UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

General and Inorganic Chemistry

2324-1-E3401Q004

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 the chemical equilibria
- chemical kinetics
- electrochemistry
- 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 (7 credits) and numerical exercises on the topics covered in the theoretical lessons (1 credits; 10 hours).
- The course is supported by tutoring activities, in a manner decided independently by the tutor and by the participants.
- In the event of a COVID-19 emergency, the course will be held through remote lessons that will be additionally recorded and uploaded to elearning.

Textbook and teaching resource

- 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 (only available in English)
  Pearson

- Slides shown during the lectures and notes as well as additional material on selected topics are available on the Bicocca elearning web-site.

Semester

I semester (october - january)

Assessment method

The final exam of the course is a single exam consisting of a written and an oral part, at the end of the course. Intermediate exams do no exist for this course.

1. The written exam consists of a maximum of 9 questions; a score between 0 and 5 points is assigned to each question, with 5 points being the maximum score that can be obtained per single question.
2. Students with a score equal to or higher than 50% of the total amount of points achievable are admitted to the oral examination, which consists in a discussion of various topics discussed during the lectures, linking concepts and findings.

In the event of a pandemic emergency, the exam will be oral only, taken on the Webex platform. In this case, the exam will start with a practical / numerical entry question aimed at verifying the acquisition of basic concepts such as nomenclature, the ability to interpret and predict chemical formulas, the ability to balance chemical equations, etc.

Office hours

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

Sustainable Development Goals

QUALITY EDUCATION