OLLSCOIL NA GAILLIMHE
UNIVERSITY OF GALWAY

Scoil na nEolaíochtaí
Bitheacha agus Ceimiceacha

School of Biological
and Chemical Sciences

Chemistry

2BS Information Booklet

Academic Year 2022 – 2023

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Welcome and General Information

Welcome to second year chemistry at the University of Galway. We look forward to working with you in your studies this year. This booklet summarises the key information about the structure and content of the third-year course, along with some important policies in the School. While every effort has been made to make sure the information in this booklet is accurate and up to date, it is inevitable that some changes to this may be needed throughout the year. These will be communicated through Canvas, the University's virtual learning environment, so please check this, along with your university email address, throughout the year. Canvas will also be used to host lecture notes and other resources.

Attendance at all timetabled lectures and tutorials is expected and will be monitored. Note that while attendance at lectures is a key part of learning, it is not on its own sufficient and you are expected to support this through independent study. For a 5 ECTS module, the total workload is expected to be in the range of 100-125 hours, so for each lecture you may expect to have under take three to four hours of self-study.

Attendance at laboratory sessions is mandatory. For short term absences (e.g. through illness) authorized absences may be obtained by submitting appropriate documentation – this should be sent to the module coordinator and the school administrators. For absences due to sports or societies activities, you must contact the module coordinator in advance of these. If you are unfortunate to be absent for a longer period of time please refer to the university's extenuating circumstances policy (https://www.universityofgalway.ie/media/registry/exams/policiesprocedures/QA209-Extenuating-Circumstances.pdf).

Note that persistent absence with appropriate explanation by a student from weekly laboratory sessions will lead to the student being marked incomplete and I be prohibited from passing and will be excluded from admission into the relevant Autumn Examination and have to repeat the whole year.

While we hope that you will not encounter any difficulties, academic or thoerwise, during this year, the university has a range of supports in areas including adacmis skills, health, and finance. A guide to these is available here (https://www.universityofgalway.ie/media/collegeofscienceandengineering/CSE_StudentSupportMap_V.5_ColourblindFriendly-3.pdf).

You are expected to adhere to the university academic integrity policy (**https://www.universityofgalway.ie/media/registrar/docs/QA220-Academic-Integrity-Policy-Final.pdf**). Note that the unauthorised use of Artificial Intelligence is not permitted in assessments. Please check with your instructor if you have any questions about what is or is not allowed to be used.

Course Structure 2023/24

Core Chemistry (CH201)

Code	***CH204***	***CH203***	***CH202***	***CH205***
Title	***Inorganic Chemistry***	***Physical Chemistry***	***Organic Chemistry***	***Analytical & Environmental Chemistry***
ECTS	*5*	*5*	*5*	*5*
Semester	*I*	*I*	*II*	*II*
Lectures	*4 hr/week*	*4 hr/week*	*4 hr/week*	*4 hr/week*
Practical duration	*4hr/week*	*4hr/week*	*4hr/week*	*4hr/week*
Delivery	*1st half Sem I*	*2nd half Sem I*	*1st half Sem II*	*2nd half Sem II*
Assessment				
Examination: ***MOSTLY 70% of final***	*2 hr* *Sem I* *65% of final mark*	*2 hr* *Sem I*	*2 hr* *Sem II* *65% of final mark*	*2 hr* *Sem II*
Practical Marks 30% of final ***Online Homework***	*Continuous Assessment+ MCQ* *5% of final mark*	*Continuous Assessment+ MCQ*	*Continuous Assessment* *5% of final mark*	*Continuous Assessment*

Expected workload for each module

5 Credit Module	**100–125 h**
Contact with staff:	~48 h
Examinations (written and practical)	~2hr
Autonomous learning:	~50–75 h (about 4 h/week)

Autonomous learning includes time spent working independently reporting on practicals, learning, revising, additional reading, studying.

Initial Schedules

First Lecture: Wednesday, 6th September 2023
MRA201 @ 10.00 am

Semester I

Week 1 to 6:	Inorganic Chemistry (CH204)
Week 7 to 12:	Physical Chemistry (CH203)

Semester II

First Lecture:	Wednesday, 10th January 2024 MRA201 @ 10.00 am
Week 1 to 6:	Organic Chemistry (CH202)
Week 7 to 12	Analytical Chemistry (CH205)

Key Contacts

2nd year coordinator – Dr David Cheung (david.cheung@universityofgalway.ie)

Chemistry Pathway coordinator – Constantina Papatriantafyllopoulou (constantina.papatriantafyllopo@universityofgalway.ie)

Medicinal Chemistry Pathway coordinator – Dr Eddie Myers (eddie.myers@universityofgalway.ie)

Biopharmaceutical Chemistry Programme coordinator – Prof Peter Crowley (peter.crowley@universityofgalway.ie)

Head of School Biological and Chemical Sciences – Prof. Olivier Thomas (olivier.thomas@universityofgalway.ie)

Chemistry adminstrators – Karen Kelly (karen.kelly@universityofgalway.ie), Judy Buckley (judy.buckley@universityofgalway.ie)

Module coordinators

CH204 Inorganic Chemistry – Dr Andrea Erxleben (andrea.erxleben@universityofgalway.ie)

CH203 Physical Chemistry – Dr David Cheung (david.cheung@universityofgalway.ie)

CH202 Organic Chemistry – Dr Eddie Myers (eddie.myers@universityofgalway.ie)

CH205 Analytical and Environmental Chemistry – Dr Stanislas Von Euw (stanislas.voneuw@universityofgalway.ie)

CH204 - Inorganic Chemistry

Staff: Dr. Andrea Erxleben (Module co-ordinator), Dr. Pau Farras

Text Book: Brown, LeMay, Bursten, Chemistry The Central Science (online access via the library)

Lecture Course Outline:

1. Introduction to the Practical Course (2 lectures, Dr A. Erxleben)
2. Structure and Bonding – Molecules, Metals and Modern Materials (8 lectures, Dr A. Erxleben)
3. The Periodic Properties of the Elements (6 lectures, Dr A. Erxleben)
4. Introduction to Transition Metals (8 lectures, Dr P. Farras)

1. Introduction to the Practical Course (2 lectures)

These lectures will cover some of the theory of the experiments that the student will carry out during the practicals. The learning outcomes that will be assessed will include:

- The student being able to interpret and explain the data and observations of the experiments carried out in the weekly laboratory sessions.

2. Structure and Bonding – Molecules, Metals and Modern Materials (8 lectures)

This lecture series will cover Molecular Orbital theory, metallic lattices, metallic bonding, polymorphism, alloys, intermetallic compounds, semiconductors and inorganic materials. The learning outcomes that will be assessed will include:

- The student being able to apply MO theory to describe the bonding in diatomic molecules, to calculate the bonding order and to predict the magnetic properties.
- The student being able to describe common types of packing in metal lattices (cubic and hexagonal close-packing, simple cubic, body-centred cubic)
- The student being able to relate the properties of metals, alloys and semiconductors to their solid-structures and to a model for metallic binding
- The student being able to explain the following terms; polymorphism, alloy (substitutional, interstitial), intermetallic compound, metallic radius, unit cell, octahedral and tetrahedral sites in lattices.
- The student being able to demonstrate an understanding of the properties and structures of inorganic materials such as ceramics and their application as superconductors

3. The Periodic Properties of the Elements (6 lectures)

This lecture series will give an overview of the properties and reactions of the elements of group 1, 2, 13 – 18. The learning outcomes that will be assessed will include:

- The student understanding trends in the physical and chemical properties in the main groups of the Periodic Table.
- The student being familiar with the physical and chemical properties of selected main group elements.

4. Introduction to Transition Metals

The reactions of transition metal compounds with ligands, the properties of the molecules formed and the theories used to explain these phenomena will be explored. The student will endeavour to be able to:

- Give valence shell electron configurations for coordination compounds of the transition metals and their ions
- Draw molecular structures for common ligands and the coordination compounds they form with the transition metals, to include isomers
- Use chemical equations to represent the reactions involved in the formation of transition metal coordination compounds
- Give scientific accounts, at the phenomenological level, of magnetism and colour and their measurement using Gouy balance and spectrometer

- Use crystal field theory to explain the origin of colour and magnetism in transition metal compounds and to account for measured magnetic moments and maximal wavelengths of absorption.

Practicals

The Inorganic Practical Course will take place over a 5 week period (4 hrs per week). There will be a tutorial at the end of each practical session. Attendance records are taken at practical classes and performance at each laboratory class will be assessed on a weekly basis. Part of the marks will be awarded for this continuous assessment. There will be an MCQ examination at the end of the practical course.

The principal objectives of the CH204 laboratory course are:

- To provide an appreciation of the scientific method in the observation, recording and interpretation of experimental data.
- To illustrate the chemical principles dealt with in the lecture course.
- To familiarise the student with important techniques fundamental to all chemical work.

The experiments include the following:

Week 1 *Preparation and analysis of an iron oxalate compound*.

Learning outcome: Obtaining accurate results in the analysis of complex materials, revision of redox reactions and calculations.

Week 2 *Chemistry of selected transition metals*.

Learning outcome: Observation and deduction, revision of balanced equations, use of redox potentials, introduction to transition metal chemistry

Week 3 *Introduction to molecular modelling*.

Lecture topic: Structure & Bonding

Week 4 *Determination of the hardness of water.*

Lecture topic: Periodic Properties of the Elements and Co-ordination Compounds Week 5 *(a) Gravimetric determination of nickel*.

(b) Application of spot tests.

Lecture topic: Co-ordination Compounds

CH203 - Physical Chemistry

Staff: Dr. David Cheung (Module Co-ordinator), Prof. Henry Curran

Text Book: "Elements of Physical Chemistry", 4^{th} or 5^{th} Edition, by Atkins and De Paula, available in the library and in the university book shop, price €39.95. This text is also the prescribed text for third year physical chemistry.

Thermodynamics and Equilibrium (8 h, DC): Chapters 2–4 and 7 of textbook
Students will be able to:

- Relate entropy to the number of arrangements of matter and energy and show how this gives rise to the 2^{nd} and 3^{rd} laws of thermodynamics.
- Predict the direction of change in chemical systems from the change in free energy.
- Relate the equilibrium constant for a chemical system to the change in the free energy.

Transitions and phases (8 h, HC): Chapters 5-6 of textbook
Students will understand that:

- A substance has a tendency to change into the phase with the lowest molar Gibbs energy
- How the molar Gibbs energy of a substance varies with pressure and temperature
- The transition temperature between two phases is the temperature, at a given pressure, at which the molar Gibbs energy of the two phases are equal
- The Clapeyron equation, and the Clausius-Clapeyron approximate equation, providea way to predict the location of phase boundaries
- The vapour pressure of a liquid is the pressure of the vapour in equilibrium with the liquid
- The equilibria between phases (at constant pressure) are represented by lines on a temperature-composition phase diagram, and the relative abundance of phases is obtained by using the lever rule.
- A regular solution is one in which the entropy of mixing, but not the enthalpy of mixing, is the same as an ideal solution.
- An azeotrope is a mixture that vaporizes and condenses without a change in composition; an eutectic is a mixture that freezes and melts without change of composition.

Chemical kinetics (8 h, HC): Chapters 10-11 of textbook
Students will understand that:

- The rates of chemical reactions can be measured by using techniques that monitor the concentration of species in a reaction mixture
- A rate law is an expression for the reaction rate in terms of the concentrations of the species that occur in the overall chemical reaction
- An integrated rate law is an expression for the rate of reaction as a function of time
- The half-life of a 1^{st} order process is the time taken for the concentration of a species to fall to half its initial value
- The temperature dependence of the rate constant of a reaction typically follows the Arrhenius law
- Derive the rate law for a first- and second-order reaction and from that determine the half-life for a reaction and the rate of reaction.
- Determine the kinetics for an elementary reaction.
- Understand how the rate constant of a reaction varies with temperature, and derive the frequency A-factor and activation energy of a reaction given the rate constant and different temperatures.
- Appreciate and understand the dependence of kinetics on thermodynamics of reactants and products.

Practicals (4 hr per week, over a 6 week period)
The Physical Chemistry Practical Course will take place over a 5 week period (4 hrs per week), commencing with a library training session. There will be a tutorial at the end of most practical sessions. Attendance records are taken at practical classes and performance at each laboratory class will be assessed on a weekly basis. Part of the marks will be awarded for this continuous assessment. There will be an MCQ examination at the end of the practical course.

The principal objectives of the CH203 laboratory course are:

- To provide an appreciation of the scientific method in the observation, recording and interpretation of laboratory data.
- To illustrate applications of the chemical principles dealt with in the lecture course.

- To familiarise the students with important techniques fundamental to all chemical work.

The practicals are to be written up as a separate ***Report*** and handed up in the lab. Attendance and performance at each laboratory class will be assessed on a weekly basis and part of the marks will be awarded for this continual assessment.

The experiments include the following:

1. Conductometric Titration of an Acid Mixture
2. Temperature Dependence of the Equilibrium Constant
3. Phase Diagram of Miscible Liquids
4. Chemical Kinetics; Fading of Phenolphthalein
5. Chemical Kinetics; Arrhenius equation

CH202 - Organic Chemistry

Staff: Dr. Eddie Myers (Module Co-ordinator), Prof. Paul Murphy, TBC

Textbook: *Organic Chemistry, 8th edition, John E. McMurry international edition. Available in the Library and the university bookshop. This text is also the prescribed text for third year Organic chemistry.* Relevant chapters: 1, 3, 4, 7, 8, 9, 11, 15, 16, 17, 19, 20, 21, 22 and 23. See online textbook map at: https://chem.libretexts.org/Bookshelves/Organic_Chemistry/Organic_Chemistry_(McMurry)

Delivery: 24 lectures (4 per week over six weeks). Weekly practical sessions (one 4-hour session per week for 5 weeks). Tutorials (evenings, end of Semester 2)

Assessment: Continuous Assessment (35%): 5 practical sessions (one afternoon per week, 2-6 pm; Week 1-5; see schedule for your assigned day) and 3 biweekly homeworks based on material in 24 lectures (Blackboard; due end of Week 3, 5, 7).

End of Semester Exam (65%)

Learning Outcomes:

a) Understand that acyclic and cyclic molecules can adopt different shapes (conformations) and appreciate the factors that determine preferred shape
b) Be able to name families of organic molecules and functional groups
c) Understand the concept of hybridization of atomic orbitals for describing the bonding of tetravalent, trivalent and divalent carbon centres.
d) Understand the factors governing substitution and elimination reactions
e) Understand the factors governing the shape of amines and alcohols, appreciate the variety of synthetic methods for preparing nitrogen- and oxygen-containing molecules and understand the factors governing the basicity of amines and alcohols.
f) Understand the structure and reactivity of carbonyl compounds (esters, carboxylic acids, acid chlorides, anhydrides, ketones and aldehydes) and nitriles
g) Understand the structure and reactivity of alkenes and alkyne
h) Understand the concept of aromaticity and appreciate the main types of reactions of aromatic systems
i) To appreciate the safety risks and risk mitigation measures associated with the preparation and isolation of organic molecules
j) To be able to analyse UV/Vis, IR and mass spectra of organic molecules for the identification of functional groups and molecules.
k) To develop expertise in carrying out distillations, filtrations, recrystallisations, reflux reactions, liquid-liquid extraction and measuring melting-point ranges
l) To develop expertise in the use of qualitative analysis in identifying functional groups.

For each practical a report will need to be submitted via Blackboard no more than one week after the practical session. For example, if you attend the lab on Monday, the report will be due the following Monday. Your attendance and performance at each laboratory class will be assessed and contributes to your continuous assessment mark. Each practical contributes 6% to your overall mark for the module! Students who do not attend a sufficient number of lab sessions may be deemed incomplete.

CH205 - Analytical & Environmental Chemistry

Staff: Dr. Stanislas Von Euw (Module coordinator), Prof. Peter Crowley, Prof. Henry Curran, Prof. Donal Leech, Prof. Olivier Thomas.

Text Books: "Quantitative Chemical Analysis", 8th Edition, by DC Harris (8+ copies available in library). "Quality Assurance in Analytical Chemistry," E. Prichard & V. Barwick, Pub. Wiley (2007). "Environmental Chemistry," C. Baird, Pub. Freeman (1995).

Lecture Course Outline:

1) Sampling & Electrochemistry (4 lectures, D. Leech)
2) Atmospheric Chemistry (4 lectures, H. Curran)
3) Water chemistry & treatment, (3 lectures, O. Thomas)
4) Atomic & Applied Spectroscopy (6 lectures, A. Ryder)
5) Separation Science/Chromatography (3 lectures, O. Thomas)
6) Bioanalytical (3 lectures, P. Crowley)

Sampling (2 h, DL): E. Prichard & V. Barwick, "*Quality Assurance in Analytical Chemistry*," Pub. Wiley (2007). Chapters 3 & 4.

Students will understand:

- The analytical approach for problem solving in chemistry
- How to select a sampling scheme to provide a sample for analysis
- How to report analytical results, using simple statistics

Electrochemistry (2 h, DL): D. C. Harris, *Quantitative Chemical Analysis*, Pub. Freeman (2010), 8th Edn.: Chapters 13, 14, 16.

Students will understand:

- Basic electrochemical reactions, terminology and conventions
- How to relate chemical amount to electrochemical parameters of potential and current

Atmospheric Chemistry (4 h, HC): Chapters 2-4 of *Environmental Chemistry* (C. Baird).

Students will understand that:

- Temperature, pressure and composition of the atmosphere changes as a function of height above sea level
- Photochemical smoke + fog = smog
- Acid rain is formed by the reaction $CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$
- Solar radiation and terrestrial energy balance is important towards global warming
- CO_2 and CH_4 are the principal greenhouse gases
- Implications of the use of different types of energy, particularly fossil fuels
- Stratospheric ozone content is adversely affected by anthropogenic emissions of chlorofluorocarbons
- Waste disposal is can be primarily by landfill and by incineration with pros and ocns for both methods

Water chemistry and treatment. Atomic Spectroscopy (3h, OT): Chapters 7–9 of *Environmental Chemistry* (C. Baird).

Students will understand that:

- The origins of drinking water from source (groundwater) to tap
- The many different chemical species that exist and are formed in groundwater
- The origin of these species with respect to the environment
- The redox chemistry and acid-base chemistry of groundwater.
- How groundwater is treated and purified at processing plants
- Pollution and the many origins of its existence (i.e. Groundwater contamination)
- Potential health problems associated with unclean / polluted drinking water
- The chemistry of Toxic Heavy Metals in water (and air).

Atomic Spectroscopy (2 L, AR): Chapter 20 of Quantitative Chemical Analysis (8th ed. Harris)

Students will understand:

- The fundamental physics of atomic absorption and emission spectroscopy
- How to apply atomic absorption to quantitative analysis
- The difference between Flame atomic absorption and Graphite Furnace Atomic Absorption
- The Beer-Lambert law and its relationship with atomic absorption
- The origin of colour within transition metal complexes in solution and its relation to atomic absorption

Applied Spectroscopy & Forensics (4 L, AR): Chapter 17 & 19 of Quantitative Chemical Analysis (8th ed. Harris).
Students will expected to have a knowledge of UV-visible, NIR, and MIR spectroscopies and understand:

- How an optical spectrometer operates and the salient features of the components (light sources, spectrometers, detectors) used in their construction.
- The sample holders used for the different spectroscopies depend on the wavelength of light being used and the sample type under investigation.
- UV-visible absorption spectroscopy typically involves the absorption of light in the 190-700 nm range.
- The Beer-Lambert Law can be used for the quantitative analysis of material.
- How Mid Infra-Red (MIR) spectroscopy works involves absorption of light in the 2000-10000 nm range. Molecules absorb light via fundamental vibrations, some overtone & combination modes.
- Attenuated Total Reflectance (ATR) sampling used the evanescent wave phenomena for robust MIR sampling.
- Optical fibres operate on the principle of Total Internal Reflection (TIR) and are very useful for spectroscopic sampling.
- Near Infra-Red (NIR) spectroscopy involves measuring the absorption of light in the 700-2500 nm range. Molecules absorb light via overtone & combination modes only.
- NIR instrumentation is relatively inexpensive, versatile and portable. One can use simple glass containers for NIR work.

Separation Science / Chromatography: (3 L, OT): D. C. Harris, Quantitative Chemical Analysis, Pub. Freeman (2010), 8th Edn.: Chapters 22, 24, and 25.
From this module students will be expected to have a knowledge of the types of separation methods available, including:

- Partitioning
- Electrophoresis
- Basic principles of chromatography
- Paper chromatography
- Thin layer chromatography
- Column chromatography
- Ion chromatography
- Size exclusion chromatography
- Separation using ion-exchange resins

Bioanalytical (3 hr., PC): D. C. Harris, Quantitative Chemical Analysis, Pub. Freeman (2010), 8th Edn.: Parts of Chapters 17 & 25.
This aspect of the course focuses on bioanalytical techniques. In particular, you will learn about three methods to study proteins:

- Method 1:
  - Absorption spectroscopy, Beer-Lambert law
  - Bradford assay for quantification of protein concentration (in mg/mL)
- Method 2:
  - Polyacrylamide gel electrophoresis (PAGE) technique for analysing proteins by molecular weight
  - SDS versus Native PAGE and the role of Cysteine will also be studied
- Method 3:
  - Column chromatography and protein purification
  - Ion exchange versus Size exclusion Chromatography

Practicals (4 hr per week, over a 5-week period)

All students must undertake the practical element of the module. The Analytical Chemistry Practical Course will take place over a 5-week period (4 hrs per week). Attendance records are taken at practical classes and performance at each laboratory class will be assessed on a weekly basis. Part of the marks will be awarded for this continuous assessment (30% of the overall module mark).

The principal objectives of the CH205 laboratory course are:

- To provide an appreciation of the scientific method in the observation, recording, and interpretation of laboratory data.
- To illustrate applications of the analytical and chemical principles dealt with in the lecture course.
- To familiarise the students with important techniques fundamental to analytical chemistry.
- To familiarise the students with the use of Excel for the plotting of data and spectra.

The practicals are to be written up as a separate ***Report*** in a hard-backed notebook and handed up in the lab. at the appropriate time. The experiments are to be done in cyclic order (by each individual student); for example, if you begin with experiment number 3, then the next week do #4, followed by #5 *etc*. For some experiments, students may work in pairs. To derive full benefit from the course the student should, before coming to the laboratory, read details of the experiment to be performed.

The experiments may include the following (these are subject to change, see blackboard for details):

1. Determination of iron using the thiocyanate method – An application of the Beer-Lambert Law.
2. Estimation of Copper and Sulphate in a solution of $CuSO_4$ using a Cation Exchange Resin.
3. Potentiometric determination of sodium.
4. Experiment in water analysis using the Hach (UV-visible spectroscopy) methodology.
5. Experiments in Mid-IR and Near-IR spectroscopy: Identification of unknown *white powders*.