



## Teaching Guide

| Teaching Guide           |  |        |                                   |         |
|--------------------------|--|--------|-----------------------------------|---------|
| Identifying Data         |  |        |                                   | 2021/22 |
| Subject (*)              | Green Chemistry  | Code   | 610500021                         |         |
| Study programme          | Mestrado Universitario en Ciencias, Tecnoloxías e Xestión Ambiental (plan 2012)  |        |                                   |         |
| Descriptors              |  |        |                                   |         |
| Cycle                    | Period   | Year   | Type                              | Credits |
| Official Master's Degree | 2nd four-month period  | First  | Optional                          | 3       |
| Language                 | Spanish  |        |                                   |         |
| Teaching method          | Face-to-face   |        |                                   |         |
| Prerequisites            |  |        |                                   |         |
| Department               | Química  |        |                                   |         |
| Coordinador              | Martinez Cebeira, Montserrat   | E-mail | monserrat.martinez.cebeira@udc.es |         |
| Lecturers                | Martinez Cebeira, Montserrat   | E-mail | monserrat.martinez.cebeira@udc.es |         |
| Web                      |  |        |                                   |         |
| General description      | <p>The sustainable chemistry is based on the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances. In this course the principles, fundamentals and some examples of applications of green chemistry will be presented</p> <p>The general objectives of this course are:</p> <ul style="list-style-type: none"><li>- Define sustainable chemistry and give an overview of the historical developments that led to the development of green chemistry and other related discoveries.</li><li>- Establish the principles of sustainable chemistry and define in practice chemical processes associated with sustainable chemistry.</li><li>- Define the tools and the general areas of sustainable chemistry.</li><li>- Recognize the toxicity / hazard as a physical / structural property that can be designed and manipulated.</li><li>- Provide examples of application of green chemistry.</li><li>- Become familiar with current trends in sustainable chemistry.</li></ul>                            |        |                                   |         |
| Contingency plan         | <p>(i) Adaptation to be made in the event of a sudden absence caused by disease outbreaks:</p> <ol style="list-style-type: none"><li>1. Modifications to the contents</li><li>2. Methodologies<ul style="list-style-type: none"><li>*Teaching methodologies that are maintained</li><li>*Teaching methodologies that are modified</li></ul></li><li>3. Mechanisms for personalized attention to students</li><li>4. Modifications in the evaluation<ul style="list-style-type: none"><li>*Evaluation observations:</li></ul></li><li>5. Modifications to the bibliography or webgraphy</li></ol> <p>(ii) Adaptation planned in the center for cases in which the capacity of the classroom assigned for the subject is exceeded: In the event of capacity problems in the spaces designated for the realization of face-to-face activities, additional spaces will be reserved in which students can follow the activities through the TEAMS platform. In the case of practical activities, the groups will be divided to adapt to the capacity of the laboratory.</p> |        |                                   |         |

## Study programme competences



| Code | Study programme competences  |
|------|--|
| A1   | Coñecemento das realidades interdisciplinares da Química e do Medio Ambiente, dos temas punteiros nestas disciplinas e das perspectivas de futuro.   |
| A3   | Capacitar ao alumno para o desenvolvemento dun traballo de investigación nun campo da Química ou do Medio Ambiente, incluíndo os procesos de caracterización de materiais, o estudo das súas propiedades fisicoquímicas e biolóxicas e dos procesos que poden sufrir no medio natural.       |
| A5   | Capacitación para o deseño de vías de síntese e retrosíntese de novos compostos.   |
| A6   | Coñecemento do comportamento de diferentes especies químicas e dos procesos aos que poden estar sometidas unha vez liberadas no medio ambiente, incluíndo as súas relacións entre distintos compartimentos ambientais.   |
| A10  | Relacionar a presenza de especies químicas no medio natural cos conceptos de toxicidade e biodisponibilidade.  |
| A11  | Coñecer as distintas técnicas experimentais e computacionais orientadas á caracterización de mecanismos de reacción.   |
| A16  | Comprender a problemática asociada aos residuos, os modos de xestionalos e as principais tecnoloxías de tratamento de residuos.  |
| A17  | Coñecer a problemática asociada coa enerxía e as súas fontes, as tecnoloxías máis empregadas actualmente e as de futuro.   |
| A19  | Coñecemento e interpretación da lexislación, normativa e procedementos administrativos básicos sobre medios acuosos, chans e atmosferas. Comprensión das bases científicas e económicas da sustentabilidade.   |
| B1   | Posuír e comprender coñecementos que acheguen unha base ou oportunidade de ser orixinais no desenvolvemento e/ou aplicación de ideas, a miúdo nun contexto de investigación.   |
| B2   | Que os estudantes saiban aplicar os coñecementos adquiridos e a súa capacidade de resolución de problemas en contornas novas ou pouco coñecidas dentro de contextos máis amplos (ou multidisciplinares) relacionados coa súa área de estudo.   |
| B3   | Que os estudantes sexan capaces de integrar coñecementos e enfrontarse á complexidade de formular xuízos a partir dunha información que, sendo incompleta ou limitada, inclúa reflexións sobre as responsabilidades sociais e éticas vinculadas á aplicación dos seus coñecementos e xuízos. |
| B6   | Ser capaz de analizar datos e situacións, xestionar a información dispoñible e sintetizala, todo iso a un nivel especializado.   |
| B8   | Comprender, a un nivel especializado, as consecuencias do comportamento humano na contorna ambiental.  |
| C1   | Ser capaz de traballar en equipos, especialmente nos interdisciplinares e internacionais.  |
| C2   | Ser capaz de manter un pensamento crítico dentro dun compromiso ético e no marco da cultura da calidade.   |
| C3   | Ser capaz de adaptarse a situacións novas, mostrando creatividade, iniciativa, espírito emprendedor e capacidade de liderado.  |
| C5   | Dominar a expresión e a comprensión de forma oral e escrita dun idioma estranxeiro.  |
| C9   | Valorar criticamente o coñecemento, a tecnoloxía e a información dispoñible para resolver os problemas cos que deben enfrontarse.  |
| C11  | Valorar a importancia que ten a investigación, a innovación e o desenvolvemento tecnolóxico no avance socioeconómico e cultural da sociedade.  |

| Learning outcomes   |                             |     |     |
|---|-----------------------------|-----|-----|
| Learning outcomes   | Study programme competences |     |     |
| Know the principles and concepts of sustainable chemistry                                       | AC1                         | BC1 | CC2 |
|   | AC5                         | BC2 | CC3 |
|   | AC6                         |     | CC5 |
|   | AC17                        |     | CC9 |
| Knowing the fundamentals for waste minimization and deepen the idea of environmental efficiency | AC1                         | BC3 | CC2 |
|   | AC3                         | BC6 | CC5 |
|   | AC10                        | BC8 | CC9 |
|   | AC16                        |     |     |
| Knowing the importance of catalysis in sustainable processes                                    | AC3                         | BC1 | CC2 |
|   | AC5                         | BC2 | CC3 |
|   | AC11                        | BC3 |     |
|   | AC19                        |     |     |



|   |      |     |      |
|---|------|-----|------|
| Importance of using alternative solvents with low toxicity, renewable raw materials and non-classical reaction conditions in industrial processes | AC1  | BC3 | CC1  |
|   | AC3  | BC6 | CC2  |
|   | AC5  |     | CC3  |
|   | AC11 |     | CC9  |
|   | AC17 |     | CC11 |
|   | AC19 |     |      |
| Design development not harmful processes according to the principles of sustainable chemistry   | AC1  | BC1 | CC1  |
|   | AC3  | BC2 | CC2  |
|   | AC5  | BC3 | CC3  |
|   | AC17 | BC6 | CC5  |
|   |      | BC8 | CC9  |
|   |      |     | CC11 |

| Contents   |   |
|--|---|
| Topic  | Sub-topic   |
| Topic 1. Principles and Concepts of Sustainable Chemistry                    | Introduction.<br>Definition of sustainable chemistry.<br>Sustainable development and green chemistry.<br>The Twelve Principles of green chemistry<br>Atom economy. Definition. Examples.<br>Toxicity. Measuring toxicity. Associated risks.<br>Measuring and controlling environmental performance.<br>Waste minimization techniques. |
| Topic 2. Catalysis and Green Chemistry                                       | Introduction to catalysis. Catalyst types<br>Heterogeneous catalysts. Introduction. Zeolites. Industrial applications<br>Homogeneous catalysis. Transition-metal catalysis.<br>Asymmetric catalysis. Introduction. Basic concepts. Examples.<br>Phase-transfer catalysis.<br>Biocatalysis.<br>Photocatalysis.                         |
| Topic 3. Alternate solvents with low toxicity                                | Introduction.<br>Solvent free systems.<br>Supercritical fluids.<br>Water as reaction solvent.<br>Ionic liquids.<br>Fluorous biphasic solvents.  |
| Topic 4. Renewable Resources   | Basic concepts.<br>Energy from renewable resources.<br>Chemicals from renewable feedstocks  |
| Topic 5. Non-conventional reaction conditions and alternative energy sources | Photochemical reactions.<br>Chemistry using microwaves.<br>Sonochemistry.<br>Electrochemical synthesis.<br>Designing Greener Processes.   |
| Topic 6. Industrial case studies   | Industrial case studies of sustainable chemistry  |

| Planning              |              |                      |                               |             |
|-----------------------|--------------|----------------------|-------------------------------|-------------|
| Methodologies / tests | Competencies | Ordinary class hours | Student's personal work hours | Total hours |



|   |                                      |   |    |    |
|---|--------------------------------------|---|----|----|
| Supervised projects   | A5 A11 A17 B1 B6 B8<br>C2 C3 C1      | 3 | 12 | 15 |
| Laboratory practice   | A3 A5 A11 B1 B6 C11                  | 7 | 14 | 21 |
| Mixed objective/subjective test   | A1 A5 A6 A10 A11<br>A16 A17 B2 B6 C2 | 1 | 2  | 3  |
| Objective test  | A1 A5 A6 A10 A11<br>A16 A17 B2 B6 C2 | 2 | 2  | 4  |
| Multiple-choice questions   | A1 A6 A10 A16 A17<br>B6 C11          | 0 | 2  | 2  |
| Guest lecture / keynote speech  | A1 A3 A5 A11 A17<br>A19 B2 B3 C5 C9  | 8 | 20 | 28 |
| Personalized attention  |                                      | 2 | 0  | 2  |
| (*)The information in the planning table is for guidance only and does not take into account the heterogeneity of the students. |                                      |   |    |    |

| Methodologies                   |  |
|---------------------------------|--|
| Methodologies                   | Description  |
| Supervised projects             | Students will develop a work a recent scientific paper or examples of sustainable chemical processes, directly related to the subject of course, that could expose it in public. In this work, previously agreed with the teacher, the student it shall indicate the highlights, and the understanding of it through a short summary. It will evaluate the ability to summarize, arrange and present the concepts of the subject presented. There will also be questions after exposure in order to assess both the knowledge acquired by the student as well as their critical ability. |
| Laboratory practice             | The student will be able to develop a set of experiments based on the material resources and the availability of laboratories according to the coordination schedule or computational examples of the aspects developed in the guest lecture. It may also analyse and manage information available at a specialized level of sustainable processes either in the literature or in a research laboratory (e.g. CICA) and prepare a scientific report.   |
| Mixed objective/subjective test | It will be A written test consisting of a series of questions developed by the students to evaluate the level of skills acquired during the course the student.  |
| Objective test                  | Periodically, in the lectures, the student will conduct several short tests for continuous assessment.   |
| Multiple-choice questions       | On a regular basis, self-assessment tests (Moodle) will be carried out, which consist of formulating a direct question with various options or response alternatives that provide possible solutions, of which only one is valid.  |
| Guest lecture / keynote speech  | The course consists of a series of classroom sessions where the general principles of each topic will be presented. The literature and material to more adequately follow classes will be previously available in Moodle. Some of these classes are also devoted to the resolution of proposed questions in advance to students so that it can work on them before the relevant meeting. Also, periodically, you can make some short tests to the continued evaluation of the student.   |

| Personalized attention                     |   |
|--|---|
| Methodologies                              | Description   |
| Supervised projects<br>Laboratory practice | Personalized care sessions are programmed to guide students in making the ward work and resolve potential issues associated.<br><br>Students a appretiation part-time and academic exemption will be attended in tutorial hours (by appointment). The student in this situation must speak with the responsible Teacher in the first week of the course to replace the face-to-face regimen with other qualifying activities. |

| Assessment     |                                      |   |               |
|----------------|--------------------------------------|---|---------------|
| Methodologies  | Competencies                         | Description   | Qualification |
| Objective test | A1 A5 A6 A10 A11<br>A16 A17 B2 B6 C2 | There will be some short tests of multiple choice or short-answer, according to the specified in section methodology. | 20            |

|                                 |                                      |  |    |
|---------------------------------|--------------------------------------|--|----|
| Supervised projects             | A5 A11 A17 B1 B6 B8<br>C2 C3 C1      | Process evaluation of student learning will take place continuously, both classroom activities as non-face tutored. Besides, it will be considered in the evaluation of students the compulsory course attendance, assessed through active participation in the sessions and targeted academic papers that could be presented through an oral exposure. The continuous assessment of student during the semester will be up a point in the overall assessment. | 30 |
| Laboratory practice             | A3 A5 A11 B1 B6 C11                  | Attendance to practical classes is necessary and active participation will contribute to the final grade.  | 10 |
| Mixed objective/subjective test | A1 A5 A6 A10 A11<br>A16 A17 B2 B6 C2 | The student also may be assessed through a written exam.   | 30 |
| Multiple-choice questions       | A1 A6 A10 A16 A17<br>B6 C11          | Self-assessment tests will be carried out, according to what is indicated in the methodology section.  | 10 |

#### Assessment comments

To pass the subject it will be necessary to get at least 5 points (maximum 10 points) between the different assessment activities. Since the qualification is based on the model of continuous assessment, specifically it assesses student progression throughout the four-month period with a maximum of 1 point that may be added to the final grade.

Students who do not attend and do not participate in scheduled activities will score zero points in this section on two occasions, unless the student has recognized a part-time academic and attendance waiver of exemption or specific modalities of learning or supporting diversity. Students will be evaluated by the mixed test (20%), supervised projects (30%), multiple-choice questions (20%) and the objective test performed during programmed personalized attention (30 %).

In the case of exceptional, objectified and appropriately justified circumstances, the Professor may fully or partly exempt the student to perform the process of continuous assessment. The student that is in this circumstance must pass a specific test that leaves no doubt about achieving academic skill in both opportunities.

The student will have a rating of not submitted when making less than 25% of academic activities scheduled.

The students evaluated on the 2nd opportunity will only be able to opt for the Honor Roll if the maximum number of these for the corresponding course was not fully covered on the 1st opportunity.

The fraudulent performance of any exercise or test required of the student for the evaluation of the subject will be subject to disciplinary responsibilities, as set out in the Norms of Evaluation, Review and Claim of University Degree and Master's Qualifications (Article 14) and in the UDC Student Statute (Article 35, point 3).

#### Sources of information

|                      |   |
|----------------------|---|
| <b>Basic</b>         | <ul style="list-style-type: none"> <li>- Lancaster, M. (2002). Green Chemistry: An Introductory Text.. Royal Society of Chemistry: Cambridge, UK</li> <li>- Anastas, P. T.; Warner, J. C. (1998). Green Chemistry: Theory and Practice.. Oxford University Press: Oxford, UK</li> <li>- Cabildo Miranda, M. P.; Cornago Ramírez, M. P.; Escolástico León, C.; Esteban Santos, S.; Farrán Mor (2006). Procesos Orgánicos de Bajo Impacto Ambiental. Química Verde.. UNED: Madrid</li> </ul>  |
| <b>Complementary</b> | <ul style="list-style-type: none"> <li>- Anastas, P. T., Farris, C. A., Eds. (1994). Benign by Design. Alternative Synthetic Design for Pollution Prevention. ACS Symposium Series 577. American Chemical Society: Washington</li> <li>- Tundo, P., Anastas, P., Eds. (2000). Green Chemistry. Challenging Perspectives.. Oxford University Press: Oxford, UK</li> <li>- Anastas, P. T., Williamson, T. C., Eds. (1996). Green Chemistry. Designing Chemistry for the Environment. ACS Symposium Series 626. American Chemical Society: Washington</li> <li>- Anastas, P. T., Williamson, T. C., Eds. (1998). Green Chemistry. Frontiers in Benign Chemical Syntheses and Processes. Oxford University Press: Oxford, UK</li> </ul> |

#### Recommendations

Subjects that it is recommended to have taken before



Subjects that are recommended to be taken simultaneously

Subjects that continue the syllabus

Other comments

It is necessary to work the subject continuously. If the students found some difficulties about the tasks assigned, it is recommended to go to the individual tutorials with the teacher to solve these problems. Geen Campus Faculty of Sciences program to help achieve an immediate sustainable environment and comply with the following points of the "Environmental Declaration of Faculty of Sciences (2020)": -Point 8: Promote curricular greening, incorporating an environmental dimension as well as teaching and research activities. -Point 6 of the "Environmental Declaration of the Faculty of Sciences (2020)", the documentary works that are requested in this subject: (a) They will be requested mostly in virtual format and computer support (b) If done on paper: -Plastics will not be used -Double-sided prints will be made -Recycled paper will be used -The realization of drafts will be avoided

(\*)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.