1	**Course title**	Geochemistry
2	**Course number**	0345751
3	**Credit hours (theory, practical)**	3 credit hours
	Contact hours (theory, practical)	15:30 – 17:00 Sunday and Tuesday
4	**Prerequisites/co requisites**	B.Sc. in Geology
5	**Program title**	M.Sc. in Geology
6	**Program code**	
7	**Awarding institution**	The University of Jordan
8	**School**	School of Science
9	**Department**	Geology Department
10	**Level of course**	
11	**Year of study and semester (s)**	Spring 2023/2024
12	**Final Qualification**	
13	**Other department (s) involved in teaching the course**	none
14	**Language of Instruction**	English
15	**Date of production/revision**	January 2024

16. Course Coordinator: Prof. Dr. Ghaleb H. Jarrar

Office numbers, office hours, phone numbers, and email addresses should be listed.

G 214; 5255000, ext 22273, jarrargh@ju.edu.jo

17. Other instructors:

Office numbers, office hours, phone numbers, and email addresses should be listed.

None

18. Course Description:

As stated in the approved study plan with some modifications

"An introduction to cosmochemistry including the origin of the universe, stars and solar system. Overview of the chemistry of geological processes in aqueous environments. Includes review of thermodynamics, chemical kinetics, phase equilibrium, mineral solubility, mineral stability diagrams. Introducing the concept of mixing and dilution. Overview of isotopes with geologic examples. Application of geochemistry to the solution of global problems. Geochemical cycles. Organic geochemistry"

Detailed description

The term ***geochemistry*** was first introduced by the Swiss chemist **Schönbein** in 1838. It is principally a link between geology and chemistry. In geochemistry, we use the tools of chemistry to solve geological problems, i.e the use of chemistry to understand the Earth and how it works. Since the Earth has been formed as part of a family of heavenly bodies, our solar system, the role of geochemistry extends beyond the Earth to include the whole solar system. The fields of geochemistry are so broad that it is almost impossible to be mastered by anyone. Therefore, geochemists specialize in one or few topics such as, geochemical thermodynamics, atmospheric chemistry, isotope geochemistry, marine geochemistry, trace elements geochemistry, etc.

The study of Earth systems has in the last two decades become more environmentally oriented and quantitative in nature. Thermodynamics form the basis of modern quantitative geochemistry.
This course assumes a modest knowledge of the principles of geochemistry that are usually covered in an introductory course. Therefore, it will concentrate on a detailed treatment of some applications of geochemistry in addition to introducing new topics that are not covered in a standard introductory course.

19. Course aims and outcomes:

A- Aims: Apply the chemical principles on Earth materials (rocks, water, atmosphere) to understand processes acting on the Earth's surface and inside the Earth itself. B- Intended Learning Outcomes (ILOs): Upon successful completion of this course students will be able to Apply the principles of chemical thermodynamics to evaluate mineral and rock forming processes.
Apply chemical principles on solutions and their role in mineral forming process
Understand the role of aqueous solutions in processes like chemical weathering and the formation of chemical sediments
Use of geochemical to tackle environmental issuess
Use geochemical data of igneous rocks to fully interpret the petrogenesis of a given igneous suite.

20. Topic Outline and Schedule:

Topic	Week	Instructor	Achieved ILOs	Evaluation Methods	Reference

1. The Earth's Aggregate physical and chemical state.
- Cosmic element abundances and meteorites.
- Composition of Earth principal solid layers
- Pressure and temperature in the Earth and heat flow.

2. Geochemical thermodynamics.
- Thermodynamic systems, internal energy (U), enthalpy (H), entropy (S) and laws of thermodynamics,
  heat capacity (C).
- Gibbs Free energy (G) , fluids, changes of G with P and T.

3. **Solutions**
- Chemical potential, mixing, G of mixtures, real mixtures, G of aqueous solutions, ionic strength
- Activity of ionic species, phase relations in mixtures

4. Mineral Chemistry
- Mineral stability, structure of silicates, polymorphism
- Chemical variability of minerals, solid solutions

5. Aqueous solutions (aqueous geochemistry)
- Acids and bases, pH, alkalinity
- Chemical weathering and mineral stability
- Solubility of rock forming minerals (silicates and carbonates)
- Diagenesis

6. Water Chemistry
- Rain water, river water, seawater.
- Carbonate saturation, evaporation of seawater, sea floor hydrothermal systems
- Groundwater, lakes.

7. Chemistry of Igneous rocks
- Chemical variability of igneous rocks; magma characteristics and water in magma, melting of rocks
- Phase diagrams
- Trace elements in igneous processes

8. Chemistry of sedimentary and metamorphic rocks
- Soil formation, diagenesis
- Metamorphism and hydrothermal ore deposits.
- Diffusion, advection
- Fluid flow
- Metamorphism, ore deposits and rock alteration.

9. **Radioactive isotope geochemistry**
   - Radioactive decay and decay-time equation
   - Isochrons and representative isotopic systems (e.g., Rb/Sr, Sm/Nd)
   - U-Th-Pb systems and concordia diagrams
   - Other methods

10. Stable Isotope Geochemistry
   - Fractionation mechanisms, mathematical notations (α, δ etc)
   - Use of stable isotopes in water-rock interaction
   - Representative stable isotope systems

11. Surface Sorption geochemistry
   - Thermodynamics of surfaces
   - Silicates and aluminum surfaces
   - Surface charge measurements
   - Alumino-silicates surface charge
   - Metal ion adsorption, colloids
   - Hydrophobic sorption.

12. Chemical kinetics
   - First-order decay and growth equations
   - Elementary reactions
   - Temperature dependence of rates
   - Diffusion and autocatalytic processes.
   - Solid fluid reactions and feldspar dissolution in H2O
   - Relative rates of silicate dissolution
   - Nucleation, surface reactions, rates of material transport, transport by fluid flow.

13. Redox Reactions
   - Gibbs Energy of redox reactions
   - Eh-pH diagrams, Eh of natural waters
   - Eh-pH in sedimentary fluids
   - Oxygen fugacity diagrams

14. Organic Geochemistry
   - Organic chemistry nomenclature
   - Organic carbon in natural waters
   - Diagenesis of organic material
   - Hazardous organic compounds.

15. Atmospheric Chemistry.
   - Early Earth atmosphere and ocean
   - Present composition of the atmosphere
   - Reactions in the atmosphere
   - Free radicals
   - Geochemical Cycles.

21. Teaching Methods and Assignments:

Development of ILOs is promoted through the following teaching and learning methods: Lectures, problem solving, interpretation of real data sets, evalution of relevant literature

22. Evaluation Methods and Course Requirements:

Opportunities to demonstrate achievement of the ILOs are provided through the following assessment methods and requirements:

23. Course Policies:

A- Attendance policies: University regulations apply B- Absences from exams and handing in assignments on time: University regulations apply C- Health and safety procedures: Not applicable D- Honesty policy regarding cheating, plagiarism, misbehavior: University regulations apply E- Grading policy: F- Available university services that support achievement in the course:

24. Required equipment: (Facilities, Tools, Labs, Training….)

None

25. References:

Required book (s), assigned reading and audio-visuals:

Textbook : The material to be discussed in this course will mainly follow the scheme given in the book:

Essentials of Geochemistry

By John Walther, second edition 2009. Jones and Bartlett, 797 pages.

Recommended books, materials, and media:

McSween et al. 2003. Geochemistry: Pathways and Processes.
G. Faure (1998): Prinicples and Applications of geochemistry.
W. White: 2012. Geochemistry: Wiley-Blackwell.
K. Misra. 2012. Introduction to Geochemistry, principles and applications. Wiley-Blackwell.
Krauskopf & Bird (1995): Introduction to geochemistry. 3rd edition. McGraw-Hill
Greg Anderson (2005): Thermodynamics of natural systems. Cambridge.
Nordstrom, D and Munoz J. (1994). Geochemical Thermodynamics.
David Waltham (2000). Mathematics : A simple tool for Geologists. Blackwell Publishing Company.
Brownlow (1996). Geochemistry, 2nd edition , Prentice Hall, 580 pp.

26. Additional information:

Grading scheme: The final grade will be based on:

1. Problem sets
2. Three exams including the final exam.

Homeworks and additional data and reading assignments will be uploaded on the webpage of this course on the E-Learning.

Name of Course Coordinator: Prof. Dr. Ghaleb H. Jarrar Signature: ***JARRAR*** Date: January 2024
Head of curriculum committee/Department: ---------- Signature: ----------

Head of Department: ---------- Signature: ----------

Head of curriculum committee/Faculty: ---------- Signature: ----------

Dean: ---------- -Signature: ----------