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, though a significant minority of students will have a Level 5 qualification in chemistry.

The aim is to equip 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 designed to develop an understanding of how chemicals function in “real world” applications and how chemistry integrates with human, social and environmental issues. The student will also develop the knowledge, skills and competences appropriate for effective and safe work in a chemistry laboratory.

Learning outcomes

On successful completion of this Module, learners should be able to:

• predict empirical formulae of compounds using valence considerations and knowledge of simple and complex cations and anions;
• perform mass- and mole-type calculations, to include isotopes, chemical equations and chemical analyses;
• use models of structure at the atomic/molecular level, including intermolecular forces, to explain the physical properties of matter and the properties of solutions;
• 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;
• show how acid-base, redox and precipitation reactions in aqueous solutions are used for qualitative and quantitative analyses;
• solve basic quantitative problems involving chemical equilibrium and chemical kinetics, to include thermochemistry, entropy, the direction of spontaneous change, and the effect of temperature on the rate of reactions;
• name inorganic and organic compounds, including IUPAC nomenclature;
• demonstrate familiarity with the chemistry of representative elements and their compounds, and with the structure and reactivity of the main organic functional groups;
• rationalize the properties of the elements and their compounds (including atomic spectra and periodic variation) using Bohr and Quantum-Mechanical models (including electronic configuration), and using the concepts of oxidation state and charge density;
• draw mechanisms for a range of simple organic reactions, including “curly arrow mechanisms”;
• relate the chemical properties of selected elements and compounds to their uses, human and social relevance, and their environmental impact.

Upon completion of the practical work in the laboratory, learners should be able to:

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

**Module delivery and workload**

The Module runs over both Semesters I and II.

The theory course is delivered in 69 lectures (normally 3 one-hour lectures per week, 33 in Semester I / 36 in Semester II) and 48 tutorials (normally 2 one-hour tutorials per week, 24 in Semester I / 24 in Semester II).

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). To gain admittance to the laboratory students must attend the pre-practical talk held prior to the beginning of each practical session.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time (h)</th>
<th>Number of weeks</th>
<th>Hours per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lectures</td>
<td>69</td>
<td>24</td>
<td>2.88</td>
</tr>
<tr>
<td>Tutorials</td>
<td>48</td>
<td>24</td>
<td>2.00</td>
</tr>
<tr>
<td>Practicals</td>
<td>40</td>
<td>16</td>
<td>2.50</td>
</tr>
<tr>
<td>Homework, lab reports and self-directed study</td>
<td>120</td>
<td>24</td>
<td>5.00</td>
</tr>
<tr>
<td>Independent learning and exam period</td>
<td>40</td>
<td>30</td>
<td>1.33</td>
</tr>
<tr>
<td><strong>Overall load</strong></td>
<td><strong>317</strong></td>
<td><strong>30</strong></td>
<td><strong>13.71</strong></td>
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</tbody>
</table>

**Course textbook and reference material**

The Module is assessed over two Semesters as follows:

- First Year Chemistry Laboratory Workbook 2016 - 2017
- Lecture notes, slides and literature papers provided in due course on Blackboard
## Module outline and learning outcomes

<table>
<thead>
<tr>
<th>Topic</th>
<th>Class/Laboratory time</th>
<th>Credits (15 overall)</th>
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</thead>
<tbody>
<tr>
<td><strong>Semester I</strong></td>
<td></td>
<td></td>
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<tr>
<td>Lectures</td>
<td></td>
<td></td>
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<tr>
<td>Basic concepts of chemistry, the structure of atoms</td>
<td>11 Lectures + 4 Tutorials</td>
<td>6</td>
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<tr>
<td>and molecules</td>
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<tr>
<td>Chemical reactions, stoichiometry and chemical</td>
<td>11 Lectures + 4 Tutorials</td>
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<tr>
<td>reactivity</td>
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<tr>
<td>Bonding and molecular structure</td>
<td>11 Lectures + 4 Tutorials</td>
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<tr>
<td>Laboratory</td>
<td></td>
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<tr>
<td>Introduction to the chemistry laboratory</td>
<td>1 Practical</td>
<td></td>
</tr>
<tr>
<td>Qualitative analysis</td>
<td>2 Practicals</td>
<td>1.5</td>
</tr>
<tr>
<td>Inorganic synthesis</td>
<td>1 Practical</td>
<td></td>
</tr>
<tr>
<td>Quantitative analysis</td>
<td>3 Practicals</td>
<td></td>
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<tr>
<td>Thermochemistry</td>
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<tr>
<td><strong>Semester II</strong></td>
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<tr>
<td>Lectures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic chemistry</td>
<td>12 Lectures + 4 Tutorials</td>
<td>6</td>
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<tr>
<td>Physical chemistry</td>
<td>12 Lectures + 4 Tutorials</td>
<td></td>
</tr>
<tr>
<td>Inorganic chemistry</td>
<td>12 Lectures + 4 Tutorials</td>
<td></td>
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<tr>
<td>Laboratory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chromatography and molecular structure</td>
<td>1 Practical</td>
<td></td>
</tr>
<tr>
<td>Identification of organic compounds</td>
<td>3 Practicals</td>
<td>1.5</td>
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<tr>
<td>Organic synthesis</td>
<td>1 Practical</td>
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<tr>
<td>Spectrophotometry</td>
<td>1 Practical</td>
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<tr>
<td>Kinetics</td>
<td>1 Practical</td>
<td></td>
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<tr>
<td>Chemical equilibrium</td>
<td>1 Practical</td>
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</tbody>
</table>

**Semester I**

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

**Syllabus and homework** (J.C. Kotz et al., *Chemistry & Chemical Reactivity*, 8th Ed., 2012)
- Chapters 1 & 2 - Matter, atoms, molecules and ions
- Chapters 6 & 7 - The structure of atoms and periodic trends

**Learning outcomes:**
- understand the difference between hypotheses, laws and theories
- apply the kinetic-molecular theory to the properties of matter
- classify matter
- recognize elements, atoms, compounds and molecules
- identify physical and chemical properties and changes
- describe atomic structure and define atomic number and mass number
- understand the nature of isotopes and calculate atomic masses from isotopic masses and abundance
- know the terminology of the periodic table
- understand the periodic properties
- interpret, predict and write formulas for ionic and molecular compounds
- name ionic and molecular compounds
- explain the concept of mole and use molar mass in calculations
- derive compound formulas from experimental data
- describe the properties of electromagnetic radiation
- understand the origin of light emitted by excited atoms and its relationship to atomic structure
- describe the experimental evidence for wave-particle duality
- describe the basic ideas of quantum mechanics
- define the four quantum numbers (\(n\), \(l\), \(m_l\) and \(m_s\)) and recognize their relationship to electronic structure

➢ Chemical reactions, stoichiometry and chemical reactivity (Dr. Paul Kavanagh)

**Syllabus and homework** (J.C. Kotz et al., *Chemistry & Chemical Reactivity*, 8th Ed., 2012)
- Chapter 3 - Chemical reactions
- Chapter 4 - Stoichiometry: quantitative information about chemical reactions
- Chapter 5 - Principles of chemical reactivity

**Learning outcomes:**
- balance equations for simple chemical reactions
- understand the nature and characteristics of chemical equilibria
- understand the nature of ionic substances dissolved in water
- recognize common acids and bases and understand their behavior in aqueous solution
- recognize the common types of reactions in aqueous solution
- write chemical equations for the common types of reactions in aqueous solution
- recognize common oxidizing and reducing agents and identify oxidation-reduction reactions
- perform stoichiometric calculations using balanced chemical equations
- understand the meaning of a limiting reactant in a chemical reaction
- calculate the theoretical and percent yields of a chemical reaction
- use stoichiometry to analyze a mixture of compounds or determine the formula of a compound
- define and use concentration in solution stoichiometry
- assess the transfer of energy as heat associated with changes in temperature and changes of state
- understand and apply the first law of thermodynamics
- define and understand state functions (enthalpy, internal energy)
- describe how energy changes are measured
- calculate the energy evolved or required for physical changes and chemical reactions using tables of thermodynamic data

➢ Bonding and molecular structure (Dr. Fawaz Aldabbagh)

**Syllabus and homework** (J.C. Kotz et al., *Chemistry & Chemical Reactivity*, 8th Ed., 2012)
- Chapter 8 - Bonding and molecular structure
- Chapter 9 - Orbital hybridization and molecular orbitals
Learning outcomes:
- know how to draw Lewis structures accurately, which includes applying valence, octet rule and formal charges
- be familiar with selected exceptions to the octet rule: e.g. NO, NO2, O2
- be able to draw Lewis structures for selected acid-base reactions and charged molecules
- know that third row elements can have expanded shells, and draw Lewis structures for PCl5, SF4, BrF3 and SF6
- be able to define electronegativity, and know Periodic Table trends according to the Pauling scale
- be familiar with the reasons that dictate the magnitude of electronegativity of an atom
- be familiar with dipole moments and classifications of bond polarity
- know how to derive the shapes of molecules from Lewis structures, and according to VSEPR theory.
- be able to predict bond angles using VSEPR theory
- know the main classifications of intermolecular forces: hydrogen bonding, and London dispersion forces
- explain intermolecular forces of hydrides, and effects on physical properties
- describe the hybridization model and the Valence Bond (VB) theory, including practical applications to derive the molecular geometry, and their limitations
- describe the Molecular Orbitals (MOs) theory
- apply MOs theory to simple homonuclear and heteronuclear diatomic molecules

Semester II

➢ Organic chemistry (Dr. Fawaz Aldabbagh)

Syllabus and homework
- Chapter 10 - Carbon: not just another element (J.C. Kotz et al., Chemistry & Chemical Reactivity, 8th Ed., 2012)

Learning outcomes:
- be able to draw the structures of organic compounds accurately from molecular and empirical formula, use IUPAC rules for naming of compounds, including branched alkanes, and apply Lewis structures and VSEPR theory when required
- be able familiar with the following organic functional groups (including drawing them), and their general reactivity: saturated as opposed to unsaturated molecules (including alkenes and alkynes), alcohols, ethers, benzene, phenol, aldehydes, ketones, carboxylic acids, esters, amines and amides
- be able to draw all structural isomers of C4H10 and C5H12
- know the trends in physical properties in alkanes (including the effect of molecular weight and branching), differences between water, alcohols, carboxylic acids and amines (including solubility in water)
- be able to apply conformational analysis to draw cyclohexane chair conformation, and know the impact of angle and torsional strain on cyclopropane to cyclohexane
- be able to draw curly arrow mechanisms for the following reactions: halogenation of alkanes and alkenes, hydrohalic acids + alkenes (and Markovnikov’s Rule), nitrations of benzene and Friedel-Crafts alkylation of benzene, Grignard reaction with aldehydes and ketones, and carboxylic acid reactions with amines or inorganic bases
- be able to identify electrophiles and nucleophiles
- know bonding of organic compounds using hybridization (sp, sp$^2$ and sp$^3$), including alkanes, alkenes, alkynes, benzene, aldehydes, ketones, and amines
- know the concept of cis-trans, E-Z priority rules in naming alkenes
- be able to draw the repeating unit of an addition polymer
- be familiar with the concept of chirality, and draw the enantiomers of 2-propanol
- be able to explain acidity of phenol and carboxylic acids using curly arrows, and resonance structures
- be familiar with oxidation-reduction reactions and formation of esters (mechanisms not required)
- explain the origins of amine basicity, and basicity of aniline

Physical chemistry (Dr. David Cheung)

Syllabus and homework (J.C. Kotz et al., Chemistry & Chemical Reactivity, 8th Ed., 2012)
- Intermolecular forces and states of matter
- Chemical equilibria
- Spontaneous change in chemistry

Learning outcomes:
- understand the role that intermolecular forces play in determining the physical state of substances
- describe how intermolecular forces contribute to properties of liquids
- describe the relationship between intermolecular forces and solubility, and recognize the driving forces for the formation of solutions
- show how the relative concentrations of solute and solvent affect the colligative properties of solutions
- understand the concept of chemical equilibrium, and express it in terms of an equilibrium constant
- evaluate equilibrium constants of reactions and equilibrium concentrations of reactants and products
- predict the effect of variables such as concentration and temperature on chemical equilibria
- define acids and bases by Arrhenius, Bronsted-Lowry and Lewis methods
- understand the pH concept and express the acidity of a solution using the pH scale
- understand what is meant by the common ion effect, and be able to calculate saturated salt concentrations in the presence of common ions
- apply principles of chemical equilibria to acid-base reactions and solubility
- understand the basic concept of entropy and recognize its contribution to the direction of spontaneous change
- understand the concept of Gibbs free energy and recognize how the relationship between enthalpy, entropy and temperature contributes to the spontaneity of a process
- understand how the Gibbs free energy of a process relates to the equilibrium constant
- understand the concept of reaction rate
- understand the effect that altering the temperature or adding a catalyst may have on the rate of a reaction

Inorganic chemistry (Dr. Luca Ronconi)

Syllabus and homework (J.C. Kotz et al., Chemistry & Chemical Reactivity, 8th Ed., 2012)
- Chapter 21 - The chemistry of the main group elements

Learning outcomes:
- relate the formulae and properties of compounds to the periodic table
- understand the difference between metals, non-metals and semimetals
- identify the chemical families focusing on main group elements
- identify and explain the chemical and physical properties/trends of the elements belonging to the same chemical family
- describe the chemistry of the main group elements, particularly: H, Na and K, Ca and Mg, B and Al, N and P, O and S, F and Cl
- apply the principles of stoichiometry, thermodynamics and electrochemistry to the chemistry of the main group elements
- understand the composition, structure and bonding in selected elements of the main group blocks
- relate the chemistry and uses of selected elements to socially relevant general themes