UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Geochimica

2627-2-E3402Q007

Aims

O1 – Knowledge and understanding

1. Understand the fundamental principles of Geochemistry and the role of chemical and isotopic processes in the interpretation of the main geological processes.
2. Understand the origin of elements and isotopes, their distribution in the main geochemical reservoirs and in the different geospheres, and the criteria for the geochemical classification of elements.
3. Understand chemical and isotopic fractionation processes and the significance of major elements, trace elements, and isotopic ratios as tools for reconstructing geological, hydrogeological, petrogenetic, volcanological, and geodynamic processes.
4. Understand the fundamental principles of natural radioactivity, radioactive decay, decay chains, geochronology, and the main radiometric dating methods.
5. Understand the geochemical cycles of elements in different natural environments and in the main geospheres, with particular reference to the atmosphere, hydrosphere, lithosphere, magmatic systems, and fluid systems.
6. Understand the basics of the main sampling methodologies for fluids and rocks, laboratory analytical techniques, and methods for the visualization and processing of geochemical data.

O2 – Ability to apply knowledge and understanding

1. Be able to apply the fundamental concepts of Geochemistry to the interpretation of natural processes that control the distribution of elements and isotopes in the different terrestrial reservoirs.
2. Be able to use chemical elements, trace elements, and isotopic ratios as tracers to recognize and interpret the origin of fluids, magmas, rocks, and geological processes.
3. Be able to interpret geochemical diagrams, isotopic diagrams, classification diagrams, activity diagrams, and simple quantitative representations of geochemical processes.
4. Be able to apply knowledge of radioactivity and unstable isotope systems to the understanding of the main radiometric dating methods and their geological implications.
5. Be able to reconstruct, in a basic qualitative and quantitative form, the geochemical cycles of elements and

the interaction processes between atmosphere, hydrosphere, lithosphere, and magmatic systems.
6. Be able to apply methods for the visualization and processing of geochemical data to the representation of concentrations, isotopic ratios, and relationships between geochemical variables.
7. At the end of the practical classes, be able to model a simple mixing process that includes both the concentration and the isotopic composition of an element or chemical species in nature.

O3 – Autonomy of judgement

1. Be able to critically evaluate the origin of a fluid, magma, rock, or geological process on the basis of geochemical and isotopic tracers.
2. Be able to distinguish between simple compositional descriptions and process-based interpretations, recognizing the geological significance of geochemical data.
3. Be able to assess the reliability and interpretative limits of geochemical data, taking into account fractionation, mixing, alteration, contamination, degassing, water-rock interaction, and radioactive decay processes.
4. Be able to recognize the main uncertainties associated with the use of elements and isotopes as tracers in natural processes.
5. Be able to formulate coherent interpretations by linking geochemical data, geological context, and chemical-physical processes.

O4 – Communication skills

1. Be able to describe the fundamental principles of Geochemistry using appropriate language and the specific terminology of the discipline correctly.
2. Be able to clearly illustrate the significance of major elements, trace elements, stable isotopes, radiogenic isotopes, unstable isotopes, isotopic ratios, and geochemical tracers.
3. Be able to explain the meaning of diagrams, formulas, basic quantitative relationships, and simple geochemical models.
4. Be able to argue, both orally and in writing, the interpretation of a geochemical datum or process, linking different topics of the course.
5. Be able to communicate the results of simple geochemical processing or modelling in an orderly and scientifically correct manner.

O5 – Learning skills

1. Be able to use the acquired knowledge to independently approach the study of geological, hydrogeological, petrogenetic, volcanological, geodynamic, and environmental processes in which the geochemical component is relevant.
2. Be able to integrate knowledge of chemistry, mineralogy, petrography, volcanology, hydrogeology, and general geology in order to understand the behavior of elements and isotopes in natural systems.
3. Be able to independently explore topics in isotope geochemistry, geochronology, fluid geochemistry, noble gas geochemistry, environmental geochemistry, and geochemistry of magmatic systems.
4. Be able to use textbooks, lecture notes, data, diagrams, and bibliographic resources to consolidate and update their geochemical knowledge.
5. Be able to transfer the basic quantitative and modelling knowledge acquired in the course to subsequent applications related to natural, environmental, and industrial processes.

Contents

Basic notions of Geochemistry. Notes on nucleosynthesis and cosmochemistry. Evolution of the Earth. Geochemical affinity of the elements. Geochemical spheres. Geochemistry of the atmosphere. Geochemistry of the Lithosphere. Geochemistry of magmatic volatiles. Solubility of volatiles. Magmatic degassing. Geochemistry of the

Hydrosphere. Mechanical and chemical weathering. Geochemical cycles. Stable isotope geochemistry. Geochemistry of unstable isotopes: radioactive decay and notes on geochronology. Geochemistry of radiogenic isotopes. Geochemistry of noble gases. Notes on some applications of Geochemistry. Main water, gas and rock sampling methodologies and analytical techniques. Methods of visualization and processing of geochemical data.

Detailed program

Presentation of the course. Basic notions of Geochemistry. Review of the main properties of the elements in relation to their position in the periodic table. The internal structure of atoms. Geochemical spheres.
Outline of nucleosynthesis and cosmochemistry: big bang theory. Red shift. Hertzsprung–russell diagram and stellar evolution. Formation and evolution of the solar system. Fraunhofer lines and chemical composition of the sun. Nucleosynthesis: hydrogen and helium fusion, carbon cycle. Exothermic reactions and the concept of nuclear binding energy. Endothermic reactions (neutron capture) from Iron onwards. Geochemical affinity of the elements, their influence on geochemical behavior.
Geochemistry of the atmosphere: the primordial atmosphere, genesis and evolution, concept of oxygen fugacity, the post-differentiation atmosphere of the Earth; chemical-physical properties, composition and current structure.
Geochemistry of the lithosphere. Chemical composition of the solid Earth: Core, Mantle and Crust. Genesis and properties of magmas. Magmatic differentiation. Classification of elements. Major and trace elements. Classification diagrams. Partition coefficients. Notes on experimental petrology.
Geochemistry of magmatic volatiles. Classification of magmatic, volcanic and hydrothermal gases. Solubility of volatiles in silicate melts. Magmatic degassing. Composition of volcanic gases in relation to geodynamic contexts and different mantle conditions. Volcanic gas sampling and analysis techniques. Volcanic gas sampling and analysis techniques.
Geochemistry of the hydrosphere, geochemistry of water. Chemical-physical properties of water. Unit of concentration of aqueous species. Langelier-Ludwig classification diagram. Ionic potential, residence time, conservative elements and removal mechanisms. Carbonate species in sea water. Chemical equilibria in the aqueous phase. Partition coefficients.
Weathering processes. Weathering of carbonates and aluminosilicates. Origin and structure of clays. Activity diagrams. Oxidation-reduction reactions. Eh-pH diagrams. Water sampling techniques and measurement of chemical-physical parameters.
Geochemistry of stable isotopes (H, O, C, N, S). Delta notation, fractionation and enrichment factor. International standards. Isotope fractionations. Evaporation and condensation process: the example of oceans and rain. Isotopic composition of precipitation, global meteoric line. Notes on the geochemical cycles of some elements. Use of isotopes in Paleoclimatology. Isotopic geothermometry. Composition of nitrogen within its (bio)geochemical cycle. Stable isotopes in the mantle and magmatic systems.
Geochemistry of unstable isotopes. Definition of radioactivity. Nuclide map. Radioactive decay mechanisms and main decay chains. Law of radioactive decay and basic equation of geochronology. The half-life. Main geochronological methods. The isochrone method. Geochemistry of radiogenic isotopes as petrogenetic tracers.
Geochemistry of noble gases. Properties of noble gases and historical notes. Noble gases in the atmosphere. Partition coefficients. Sampling methods for various matrices that can be analyzed for noble gases and analytical techniques. Classification into the main geochemical reservoirs and geospheres.
Methods of visualization and processing of geochemical data.

Prerequisites

Chemistry

Teaching form

Total hours: 68
28 two-hour lectures delivered in person
2 three-hour laboratory activities conducted interactively in person
2 three-hour practical sessions conducted interactively in person

Textbook and teaching resource

Slides provided during the lessons

BOOKS
W.M. White, Geochemistry
McSween H.Y., Richardson S.M. Jr., Uhle M.E., Geochemistry (Pathways and Processes)
Longinelli A., Deganello S., Introduzione alla Geochimica
J. Hoefs, Stable isotope Geochemistry
Walker M., Quaternary Dating Methods, Wiley
Porcelli, D., Ballentine, C.J. and Wieler, R. (2002). An introduction to noble gas geochemistry and cosmochemistry. Reviews in Mineralogy and Geochemistry, 47: 1-18.

FURTHER INSIGHTS
Faure G. (1998), Principles and Applications of Geochemistry
Krauskopf K.B. & Bird, D. K., Introduction to Geochemistry, 1995. McGraw-Hill International Editions.
Ozima M. & Podosek F.A. (2002), Noble Gas Geochemistry, Cambridge University
Burnard P., The Noble Gases as geochemical tracers, Springer
Dongarrà G. & Varrica D. (2004) “Geochimica e ambiente” EDISES
C.J. Allègre, Isotope Geology

Semester

II year, II semester

Assessment method

The assessment of learning includes a final examination divided into two parts:

1. a prerequisite written test;
2. an oral examination.
   Both parts are assessed out of thirty.

Written test
The written test is a prerequisite for access to the oral examination. Its purpose is to assess the acquisition of basic knowledge, the ability to apply the fundamental concepts of Geochemistry, and the ability to use appropriate scientific language.
The written test will consist of a maximum of 20 questions, including:

- multiple-choice questions;
- short open-answer questions;
- possible exercises or interpretative questions based on formulas, diagrams, or simple geochemical case studies.

  The multiple-choice questions will mainly be aimed at assessing knowledge of fundamental concepts, definitions, and main relationships. The open-answer questions will be aimed at assessing the ability to argue, connect different topics of the course, and correctly use geochemical terminology.

  The written test is assessed out of thirty. In order to access the oral examination, students must obtain a mark equal to or higher than 18/30 in the written test. Students who obtain a mark lower than 18/30 in the written test cannot take the oral examination in the same examination session.

Oral examination
The oral examination consists of an interview on the topics covered during the course. The examination consists of no fewer than three open questions. The instructor will assess knowledge and depth of understanding of the concepts, the ability to connect topics, clarity of exposition, and the use of language appropriate to the subject.
The oral examination is assessed out of thirty.
Formulation of the final mark: indicatively, the final mark will be determined as the average between the mark obtained in the written test and the mark obtained in the oral examination, with the possibility for the examination board to adjust the final assessment on the basis of the overall quality of the oral examination, the ability to connect topics, and the scientific maturity demonstrated by the candidate.

Grade < 18
Knowledge and understanding: The student only partially identifies the characteristics of the concepts. Connections between concepts are fragmentary and poorly supported by theoretical knowledge.
Ability to apply knowledge and understanding: The student identifies only some relevant elements in a phenomenon, without being able to integrate them into an organic analysis.
Communication and argumentation skills: In the oral examination, the student develops an essential argument, lacking logical articulation and characterized by numerous inaccuracies in exposition.
Learning, self-assessment, and self-regulation skills: The student is able to reconstruct only some aspects of their own learning and professional development path.

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

Grade 23–27
Knowledge and understanding: The student demonstrates an in-depth understanding of the conceptual characteristics. In the oral examination, the explanations are well articulated and supported by 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 takes place with methodological rigor that is not always fully solid.
Communication and argumentation skills: In the oral examination, 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 their own learning path in a clear and structured way, highlighting significant relationships between the different stages of development and demonstrating good critical reflection skills.

Grade 28–30
Knowledge and understanding: The student demonstrates complete mastery of the concepts, articulating complex connections and providing comprehensive explanations. Theoretical references are used appropriately and rigorously.
Ability to apply knowledge and understanding: The student demonstrates an advanced ability to analyze a phenomenon, identifying and interpreting all the salient elements in a comprehensive way. The application of knowledge takes place with methodological rigor, supported by a solid and articulated argument.
Communication and argumentation skills: In the oral examination, the student develops a solid and articulated argument, with a rigorous logical structure and a high level of textual coherence. The discourse is fluent and well structured.
Learning, self-assessment, and self-regulation skills: The student demonstrates an advanced capacity for self-reflection, producing an articulated and in-depth analysis of their own learning and professional development path. The connections between educational experiences and theoretical concepts are clear, coherent, and rigorous.

Office hours

To make an appointment, please write to andrealuca.rizzo@unimib.it

Sustainable Development Goals