UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

General and Inorganic Chemistry

2627-1-E3402Q001

Aims

General aims

The aim of the course is to provide the students with basic knowledge concerning the structure of matter, chemical principles and chemical reactivity, stoichiometric aspects in reactions, theory of equilibria, theory of acids and bases, and the properties of the most important elements and chemical compounds. While obviously placing special emphasis on chemical aspects related to the field of geology, the course will also discuss, where appropriate, the relevance of covered aspects in terms of environmental aspects. The latter includes a more profound discussion of organic chemistry aspects, including the theoretical background of emerging 'persisting' organic pollutants and their physicochemical characteristics that determine potential remediation strategies.

Knowledge and understanding

At the end of the course the student will have a fundamental understanding of:

- matter, atomic theory, atomic and molecular mass, importance of Avogadro’s constant and use of moles.
- chemical compounds. chemical nomenclature, electronic structure of atoms and molecules, atomic periodic properties, ionic and covalent bonding, bond theories, Lewis formalism, Valence Bond, and Molecular Orbital theories, intermolecular and intramolecular interactions.
- various forms of solid matter like crystals and metals, including aspects of crystallography and band theory.
- theory of ideal gases and application of descriptive laws.
- thermochemistry and thermodynamics.
- stoichiometry.
- mixtures and aqueous solutions, colligative properties of solutions, solubility of salts and its theoretical description via solubility products, chemical equilibria and their manipulation according to the principle of LeChatelier.
- chemical kinetics.
- acids and bases, including conceptual definitions according to Arrhenius, Brønsted-Lowry and Lewis, the meaning of pH, design and use of buffer solutions, titrations for qualitative and quantitative purposes, use of

indicators.
- oxidative and reductive process, their coupling.
- electrochemical potentials, function of batteries.
- nuclear chemistry and radiation types.
- descriptive chemistry of main group elements and transition metals.
- organic chemsitry principles, important functional groups and their reactivities, reactions in organic chemistry, selected important biomolecules and unnatural organic structures representing important classes of oragnic pollutants.

Applying knowledge and understanding

At the end of the course the student will be able to:

- write correctly a chemical reaction equation.
- perform simple stoichiometric calculations.
- understand the behaviour and classify the substances on the basis of their chemical nature.
- understand the bond types and tridimensional shapes of simple molecules.
- predict the spontaneity of a chemical reaction.
- evaluate the energy transfer related to such chemical transformation.
- describe the condition for the chemical equilibrium.
- evaluate the behaviour of acids, bases and their mixtures in aqueous solutions, as well as the behavior of chemical species that produce insoluble salts.
- understand basic chemistries of organic substances, the importance of functional groups and their interconversion, and the problematic of 'persisting' orgabic structures.

Making judgements

At the end of the course the student will be able to

- apply the acquired knowledge in various contexts.
- transfer concepts and approaches to new fields.
- elaborate the topics of the course.

Communication skills

At the end of the course the student should be able to

- analyse a chemistry-related problem in a clear and concise way.
- explain orally with a suitable language the objectives, the procedures and the results of the elaborations carried out.

Learning skills

At the end of the course the student should be able to apply the acquired knowledge to different contexts than those discussed during the course.

Contents

- the fundamental chemical properties such atomic mass and mole
- the electronic structure of atoms and their periodic properties
- bonding theories and the principles that regulate atom binding
- the nature of intermolecular interactions and their relation with the states of matter

- the energy transfer related to physical and chemical transformations, and the criteria to evaluate the spontaneity of a process
- the properties of homogeneous and heterogeneous mixtures
- the basic concepts of chemical reactivity and the main classes of reactions (redox, acid-base, precipitation etc)
- the general principles of chemical equilibria
- the general principles of chemical kinetics
- the general principles of electrochemistry
- the general principles of nuclear chemistry
- the descriptive chemistry of the main groups of the PSE (block s, block p, block d)
- organic chemistry, comprising basic nomenclature, functional groups and fundamental reaction and mechanisms
- important classes of organic compounds, phenomenon of 'persisting' organic structures
- remediation strategies targeting organic pollutants

Detailed program

- The electronic structure of atoms. Bohr model, electron spin. Heisenberg principle and Schrodinger equation. Atomic orbitals.

- The periodic table and the periodic properties of the elements; ionization energies, electron affinities, polarizabilities, atomic and ionic radii.

- The chemical bond: ionic and covalent bonds. The electronic and geometrical structure of molecules; The Lewis formalism and the octect rule, resonance and hypervalent compounds, VSEPR theory. Valence bond theory, hybrid orbitals and sigma and pi bonds. Basic of molecular orbitals theory.

- Atomic and molecular mass. Concept of mole. Chemical reactions, stoichimetric coefficients and and procedures to balance a reaction. Classes of reactions. Stoichiometric calculations to determine the mass of reagents and products, limiting reactant. Reactions in aqueous solution; precipitation reactions, acid-base reactions, redox reactions. Physical and chemical modes for the expression of concentrations.

- Intermolecular interactions; dispersion interactions, dipole-dipole interactions, dipole-ion interactions, H-bonds.

- The macroscopic chemical systems and basic of thermochemistry: definition of thermodynamic state of a system, state functions. Internal energy, work, heat and the first principle of thermodynamics. Enthalpy and Hess law. Standard state of a compound, reaction and formation sthandard enthalpies.

- The states of the matter and state transformations.
  (i) The Gas state; ideal and real gases, gaseos mixtures and Dalton law. Basic on the kinetic theory of gases and Maxwell-Boltzmann equation.
  (ii) The solid state. The crystal lattice and the unit cell of a crystal.Classification of solids on the bases of their structure; ionic solids, metallic solids and band theory, covalent solids and molecular solids. Conductors, semiconductors and insulators.
  (iii) The liquid state; properties of liquids, vapor pressure and Clausius-Claypeiron equation. Phase diagrams and phase rule.

- Solutions and colligative properties of solutions; Raoult law, boiling point elevation and freezing point depression, osmotic pressure.

- Basic of chemical kinetics; reaction rate, activation energy and reaction pathways. Transition state theory,

velocity law and reaction order, Arrhenius equation, catalysis.

- The chemical equilibrium. Equilibrium constants as a function of concentrations, partial pressure and molar fractions. Equilibria in gas phase; methods to determine the amount of reactants and products at the equilibrium conditions. The LeChatelier principle and the effects on the equilibrium due to changes in the reactants and products amounts, temperature and pressure. Heterogeneous equilibria.

- Acid and base theories; Arrhenius, Brønsted and Lewis definitions of acids and bases. Water protolysis and ionic product of water. pH and methods to calculate the pH and acids and bases. Buffer solutions and their applications. Idrolysis of salts. General method for the calculation of the concentration of species in a complex aqueous solution. Acid-base titrations and indicators

- Solubility of salts and solubility product. Methods to calculate the solubility of a salt in aqueous solution. Common ion effect. Effect of pH on the solubility of a salt.

- Second principle of thermodynamics; Carnot cycle, entrophy and Gibbs free energy. Methods to determine the spontaneous direction of a reaction. statistical definition of entrophy and the Boltzmann equation.

- Electrochemistry; galvanic cells, the SHE electrode, standard reduction potentials and the Nernst equation.

- Descriptive chemistry of the main elements; hydrogen, boron, carbon, nitrogen, oxygen. silicon, sulphur, phosphorous, alluminium, alkaline- and alkaline-earth metals.

- Basics of the transition metal chemistry and coordination compounds.

- Main concepts of organic chemistry, general nomenclature aspects, recognition and typical chemistries of important functional groups, standard reaction mechanisms including polymerisation and condensation reactions, polyaromatic, polycondensed and perfluorinated compounds.

Prerequisites

- Basic physical concepts (mechanics).
- Basic mathematical concepts (algebra, exponential logarithms, trigonometry).
- Units, conversion factors and dimensional calculations.

Teaching form

- Theoretical lessons in the classroom and numerical exercises on the topics covered in the theoretical lessons:
  -> 24 two-hour lectures, in person, Delivered Didactics
  -> 12 two-hour practical classes, in person, Interactive Teaching
- The course is supported by tutoring activities, in a manner decided independently by the tutor and by the participants.

Textbook and teaching resource

- T. L. Brown, H. E. LeMay Jr., B.E. Bursten, C.J. Murphy, P.M. Woodward, M.W. Stoltzfus
  Fondamenti di Chimica
  EdiSES

- M. S. Silberberg, S. Licoccia
  Chimica. La natura moleculare della materia e delle sue trasformazioni
  McGraw- Hill

- J. C. Kotz, Paul M. Treichel, J. R. Townsend
  Chimica
  EdiSES

- C. E. Housecroft, A. G. Sharpe
  Inorganic Chemistry, 4?? edition (solo in lingua Inglese)
  Pearson

- diapositive e appunti mostrati durante le lezioni e materiale aggiuntivo su argomenti selezionati disponibili sul sito elearning della Bicocca.

Semester

I semester (october - january)

Assessment method

The exam consists of a single written test at the end of the course. There will be no mid-course exam.

The written test will consist of a maximum of 12 questions. Three of the questions must be answered in free text format and are intended to assess the student's ability to use specific professional terminology in the given context. Each question is assigned a score between 0 and 5 points; 5 points is the maximum score achievable for a single question.

Students with a score below 50% of the total achievable points have failed the exam.
Students with a score between 50% and 60% of the total achievable points must take a short oral exam, which consists of an in-depth discussion of the topics covered in the written test, to give the student the opportunity to demonstrate sufficient knowledge to pass the exam.
Students with a score higher than 60% of the total achievable points will be assigned final scores between 18 (60% of the total points) and 30/30 with honors (maximum number of points).

The final score will range from 18/30 to 30/30 with honors, based on the overall assessment, taking into account the following criteria:

1. conceptual knowledge and understanding
2. ability to apply knowledge and understanding
3. communication and argumentation skills
4. learning, self-assessment, and self-regulation skills

Grade < 18

Knowledge and Understanding: The student only partially identifies the characteristics of the concepts. The connections between the concepts are fragmented and poorly supported by theoretical knowledge.
Ability to apply knowledge and understanding: The student identifies only a few relevant elements in a phenomenon, unable to integrate them into a coherent analysis.
Communication and Argumentation Skills: In the oral exam, the student develops a basic argument, lacking logical structure and characterized by numerous expository inaccuracies.
Learning, self-assessment, and self-regulation skills: The student is able to reconstruct only some aspects of their learning and professional development journey.

Grade 18-22
Knowledge and Understanding: The student recognizes and explains most of the conceptual features and is able to provide a relatively coherent explanation, albeit with some inaccuracies. Theoretical references are present but not always rigorously.
Ability to apply knowledge and understanding: The student is able to recognize a significant number of elements and provide a partial explanation, while highlighting some gaps in the analysis.
Communication and argumentation skills: In the oral exam, the student constructs a basic argument, with a minimal structure but with some inaccuracies.
Learning, self-assessment, and self-regulation skills: The student demonstrates a basic awareness of their learning path, managing to draw essential connections between learning experiences, albeit with some inaccuracies.

Grade 23-27
Knowledge and Understanding: The student demonstrates a thorough understanding of conceptual characteristics. In the oral exam, explanations are well-articulated and supported by an appropriate use of theoretical references.
Ability to apply knowledge and understanding: The student accurately identifies the essential elements of a phenomenon. The application of knowledge occurs with methodological rigor that is not always solid.
Communication and argumentation skills: In the oral exam, the student develops a coherent and well-organized argument, demonstrating good command of language and a solid logical-argumentative structure. Communication is clear and effective.
Learning, self-assessment, and self-regulation skills: The student analyzes his or her learning journey in a clear and structured manner, highlighting significant relationships between the various developmental stages and demonstrating a good capacity for critical reflection.

Grade 28-30
Knowledge and Understanding: The student demonstrates a thorough mastery of concepts, articulating complex connections and providing comprehensive explanations. Theoretical references are used with relevance and rigor.
Ability to apply knowledge and understanding: The student demonstrates an advanced ability to analyze a phenomenon, comprehensively identifying and interpreting all salient elements. Knowledge is applied with methodological rigor, supported by solid and detailed argumentation.
Communication and argumentation skills: In the oral exam, the student develops a solid and detailed argument, with a rigorous logical structure and a high level of textual coherence. The presentation is fluent and well-structured.
Learning, self-assessment, and self-regulation skills: The student demonstrates an advanced capacity for self-reflection, developing a detailed and in-depth analysis of their learning and professional development journey. The connections between learning experiences and theoretical concepts are clear, coherent, and rigorous.

Office hours

Always, after scheduling an appointment *via* phone or e-mail.

Sustainable Development Goals

QUALITY EDUCATION | SUSTAINABLE CITIES AND COMMUNITIES | RESPONSIBLE CONSUMPTION AND PRODUCTION