

Fundamentals of Chemistry

1. GENERAL			
SCHOOL	Faculty of Sciences in collaboration with Faculty of Engineering, Aristotle University of Thessaloniki		
DEPARTMENT	Materials Science and Engineering		
LEVEL OF STUDIES	ISCED level 7 (5-year Integrated Master's programme) ISCED level 6 (4-year BSc programme)		
COURSE CODE	MSEN 102	SEMESTER	1 st Semester
COURSE TITLE	Fundamentals of Chemistry		
TEACHING ACTIVITIES	Lectures, tutorials/problem sessions, laboratory/computer exercises (where applicable), case studies and guided self-study.	TEACHING HOURS PER WEEK	ECTS CREDITS
		4 (3L + 1T)	6
COURSE TYPE	Background / General knowledge / Scientific area		
PREREQUISITES	None. Recommended: high-school Chemistry and Physics; basic Calculus.		
TEACHING AND EXAMINATION METHODS	Face-to-face lectures and guided problem-solving sessions; short in-class quizzes; final written examination.		
COURSE OFFERED TO ERASMUS STUDENTS	Yes.		
COURSE URL	https://elearning.auth.gr/course/view.php?id=xxxxx		

2. LEARNING OUTCOMES	
Learning Outcomes	<p>Upon successful completion of this course, students will be able to:</p> <ul style="list-style-type: none"> • Demonstrate fundamental knowledge across organic, inorganic, and physical chemistry • Apply chemical principles to explain structure, bonding, reactivity, and properties of matter • Interpret experimental and spectroscopic data • Develop problem-solving and analytical skills appropriate for undergraduate chemistry <p>By the end of this course, students will be able to:</p> <ul style="list-style-type: none"> • Explain the nuclear model of the atom, the nature of electromagnetic radiation, and the basic quantum concepts related to atomic structure. • Describe atomic orbitals, quantum numbers, electron spin, and the electronic structure of both hydrogen and many-electron atoms.

- Relate electronic structure to the periodic table and interpret major periodic trends such as atomic/ionic radii, ionization energies, and electron affinity.
 - Summarize the fundamental models of chemical bonding: ionic bonding, covalent bonding and Lewis structures, VSEPR geometry, valence-bond theory, and molecular-orbital theory.
 - Explain the molecular basis of the gaseous, liquid, and solid states of matter and relate macroscopic properties to intermolecular interactions.
 - Describe ideal and real gas behavior and interpret deviations from ideality using qualitative models.
 - Interpret phase diagrams and explain phase transitions in one- and two-component systems.
 - Explain the interaction of electromagnetic radiation with matter and relate energy quantization to molecular energy levels.
 - Distinguish between rotational, vibrational, and electronic molecular transitions and the regions of the electromagnetic spectrum in which they occur.
 - Describe the behavior of electrolytes in solution, including ion formation, solvation, and ionic interactions.
 - Explain deviations from ideal behavior in electrolyte solutions using the concepts of ionic strength and activity.
- By the end of this course, students will acquire skills to:
- Write electron configurations for atoms and ions and use them to rationalize periodic trends and chemical behavior.
 - Construct Lewis structures, evaluate resonance and formal charges, and predict molecular shapes using VSEPR.
 - Assess bond type, polarity, and approximate bond strengths based on electronegativity and bonding models.
 - Apply valence-bond and molecular-orbital theory to simple diatomic and small polyatomic molecules to determine bond order, magnetic properties, and qualitative bonding features.
 - Apply gas laws and simple equations of state to calculate and predict properties of gases under different conditions.
 - Analyze phase diagrams to determine stable phases and phase transitions as a function of temperature and pressure.
 - Interpret basic IR, Raman, and UV–Vis spectra to extract information about molecular structure and bonding.
 - Relate spectroscopic features to rotational, vibrational, and electronic energy level changes in molecules.

	<ul style="list-style-type: none"> • Calculate and apply ionic strength and activity coefficients to describe non-ideal electrolyte solutions. • Use conductivity and colligative property concepts to assess electrolyte behavior in solution. understand the concept of organic molecules. • recognize the chemical structural unit of several basic organic materials. • understand the mechanisms of fundamental organic reactions. • realize the chemical properties and reactions of basic organic moieties. <p>By the end of the course, students will be able to:</p> <ul style="list-style-type: none"> • Integrate atomic and bonding principles to interpret the structure and reactivity of simple inorganic and molecular systems relevant to materials chemistry. • Choose appropriate bonding models (Lewis, VSEPR, valence-bond and molecular-orbital theory) to explain observed or predicted molecular properties. • Communicate concepts of atomic structure and bonding clearly using correct chemical terminology and representations. • Integrate concepts of states of matter, spectroscopy, and electrolyte solutions to explain physical and chemical properties of molecular systems. • Select appropriate physical chemistry models to interpret experimental observations and molecular behavior. • Evaluate the limitations of idealized models (ideal gases, ideal solutions) and justify the use of more realistic descriptions. • Communicate physical chemistry concepts clearly using correct scientific terminology, equations, graphs, and spectra.
<p>General Skills</p>	<ul style="list-style-type: none"> • Problem solving with quantitative reasoning • Teamwork in tutorial and lab-style activities • Information literacy (handbooks, databases, standards awareness) • Technical reporting and oral communication • Searching, analyzing and synthesizing data and information • Decision-making • Independent work • Teamwork • Promoting free, creative and inductive thinking • Working in a multidisciplinary environment

3. COURSE CONTENT

Part 1 – Introductory Inorganic Chemistry

- The nuclear model of the atom; Electromagnetic radiation; Atomic spectra
- Radiation, quanta, and photons; The wave-particle duality of matter; The uncertainty principle; Wavefunctions and energy levels
- The principal quantum number; Atomic orbitals; Electron spin; Electronic structure of hydrogen
- Orbital energies; The building-up principle; Electronic structure of many-electron atoms and the periodic table
- The periodicity of atomic properties - Atomic radius; Ionic radius; Ionization energy; Electron affinity; The inert-pair effect; Diagonal relationships; The general properties of the elements
- Ionic bonds - Lewis symbols of ions; The energetics of ionic bond formation; Interactions between ions
- Covalent bonds - Lewis structures; Resonance; Formal charge; Radicals; Expanded and incomplete valence shells; Electronegativity and polarizability; Bond strengths and lengths
- The VSEPR Model
- Valence-bond theory - Sigma and pi Bonds; Hybridization of orbitals; Characteristics of multiple bonds
- Molecular orbital theory - Molecular orbitals; Electron configurations of diatomic molecules; Bonding in homonuclear and heteronuclear diatomic molecules; Orbitals in polyatomic molecules
- Introduction to the solid state – Covalent network structures; Structures based on the packing of spheres; Metallic bonding; Ionic bonding and lattice enthalpy
- Acids and bases – Brønsted-Lowry acids and bases; Lewis acids and bases

Part 2 – Introductory Physical chemistry

- States of matter – Gases, liquids, and solids; Macroscopic and molecular descriptions of matter
- The gaseous state – Ideal gas laws; Kinetic molecular theory of gases; Molecular speed distributions; Deviations from ideal behavior and real gases
- Intermolecular forces
- The liquid state – Structure of liquids; Viscosity; Surface tension; Vapor pressure
- The solid state – Crystalline and amorphous solids; Unit cells; Packing efficiency; Introduction to phase transitions
- Phase equilibria – Phase changes; Phase diagrams;
- Light matter interaction – The electromagnetic spectrum; Absorption and emission processes; Selection rules (qualitative)
- Molecular rotation – Rotational energy levels; Rotational spectra of diatomic molecules
- Molecular vibration – Vibrational energy levels; Infrared spectroscopy; Normal modes of vibration
- Raman spectroscopy – Raman scattering; Complementarity of IR and Raman spectroscopy
- Electronic transitions – UV-visible spectroscopy; Electronic excitation and molecular structure
- Spectroscopy as a structural tool – Qualitative interpretation of molecular spectra
- Electrolyte solutions – Formation of ions in solution; Solvation and hydration

- Strong and weak electrolytes – Degree of dissociation; Acid–base behavior in aqueous solution

Part 3 – Introductory Organic chemistry

- Structure and Bonding, Orbital Theories
- An Overview of Organic Molecules: Names and Properties
- An Overview of Organic Reactions
- Stereochemistry at Tetrahedral Centers
- Hydrocarbons: Alkanes, Alkenes and Alkynes, Stereochemistry
- Halogenoalkanes: Properties and reactivity.
- Nuclear Magnetic Resonance (NMR) Spectroscopic and its application in Materials.
- Benzene and Aromaticity, Polyaromatic compounds. Structure, properties.
- Characteristic Main Polar Groups in Organic Materials: Alcohols, Carbonyl Compounds, Acids, Amines.

4. LEARNING & TEACHING METHODS - EVALUATION

Teaching method	Face-to-face.		
Use of ICT	ICT will be used in teaching the course, and in communication with students: <ul style="list-style-type: none"> • teaching of the course with modern distance learning (ZOOM) and asynchronous education tools via elearning platform of AUTH, • communication with students via email, ZOOM, and elearning platform of AUTH. 		
Teaching organization	The supervised and unsupervised workload per activity is indicated below (total workload complies with ECTS standards).		
	Activity	Workload/semester (hours)	ECTS
	Lectures	39	1.56
	Tutorials / problem sessions	13	0.52
	Bibliographic Research and analysis	10	0.4
	Independent study	70	2.8
	Exam preparation	16	0.64
	Final written exam	2	0.08
	Total	150	6
Student evaluation	<p>Assessment language The assessment language is English.</p> <p>Assessment methods The course uses the following methods:</p> <ul style="list-style-type: none"> • Multiple choice tests: three midterm exams to check recall of definitions, concepts, and terminology on core concepts of chemistry. • Problem solving assignments: three written assignments in which students review course material, analyze literature data, and solve problems on fundamentals of chemistry. • Final written exam: it combines short answers, problem solving, and data interpretation questions to evaluate cumulative understanding on core concepts of chemistry. 		

	<p>Weighting</p> <ul style="list-style-type: none"> • Multiple choice tests): 20% • Problem solving assignments: 20% • Final written exam: 60% <p>Student information</p> <p>Students are informed about the assessment process through:</p> <ul style="list-style-type: none"> • The course outline distributed in the first lecture. • Detailed instructions for the written assignment and presentation posted on the course website. • A dedicated assessment briefing during tutoring time where expectations and criteria are explained.
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5. SUGGESTED BIBLIOGRAPHY

Course Bibliography

Andrew Burrows, John Holman, Andrew Parsons, Gwen Pilling, Gareth Price, Chemistry³:
Introducing inorganic, organic and physical chemistry

Additional bibliography for study

- Teaching material slides