Teaching Guide				
Identifying Data				2022/23
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	Química			
Coordinador	Hernández Hernández, Armand	E-mail	armand.hernandez@udc.es	
Lecturers	Hernández Hernández, Armand López Vicente, Manuel	E-mail	armand.hernandez@udc.es manuel.lopez.vicente@udc.es	
Web				
General description	"Crystallography and Symmetry" is a subject of the second semester of the first year of the Degree in Nanoscience and Nanotechnology, which belongs to the Basic Training Module. This course aims at training students on knowing and learning to apply the fundamentals of point symmetry and spatial symmetry, to become familiar with the world of crystals, with the most common structures of crystalline solids, with X-ray diffraction as a tool for characterising crystals, and with the relationship between crystallography and symmetry with other disciplines. This knowledge and skills will provide the theoretical and practical basis necessary for the student to delve into the world of crystalline nanomaterials and their characterisation by diffractometric and spectroscopic methods in subsequent subjects of the degree in Nanoscience and Nanotechnology.			

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

Learning outcomes	Study programme competences / results		
Identify the main crystalline forms, structures, growths, optics and systems.	A3 A5 A7	B6 B7 B8	C3 C8
Describe and analyse the external shape of crystals, their structural patterns and their possible transformations	A3 A5 A7	B6 B7 B8	C3 C8
Differentiate the main elements of symmetry and their nomenclature.	A5	B4	C3
Recognise the fundamentals of diffraction.	A3 A6 A8		C3 C7 C8
Solve basic crystallography problems.	A3 A5 A7	B7 B8	C3

Contents	
Topic	Sub-topic
Unit 1. Introduction.	Introduction to the world of crystals and symmetry. Its relevance in the field of nanoscience and nanotechnology.
Unit 2. Cristal lattice theory.	Crystal lattices. Knots, rows, lattice planes and their notations. Elementary cells. Reciprocal lattices. Lattice spacing. Exercises and problems.
Unit 3. Symmetry of crystals I: Point symmetry.	Concept of symmetry. Point symmetry operators. Stereographic projection. Applications of point symmetry.
Unit 4. Symmetry of crystals II: Group theory.	Fundamentals of group theory. Description and representation of Symmetry Point Groups (S.P.G.). Applications of S.P.G.: Description of the symmetry of molecules and crystal morphology. Bravais lattice. Simple problems resolution.
Unit 5. Symmetry of crystals III: Space groups.	Planar and three-dimensional space groups. Spatial symmetry operations. Translations. Sliding planes. Helical axes. Projections of crystalline structures. Tables of space groups. Exercises and problems.
Unit 6. Crystalline morphology and properties of crystals.	Shapes and habits. Mechanisms of crystal growth. Physical properties. Crystalline optics. Optical properties and structure of minerals. Exercises and practical examples.
Unit 7. Introduction to X-ray diffraction.	Basic concepts of radiation-matter interaction. Bragg's law. X-ray powder diffractograms and their 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	A5 B6 C7	4	14	18
Mixed objective/subjective test	A3 A5 A7 B4 B7 B8 C8	3	18	21
Objective test	A3 A5 A7 B4 B7 B8 C8	1	0	1
Seminar	A3 A5 C3 C7	3	12	15
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**
Guest lecture / keynote speech	Lectures and masterclasses will be used to deliver the main the contents of each unit of the course, highlighting their most important aspects and focusing on those concepts that are fundamental and/or most difficult for students to understand. These are interactive sessions, in which students are expected to participate by asking questions and requesting clarification of ideas or concepts.
Laboratory practice	Exercises and problems using morphological and structural models of minerals. Preparation and study of crystalline substances, as well as their characterisation by X-ray diffraction, and the interpretation of the results obtained using computer programmes. Students will prepare a laboratory notebook in which they will describe the work carried out in the laboratory and the analysis of the results, as well as 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.
Mixed objective/subjective test	Final exam that will be carried out in the date fixed by the faculty board. Its content will include development and multiple-choice questions, as well as problem exercises that will be similar to those analysed throughout the course. The aim is to assess the level of knowledge and competences reached by the students, as well as to evaluate their ability to relate them and to obtain an overview of the subject.
Objective test	Periodically, students will carry out a series of short tests in the problem-solving sessions, which will include multiple-choice or short-answer questions. These tests are conceived both to assess the degree of acquisition of competences and to consolidate of the contents presented in the lecture sessions. This activity will not only allow monitoring the students' progress, but will also serve to detect those aspects of the subject that are more difficult to understand.
Seminar	These sessions will be devoted to the resolution of problems and questions by the students, with the guidance of the teaching staff. These problems will be sequenced over time in accordance with the contents discussed in the lectures, and will be made available to students sufficiently in advance so that they can work on them before the corresponding classroom session.

Personalized attention	
Methodologies	**Description**
Mixed objective/subjective test Laboratory practice Seminar Workshop Objective test Guest lecture / keynote speech	The proposed teaching methodology 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 obtain 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 be able to determine to what extent the student is achieving the objectives proposed in each thematic unit and guide them in this regard. 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 at times that are convenient for both students and teaching staff.

Assessment			
Methodologies	**Competencies / Results**	**Description**	**Qualification**
Mixed objective/subjective test	A3 A5 A7 B4 B7 B8 C8	A test containing multiple-choice questions, short- and long-answer questions and problems, which will be similar to those presented throughout the course.	60
Laboratory practice	A5 A6 A7 A8 B6 B7 B8 C3 C7	The following aspects of laboratory work will be evaluated: - Organization of work and safety. - Attitude, scientific curiosity and degree of involvement in work. - Quality in the interpretation of the results. - Quality of the final report (laboratory notebook).	15

Seminar	A3 A5 C3 C7	Both the students' answers and their individual or group participation in the corresponding classroom activities will be graded. Occasionally, and at the teachers' request, students must submit problem tests which may also be assessed.	5
Workshop	A5 B6 C7	The activities carried out in workshops and the quality and frequency of the participation of the students will be evaluated.	5
Objective test	A3 A5 A7 B4 B7 B8 C8	Periodically, students will take a series of short tests, with multiple-choice answer or short-answer questions, during the seminar sessions. These objective tests are designed both to assess the degree of acquisition of competences and to strengthen the content seen in the lectures. This activity will not only monitor the progress of the students, but will also serve as a tool for detecting those aspects of the course that are most difficult to understand.	15

Assessment comments

Passing the course requires a minimum of 50 points, and at the same time the condition of obtaining a minimum of 40% of the Mixed Test, the Objective Tests, and the laboratory practice score must be met. In the case that the minimum score is not reached in any part, if the mean of the set is greater than or equal to 50 points, a failing grade will be awarded (45 out of 100 points). Since the qualification is based on a continuous assessment model, the progression of the students throughout the semester will be specifically assessed, with a maximum of 10 point that can be added to the final grade. The evaluation cannot be positive if students did not attend all the laboratory practices. The student will not be graded if the participation in activities that contribute to the final grade is below 25% of the activities. The "second chance in July" is understood exclusively as a second opportunity to take the mixed-test: the mixed-test will be repeated, representing 50% of the grade. The marks obtained in the other activities carried out during the course will be added to this mark. Honours will be awarded mainly to students who pass the subject at the first opportunity. It will only be awarded on the "second chance" if the maximum number is not covered on the first opportunity.

Students who qualify for the "Part Time Dedication Recognition and Academic Waiver of Attendance" in accordance with UDC regulations, must attend laboratory practices. The final mark for these students will consist of two parts: the grade obtained in the laboratory practices, which will contribute 20% to the final mark, and the mixed test, which will compute for the remaining 80%. These grading percentages will apply to both opportunities. In the case of exceptional, objectionable and duly justified circumstances, the coordinator of the subject may totally or partially exempt the student from participating in the continuous assessment process. Students who are in this circumstance must pass a specific test that leaves no doubt about the achievement of the subject's competences.

Fraudulent performance
in the assessment tests or activities, once verified, will directly imply a
failing mark of "0" in the subject at the corresponding opportunity.

According to the "Regulations of the regime of dedication to the study of undergraduate students at the UDC" (Art.3.be 4.5) and the "Rules of evaluation, review and claims of the qualifications of undergraduate and master's studies" (Art 3 and 8b), students with recognition of part-time dedication and academic dispensation of the attendance exemption must be able to participate in a training and associated teaching activities that allow them to achieve the training objectives and competencies of the subject. Therefore, they will participate in a personalised guidance system and assessment tutorials that will serve, on the one hand, to guide the autonomous work of the students and monitor their progress during the course, and on the other hand, to assess the degree of development of competence achieved.

The percentage of dispensation will be fixed in a first interview with the students, once their personal situation is known. In this way, a schedule will be established for the guidance tutorials, and the number of problem-solving workshops that will be evaluated using this methodology will be determined (every two seminars or workshop sessions will be evaluated using 1 tutorial). Once they are known, their number will be weighted over the total and the number of tutorials in which these students must participate will be established. All of them will be agreed with the students according to their availability, according to the schedule of contents of the subject and specifying the deadlines of the different materials to mark (problems and questions). This material will be delivered to the student in advance through the Moodle platform according to the schedule agreed in the initial interview.

The tutoring sessions will be used to discuss aspects associated with both the contents of the subject and the review of the submitted tasks, in addition to the performance of short assessment tests to verify whether students take advantage of these activities.

Sources of information

Basic	- Sands, Donald E. (1974). Introducción a la cristalografía. Barcelona, Reverté - Kettle, Sidney F.A. (2007). Symmetry and structure readable group theory for chemists. Hoboken: John Wiley - Borchardt-Ott, Walter (2011). Crystallography : an introduction . Berlin, Springer - Dept. de Cristalografía y Biol. Estruc. , CSIC (2020). Crystalografía. - Hargittai, István (1995). Symmetry through the eyes of a chemist. New York : Plenum Press - Hammond, C (2009). The Basics of crystallography and diffraction. Oxford University Press - Klein, C; Hurlbut, C.S. Jr. (1996-1997). Manual de mineralogía basado en la obra de J.D. Dana. Vol. 1.. Barcelona, Reverté - Bloss, F.D. (1994). Crystallography and crystal chemistry: an introduction. Washington, Mineralogical Society of America
Complementary	- Müller, Ulrich (2013). Relaciones de simetría entre estructuras cristalinas : aplicaciones de la teoría de grupos cristalográficos en cristaloquímica. Madrid - DAVID J. WILLOCK (2009). Molecular Symmetry. Willey - Giacovazzo, C (2011). Fundamentals of crystallography. Oxford ; New York : Oxford University Press - Amorós, J.L. (1990). El Cristal : morfología, estructura y propiedades físicas. Madrid, Ed. Atlas - Nesse, W.D. (2009). Introduction to optical mineralogy. New York : Oxford University Press - Amigo, J.M. et al. (1981). Cristalografía.. Madrid, Rueda.

Recommendations
Subjects that it is recommended to have taken before
Chemistry: Structure and Bonding/610G04005
Subjects that are recommended to be taken simultaneously
Subjects that continue the syllabus
Advanced Crystallography/610G04042 Techniques of Characterisation of Nanomaterials 2/610G04030 Techniques of Characterisation of Nanomaterials 1/610G04025 Solid State/610G04022 Spectroscopy/610G04017
Other comments
Students must pass the course "Structure and Bonding" (610G04005) before this one.Green Campus Program - Faculty of Sciences To achieve a sustainable environment and accomplish with point 6 of the "Environmental Declaration of the Faculty of Sciences (2020)", the documentary work carried out in this course:a.- It will be requested mainly in digital format and computer support.b.- If paper is used:- Plastics will not be used.- Double-sided prints will be made.- Recycled paper will be used.- The preparation of drafts will be avoided.