 2)
- Second test: 45% (30% Units 3, 4, 5; 15% Unit 6)
- Laboratory practical: 20%
- Seminars and Workshops: 10%

The evaluation cannot be considered positive if the student has not attended all laboratory classes.

Honors will be granted primarily to students who pass the subject on the first attempt. They will only be awarded in the "second chance" if the maximum number of honors has not been reached in the first attempt.

Students who do not pass the subject on the first attempt will be evaluated in the official exams of the Second Chance. In this session, they will be evaluated in the same way (percentages) through exams covering theoretical and practical contents, as well as the submission of seminar works. To receive the grade of "NO SHOW," students must not have participated in more than 25% of the scheduled evaluative activities.

Students who benefit from "recognition of part-time dedication and academic exemption from attendance" in accordance with UDC regulations must attend laboratory practices.

The final grade for these students will consist of two parts: the grade obtained in the laboratory practices, which will contribute 20% to the final grade, and the objective test, which will account for the remaining 80%. These grading percentages will be applied to both chances.

In exceptional circumstances that can be objectively demonstrated and properly justified, the responsible faculty may fully or partially exempt any student from participating in the continuous evaluation process. Students in this situation must pass a specific exam that leaves no doubt about the acquisition of the subject's competencies.

Once fraudulent completion of tests or evaluation activities is confirmed, the student will directly receive a failing grade for the corresponding academic year, whether the offense occurred in the first or second chance. If necessary, their grade in the first chance will be modified accordingly.

According to the "Regulations governing the study dedication regime for undergraduate students at UDC" (Art. 3.be 4.5) and the "Rules for evaluation, review, and appeals of grades for undergraduate and master's studies" (Art. 3 and 8b), students with recognition of part-time dedication and academic exemption from attendance must be able to participate in a training methodology and associated teaching activities that allow them to achieve the training objectives and competencies of the subject. Therefore, they will take part in a personalized system of guidance and evaluation tutorials that will serve to guide their independent work and monitor their progress throughout the course, as well as assess the level of competency development achieved.

During the tutoring sessions, aspects related to
the subject's content will be addressed, as well as the joint review of
submitted assignments.

| Sources of information | |
|---|---|
| **Basic** | - Sands, Donald E. (1974). Introducción a la cristalografía. Barcelona, Reverté<br>- Kettle, Sidney F.A. (2007). Symmetry and structure readable group theory for chemists. Hoboken: John Wiley<br>- Borchardt-Ott, Walter (2011). Crystallography : an introduction . Berlin, Springer<br>- Dept. de Cristalografía y Biol. Estruc. , CSIC (2020). Crystalografía.<br>- Hargittai, István (1995). Symmetry through the eyes of a chemist. New York : Plenum Press<br>- Hammond, C (2009). The Basics of crystallography and diffraction. Oxford University Press<br>- Klein, C; Hurlbut, C.S. Jr. (1996-1997). Manual de mineralogía basado en la obra de J.D. Dana. Vol. 1.. Barcelona, Reverté<br>- Bloss, F.D. (1994). Crystallography and crystal chemistry: an introduction. Washington, Mineralogical Society of America |

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| Complementary | - Müller, Ulrich (2013). Relaciones de simetría entre estructuras cristalinas : aplicaciones de la teoría de grupos cristalográficos en cristaloquímica. Madrid<br>- DAVID J. WILLOCK (2009). Molecular Symmetry. Willey<br>- Giacovazzo, C (2011). Fundamentals of crystallography. Oxford ; New York : Oxford University Press<br>- Amorós, J.L. (1990). El Cristal : morfología, estructura y propiedades físicas. Madrid, Ed. Atlas<br>- Nesse, W.D. (2009). Introduction to optical mineralogy. New York : Oxford University Press<br>- Amigo, J.M. et al. (1981). Cristalografía.. Madrid, Rueda. |

| Recommendations |
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| **Subjects that it is recommended to have taken before** |
| Chemistry: Structure and Bonding/610G04005 |
| **Subjects that are recommended to be taken simultaneously** |
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| **Subjects that continue the syllabus** |
| Advanced Crystallography/610G04042<br>Techniques of Characterisation of Nanomaterials 2/610G04030<br>Techniques of Characterisation of Nanomaterials 1/610G04025<br>Solid State/610G04022<br>Spectroscopy/610G04017 |
| **Other comments** |
| It is recommended to have completed and passed the course "Bonding and Structure" (610G04005).Attendance and participation in lectures are highly recommended. Students should be able to write, synthesize, and present their work organized, as well as have basic computer skills (Internet use, text processing, presentations, etc.). Program of the GreenCampus Faculty of Sciences To contribute to an immediate sustainable environment and comply with point 6 of the "Environmental Declaration of the Faculty of Sciences (2020)," the documentary work carried out in this subject will: a) Be predominantly requested in virtual format and electronic support. b) If printed: - Plastics will not beused. - Double-sided printing will be employed. - Recycled paper will be used. - Drafts will be avoided. Incorporation of a gender perspective - As stated in the various applicable regulations for university teaching, the gender perspective must be integrated into this subject (using non-sexist language, using bibliography from authors of both genders, encouraging the participation of male and female students in classroom...).- Efforts will be made to identify and modify sexist biases and attitudes, and the environment will be influenced to change them and promote values of respect and equality.- Situations of gender discrimination should be identified, and actions and measures will be proposed to correct them. |