

CH101 - Chemistry

Instructors: Dr. David Cheung, Dr. Fabien Cougnon, Prof. Paul Murphy, Dr. Luca Ronconi (Coordinator)

Module Overview and General Aims

This Module lays a broad foundation in chemistry for students who have an option of continuing to study chemistry in subsequent years. Some of these students will study chemistry to degree level and pursue careers as chemists. The Module assumes no prior knowledge of chemistry, although a significant minority of students will have a Level 5 (NFQ Level 5) qualification in chemistry.

The aim is to provide the learner with the knowledge, skills and competences associated with molecular and physico-chemical approaches to the study of matter and of chemical change. The Module is also designed to develop an understanding of how chemicals function in “real world” applications and how chemistry integrates with human, social and environmental issues. Students will also develop the knowledge, skills and competences appropriate for effective and safe work in a chemistry laboratory.

Course Instances

- 1BPC1 - BSc Biopharmaceutical Chemistry (core)
- 1BS1 - BSc Undenominated (optional)
- 1EV1 - BSc Environmental Science (optional)
- 1PHO1 - BSc Physics Applied, Astrophysics, Biomedical, Climate, Theoretical (optional)

Module Delivery

The Module runs over both Semesters I and II (24 weeks overall, 12 in Semester I/12 in Semester II).

The theory course is delivered in 72 lectures (normally 3 one-hour lectures per week, 36 in Semester I/36 in Semester II) and 18 tutorials (normally 1 one-hour tutorial per week, 9 in Semester I/9 in Semester II). In order to improve the learning process and facilitate the effective interaction between the students and the lecturers, the same tutorial is delivered twice per week.

The indicative timetable is reported below and may be subject to changes.

Academic Year 2021/2022 (Semester I)

Week beginning	27-Sep	4-Oct	11-Oct	18-Oct	25-Oct	1-Nov	8-Nov	15-Nov	22-Nov	29-Nov	6-Dec	13-Dec
Week n.	1	2	3	4 (TEST)	5	6	7	8 (TEST)	9	10	11	12 (TEST)
Lectures & Tutorials (CH101/CH140/CP102)												
Mon 10-11 am (online)	LR	LR	LR	LR	Bank Holiday	PM						
Tue 12-1 pm (online)	LR	LR	LR	LR	PM	PM	PM	PM	PM	PM	PM	PM
Thu 12-1 pm (online)	LR	LR	LR	LR	PM	PM	PM	PM	PM	PM	PM	PM
Thu 1-2 pm (tutorial) (on-campus, AMB-1021)		LR	LR	LR	PM	PM	PM		PM	PM	PM	
Fri 2-3 pm (tutorial) (on-campus, O'Flaherty)		PG	PG	PG	PG	PG	PG		PG	PG	PG	
Practicals (CH101/CH120 (1BGG1 & 1MR1 only)/CH130/CP102)												
Mon 2-4.30 pm (on-campus)				Practical 1	Bank Holiday (moved to 13 Dec)	Practical 3	Practical 4	Practical 5	Practical 6	Practical 7	Practical 8	Practical 2
Tue 3-5.30 pm (on-campus)				Practical 1	Practical 2	Practical 3	Practical 4	Practical 5	Practical 6	Practical 7	Practical 8	
Wed 2-4.30 pm (on-campus)				Practical 1	Practical 2	Practical 3	Practical 4	Practical 5	Practical 6	Practical 7	Practical 8	
Thu 3-5.30 pm (on-campus)				Practical 1	Practical 2	Practical 3	Practical 4	Practical 5	Practical 6	Practical 7	Practical 8	
Fri 2-4.30 pm (on-campus)				Practical 1	Practical 2	Practical 3	Practical 4	Practical 5	Practical 6	Practical 7	Practical 8	

LR	Dr. Luca Ronconi (12 lectures + 3 tutorials)
PM	Prof. Paul Murphy (11 lectures + 3 tutorials)
PM	Prof. Paul Murphy (12 lectures + 3 tutorials)
PG	TBA (9 tutorials)

Academic Year 2021/2022 (Semester II)

Week beginning	10-Jan	17-Jan	24-Jan	31-Jan	7-Feb	14-Feb	21-Feb	28-Feb	7-Mar	14-Mar	21-Mar	28-Mar
Week n.	1	2	3	4	5	6	7	8	9	10	11	12
Lectures & Tutorials (CH101)												
Mon 10-11 am (online)	FC	FC	FC	FC	DC	DC	DC	LR	LR	LR	FC	DC
Tue 12-1 pm (online)	FC	FC	FC	DC	DC	DC	DC	LR	LR	LR	FC	LR
Thu 12-1 pm (online)	FC	FC	FC	DC	DC	DC	LR	LR	LR	Bank Holiday	DC	LR
Thu 1-2 pm (tutorial) (on-campus, TBA)		FC	FC	FC	DC	DC	DC	LR	LR	Bank Holiday	LR	
Fri 2-3 pm (tutorial) (on-campus, TBA)		PG	PG	PG	PG	PG	PG	PG	PG	PG		
Practicals (CH101/CH120 (0MB3 & 1BO1 only)/CH130)												
Mon 2-4.30 pm (on-campus)			Practical 9	Practical 10	Practical 11	Practical 12	Practical 13	Practical 14	Practical 15	Practical 16		
Tue 3-5.30 pm (on-campus)			Practical 9	Practical 10	Practical 11	Practical 12	Practical 13	Practical 14	Practical 15	Practical 16		
Wed 2-4.30 pm (on-campus)			Practical 9	Practical 10	Practical 11	Practical 12	Practical 13	Practical 14	Practical 15	Practical 16		
Thu 3-5.30 pm (on-campus)			Practical 9	Practical 10	Practical 11	Practical 12	Practical 13	Practical 14	Practical 15	Bank Holiday (moved to 24 Mar)	Practical 16	
Fri 2-4.30 pm (on-campus)			Practical 9	Practical 10	Practical 11	Practical 12	Practical 13	Practical 14	Practical 15	Practical 16		

FC	Dr. Fabien Cougnon (12 lectures + 3 tutorials)
DC	Dr. David Cheung (12 lectures + 3 tutorials)
LR	Dr. Luca Ronconi (11 lectures + 3 tutorials)
PG	TBA (9 tutorials)

All lectures will be delivered online, either live or pre-recorded, according to the timetable provided. Live lectures will be also recorded. All recordings will be made available on Blackboard. Further details will be provided in due course.

All tutorials will be delivered on campus. Students will have the option to attend the weekly tutorials either on Thursday or on Friday. Note that, due to the restrictions in place to prevent the spread of COVID-19, the capacity of the lecture theaters is reduced to 80%. Therefore, students are advised to split evenly between the two days.

As far as the practical component of the course is concerned, there are 40 hours of laboratory work split into 16 practical sessions of 2.5 hours each (1 practical per week, 8 in Semester I/8 in Semester II). Students will be notified by the College the day of practicals and allocated a bench number. A pre-recorded pre-practical talk will be made available on Blackboard in advance to each practical session. Further details will be provided in due course.

All practicals will be carried out on campus. Students are expected to perform their laboratory work on the assigned day (**no day swapping allowed**).

Laboratory prerequisites:

- **It is mandatory to wear a face mask (not a visor) at all times while in the laboratory.** Should a student arrive at a practical without their own face mask, they **will not** be allowed to carry out the practical and, as such, will be given an **unauthorized absence**. Should a student have a **certified issue** which prevents them from using a face mask, they should engage with the course Coordinator to determine if a visor is appropriate or if another accommodation is required.
- Students **must** bring their own white laboratory coat and safety glasses (available at the SU shop). Laboratory coats and safety glasses **cannot** be hired or borrowed anymore: should a student arrive at a practical without their own laboratory coat and/or safety glasses, they **will not** be allowed to carry out the practical and, as such, will be given an **unauthorized absence**.
- The electronic version of the laboratory manual will be available on Blackboard. Students **must** bring their own printout of the laboratory manual (no hardcopy provided, **mobile phones/tablets/laptops strictly prohibited**).

Learning Outcomes

On successful completion of this Module, the learner will be able to:

- LO1 predict chemical formulas of compounds using valence considerations and the knowledge of simple and complex cations and anions;
- LO2 perform mass- and mole-type calculations, to include isotopes, chemical equations and chemical analyses;
- LO3 use models of structure at the atomic/molecular level, including intermolecular forces, to explain the physical properties of matter and the properties of solutions;
- LO4 draw representations of the bonding and geometry of simple inorganic and organic molecules and ions, to include Lewis structures, resonance structures, formal charges, ionic character, and the use of Valence Shell Electron Pair Repulsion (VSEPR) theory;
- LO5 show how acid-base, redox and precipitation reactions in aqueous solutions are used for qualitative and quantitative analyses;
- LO6 solve basic quantitative problems involving chemical equilibrium and chemical kinetics, to include thermochemistry, entropy, Gibbs free energy, the direction of spontaneous change, and the effect of temperature on the rate of reactions;
- LO7 name inorganic and organic compounds according to IUPAC nomenclature;
- LO8 demonstrate familiarity with the chemistry of representative elements and their compounds, and with the structure and reactivity of the main organic functional groups;
- LO9 rationalize the properties of the elements and their compounds using basic quantum-mechanical models (including electron configuration, atomic spectra and periodic trends), and using the concepts of oxidation state and charge density;
- LO10 draw mechanisms for a range of simple organic reactions;
- LO11 relate the chemical properties of selected elements and compounds to their uses, human and social relevance, and environmental impact.

On successful completion of the associated practical work in the laboratory, the learner will be able to:

- LO12 analyze salts for the presence of common cations and anions, and simple organic substances for the presence of common functional groups;
- LO13 use appropriate laboratory techniques and equipment to synthesize, separate and purify chemical compounds;
- LO14 use titrimetry and physico-chemical techniques for quantitative analysis and to determine physico-chemical properties;
- LO15 implement safe work practices in a chemistry laboratory, to include awareness of common hazards and appropriate safety precautions;
- LO16 report to a scientifically acceptable standard on laboratory work.

Textbook and Reference Material

- P. Flowers, K. Theopold, R. Langley, W.R. Robinson, *Chemistry 2e*, OpenStax™, 2019 (downloadable for free at https://assets.openstax.org/oscms-prodcms/media/documents/Chemistry2e-OP_TkF9Jl3.pdf).
- First Year Chemistry Laboratory Manual (downloadable from Blackboard).
- Lecture notes, slides and literature papers provided in due course on Blackboard.

Module Outline

Topic		Class/Laboratory time	Credits (15 overall)
<i>Semester I</i>			
Lectures	Basic concepts of chemistry, the structure of atoms and molecules	12 Lectures + 3 Tutorials	6
	Chemical reactions, stoichiometry and chemical reactivity	12 Lectures + 3 Tutorials	
	Bonding and molecular structure	12 Lectures + 3 Tutorials	
Laboratory	Introduction to the chemistry laboratory	1 Practical	1.5
	Qualitative analysis of inorganic salts	2 Practicals	
	Inorganic synthesis	1 Practical	
	Quantitative analysis	3 Practicals	
	Thermochemistry	1 Practical	
<i>Semester II</i>			
Lectures	Organic chemistry	12 Lectures + 3 Tutorials	6
	Physical chemistry	12 Lectures + 3 Tutorials	
	Inorganic chemistry	12 Lectures + 3 Tutorials	
Laboratory	Chromatography and molecular structure	1 Practical	1.5
	Identification of organic compounds	3 Practicals	
	Organic synthesis	1 Practical	
	Spectrophotometry	1 Practical	
	Kinetics	1 Practical	
	Chemical equilibrium	1 Practical	

Semester I

- Basic concepts of chemistry, the structure of atoms and molecules (Dr. Luca Ronconi)

Syllabus and homework (P. Flowers *et al.*, *Chemistry 2e*, OpenStax™, 2019)

- Chapter 1: Essential Ideas
- Chapter 2: Atoms, Molecules, and Ions
- Chapter 3: Composition of Substances and Solutions
- Chapter 6: Electronic Structure and Periodic Properties of Elements

Contents:

- Classification and properties of matter
- Elements, atoms, compounds and molecules
- Atomic number and mass number

- Isotopes and calculation of atomic masses from isotopic masses and natural abundances
- The Periodic Table
- Interpretation, prediction and drawing of formulas of ionic and molecular compounds
- Naming ionic and molecular compounds
- The concept of mole and the use of molar mass in calculations
- Derivation of chemical formulas (including empirical, molecular, structural and condensed formulas) from experimental data
- Properties of the electromagnetic radiation and the wave-particle duality
- The atomic structure, the atomic quantum numbers and their use to predict the electron configuration of atoms

➤ Chemical reactions, stoichiometry and chemical reactivity (Prof. Paul Murphy)

Syllabus and homework (P. Flowers *et al.*, *Chemistry 2e*, OpenStax™, 2019)

- Chapter 4: Stoichiometry of Chemical Reactions
- Chapter 5: Thermochemistry

Contents:

- Reactants, products and stoichiometric coefficients in the chemical reactions
- Aqueous solutions and solubility
- Balancing simple chemical reactions
- Definition of acids and bases, and their behavior in aqueous solution
- The oxidation numbers and their use in oxidation-reduction (redox) reactions
- Stoichiometric calculations using balanced chemical equations
- The concept of limiting reactant and its consequences in chemical reactions
- Theoretical and actual percent yields of chemical reactions
- Definition, measurement and calculation of the concentration of chemical compounds in solution
- The transfer of energy as heat associated with changes in temperature and changes of state
- The First Law of Thermodynamics
- Definition of state functions (enthalpy, internal energy) and their relationship with chemical reactions
- Calculation of the energy evolved or required for physical changes and chemical reactions using the tables of thermodynamic data

➤ Bonding and molecular structure (Prof. Paul Murphy)

Syllabus and homework (P. Flowers *et al.*, *Chemistry 2e*, OpenStax™, 2019)

- Chapter 7: Chemical Bonding and Molecular Geometry
- Chapter 8: Advanced Theories of Covalent Bonding

Contents:

- Application of valence, octet rule and formal charges to draw Lewis structures of simple chemical compounds
- Selected exceptions to the octet rule (*e.g.* B₂H₆, NO, NO₂, O₂)
- Application of the expanded octet to draw Lewis structures of PCl₅, SF₄, BrF₃ and SF₆
- Definition of electronegativity and its periodic trends according to the Pauling scale
- Dipole moments and classification of bond polarity
- Derivation of the shape of molecules from Lewis structures and according to the Valence Shell Electron Pair Repulsion (VSEPR) theory
- Prediction of bond angles using the VSEPR theory

- Classification of intermolecular forces (*e.g.* hydrogen bonding and London dispersion forces) and their effects on physical properties
- Description of the hybridization model and the Valence Bond (VB) theory (including their limitations), and their practical applications to derive the molecular geometry of simple chemical compounds

Semester II

➤ Organic chemistry (Dr. Fabien Cougnon)

Syllabus and homework (P. Flowers *et al.*, *Chemistry 2e*, OpenStax™, 2019)

- Chapter 20: Organic Chemistry

Contents:

- Drawing accurately the structures of organic compounds from chemical formulas and by applying Lewis method and the VSEPR theory where appropriate
 - Naming organic compounds according to IUPAC rules and nomenclature (including the concept of *cis-trans* and the *E-Z* priority rules in naming alkenes)
 - The main organic functional groups (including alkanes, alkenes, alkynes, alcohols, ethers, benzene, phenols, aldehydes, ketones, carboxylic acids, esters, amines and amides) and their general reactivity
 - How functional groups determine a molecule's reactivity and physical properties
 - Acidity and basicity, acid/base reactions
 - Curly arrow mechanisms
 - Electrophiles and nucleophiles
 - Chemical bonding in organic compounds (*e.g.* alkanes, alkenes, alkynes, benzene, aldehydes, ketones and amines) using the hybridization model (sp , sp^2 and sp^3)
 - The concept of chirality
- Physical chemistry (Dr. David Cheung)

Syllabus and homework (P. Flowers *et al.*, *Chemistry 2e*, OpenStax™, 2019)

- Chapter 9: Gases
- Chapter 10: Liquids and Solids
- Chapter 11: Solutions and Colloids
- Chapter 12: Kinetics
- Chapter 13: Fundamental Equilibrium Concepts
- Chapter 14: Acid-Base Equilibria
- Chapter 15: Equilibria of Other Reaction Classes
- Chapter 16: Thermodynamics

Contents:

- Role of the intermolecular forces in determining the physical state of substances (contribution to the properties of liquids, relationship with solubility, driving forces for the formation of solutions)
- Chemical equilibrium and the effect of concentration and temperature
- Evaluation of the equilibrium constants of reactions and the concentration of reactants and products at the equilibrium
- Application of the principles of chemical equilibrium to acid-base reactions and solubility
- Basis of entropy and Gibbs free energy, and their contribution to the direction of spontaneous change
- The concept of reaction rate and the effect induced by altering the temperature or adding a catalyst

➤ Inorganic chemistry (Dr. Luca Ronconi)

Syllabus and homework (P. Flowers *et al.*, *Chemistry 2e*, OpenStax™, 2019)

- Chapter 4: Stoichiometry of Chemical Reactions
- Chapter 6: Electronic Structure and Periodic Properties of Elements
- Chapter 9: Gases
- Chapter 14: Acid-Base Equilibria
- Chapter 15: Equilibria of Other Reaction Classes
- Chapter 18: Representative Metals, Metalloids, and Nonmetals

Contents:

- The periodic properties/trends of the elements
- Definition and identification of metals, non-metals and semimetals
- Chemical families of the main group elements
- Chemical and physical properties/trends of the elements belonging to the same chemical family (including the diagonal relationship and the inert pair effect)
- Chemistry, bonding, composition and structure of selected compounds of the main group elements
- Practical application of the principles of stoichiometry (*e.g.* stoichiometric coefficients and calculations, reactions going to completion *vs.* reactions at the equilibrium, reactions in gaseous phase, homogeneous and heterogeneous reactions, acid-base reactions, pH, solubility, etc.)
- Practical uses and implications of selected main group elements and derivatives to socially relevant general themes, and their environmental impact

Module Assessment

NO FORMAL WRITTEN EXAMINATION AT THE END OF SEMESTER I

The Module will be assessed over the two Semesters as follows.

- Continuous Assessment (CA, worth 70% overall)
 - Three 45 min duration online tests on topics dealt with during lectures/tutorials to be held during the teaching Semester I (worth 30%)
 - Mandatory attendance to laboratory sessions and submission of a written report on the laboratory work each week (worth 30%)
 - 18 weekly online homework on topics dealt with during lectures/tutorials (worth 10%)
- One formal 2 h duration written examination at the end of Semester II on the theory course (worth 30%)

Continuous Assessment

- **Attendance** ⇒ mandatory for all laboratory sessions
- **Laboratory reports** ⇒ reports of the laboratory work submitted each week through Blackboard
Templates of the laboratory reports are included in the laboratory manual. Downloadable templates of the laboratory reports (as Word documents) will be available in due course in the "Lab Reports Submission" section on Blackboard.

Attending the laboratory only is **not** enough to get credits: practicals must be completed satisfactorily and complete laboratory reports must be submitted weekly through Blackboard by the relevant deadline (see table below).

Day of the Practical	Submission deadline
Monday	the following Saturday by 5pm
Tuesday	the following Sunday by 5pm
Wednesday	the following Monday by 5pm
Thursday	the following Tuesday by 5pm
Friday	the following Wednesday by 5pm

Each report will be marked out of 10. A “zero” will be assigned for late or no submission.

- **Online homework** ⇒ weekly assignments to be worked out online over the two semesters
A total of 18 online homework will be assigned on a weekly basis over the two semesters and will need to be completed and submitted through Blackboard by the relevant deadline (to be communicated in due course). Each homework will be marked out of 10 and will comprise of short-answer questions, numerical problems and multiple-choice questions.
- **Online tests** ⇒ periodic assignments to be worked out online during Semester I
Three online tests of 45 min duration each will be held during Semester I and will need to be completed and submitted through Blackboard. Each test will be marked out of 10 and will comprise of short-answer questions, numerical problems and multiple-choice questions. Further details will be provided in due course.

Written Exam

Past exam papers are available in the Exam Papers Archive (https://www.mis.nuigalway.ie/regexam/paper_index_search_main_menu.asp) of the James Hardiman Library. Note that, according to the policy in place at the School of Chemistry, past repeat (*i.e.* 2nd sitting) exam papers are **not** made available, nor are multiple-choice questions-type examinations.

- **Final Exam at the end of Semester II**
The written examination of 2 h duration will be marked out of 100 and will be divided into three parts (sections A, B and C). Students are required to answer questions from **all** three sections as described in the exam paper.
Questions will be allocated to the three sections as follows:
 - Section A: Organic chemistry (Dr. Fabien Cougnon)
 - Section B: Physical chemistry (Dr. David Cheung)
 - Section C: Inorganic chemistry (Dr. Luca Ronconi)
Further details about the format/type of exam paper will be provided in due course.

Marks of online tests, laboratory reports and online homework will be made available on Blackboard.

Students will be communicated the aggregate mark for the Module once the overall examination process is complete (that is, at the end of Semester II after the final written examination has been marked).

A student will have **passed** if the mark in the CA component is at least 35% **and** the aggregate mark for the Module is at least 40%.

A student will be deemed **incomplete** if the mark in the CA component is less than 35%. Should this be the case they **will not** be able to progress **regardless** of the performance in the written examination for the Module in the 1st sitting. Consequently, the student **will not be allowed** to re-sit either, and must **re-register** for the Module the following year and **re-engage in all parts** of the Module again.

A student will have **failed** the 1st sitting where the mark in the CA component is at least 35% but the aggregate mark for the Module is less than 40%. In this case, the student must repeat the written examination in the 2nd sitting with a view to improving the overall Module mark, retaining the CA mark from the 1st sitting. Should the student underperform also in the 2nd sitting (that is, by obtaining an aggregate mark for the Module lower than 40%), they will have **failed** the 2nd sitting and will have to **re-register** for the Module the following year and **re-engage in all parts** of the Module again.