Academic Year	2023/2024	**Semester**	1
Course Coordinator	Associate Professor WANG Xianfeng		
Course Code	ES3003		
Course Title	Introduction to Geochemistry		
Pre-requisites	ES1003 E2S2 Solid Earth		
No of AUs	3		
Contact Hours	Lectures: 26 hrs. Tutorials and lab activities: 13 hrs. TOTAL = 39 hrs.		
Proposal Date	14 July 2023		

Course Aims

This course is designed to introduce you the principles of chemistry related to geology and their applications to understand processes taking place on and within the Earth. The aim is to provide you with a powerful toolbox and the related skills, more than a static bank of knowledge. You will become familiar with the principles of geochemistry, including analytical chemistry, governing equations and typical applications in the Earth Systems Sciences (e.g., atmosphere, hydrosphere, biosphere, solid earth, anthroposphere). You will learn to organize and present geochemical data, including writing a report on a problem of your choice. With this set of tools and knowledge, you will have the mind skills and technical know-hows to answer a range of practical problems, including some that may not have been addressed in the class.

Intended Learning Outcomes (ILO)

By the end of this course, you (as a student) would be able to:

1. Become familiar with the basic principles and tools of geochemistry;
2. Practice problem solving with application of governing equations to investigate main geochemical processes;
3. Formulate questions about the dynamics within Earth System Sciences;
4. Develop intellectual flexibility and critical thinking to identify the most useful geochemical tool to address some geological and environmental problems;
5. Perform geochemical research which involves hands-on acquisition, data analysis and interpretation;

Course Content

This course is divided into two parts:

In Part (i) lecture classes, you will be introduced to the basic principles and tools of geochemistry. You will learn about the large scale processes occurring in the geosphere, hydrosphere, biosphere, atmosphere and anthroposphere on the Earth, using major and trace element geochemistry, and stable and radiogenic isotopes. You will also learn processes such as element and isotope fractionation, element transport and mixing as well as radiogenic isotopes and their application for geochronological purposes.

In Part (ii) tutorial classes and individual time, you will work closely with our research fellows and undertake hands-on data collection via geochemistry analytical instruments and data analysis.

Assessment (includes both continuous and summative assessment)

Component	Course LO Tested	Related Programme LO or Graduate Attributes	Weighting	Team/ Individual	Assessment Rubrics
1. Research project report	1, 3, 4, 5	Knowledge, Intellectual flexibility and critical thinking, problem solving, passion and communication	40%	Individual	10-15 page long research writing based on geochemistry research project conducted See Appendix 3 for details
2. Group project Presentations	1, 3, 4, 5	Intellectual flexibility and critical thinking, formulating questions, passion and communication	30%	Group	20-minute oral presentation + Questions and answers See Appendix 2 for details
3. Weekly assignments	1, 2, 4	Knowledge, Intellectual flexibility and critical thinking, formulating questions, and problem solving	30%	Individual	Weekly assignments See Appendix 1 for details
Total			100%		

Formative feedback

Following tutorial classes, you will receive direct written feedback (normally in a week) on your weekly assignments. In this way the lecturer and you can monitor progress. You will also be given written feedback on your group projects.

Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
Lecture	Lectures will pass on the theoretical knowledge required to understand the different components of principles and tools of geochemistry.
Tutorial and Research activities	Tutorial sessions will introduce you to the principles of individual geochemical instruments. You will also get hands-on research experiences on these instruments with peers, and work with experts in the field.

Reading and References

This is course aims to encourage you to think critically, and solve practical problems with a series of tools. The following books will be used as the main references/textbooks:

1- White, W.M. (2013) *Geochemistry.* Wiley-Blackwell. 1st edition, 660pp. ISBN: 978-0-470-65668-6;

2- Albarede F. (2009) Geochemistry: An Introduction. Cambridge University Press. 2nd edition, 342pp. ISBN: 978-0-521-7069-3.

3- Van Loon G.W. and Duffy, S.J. (2017) Environmental Chemistry: A Global Perspective. Oxford University Press. 4th edition, 585pp. ISBN: 978-0-19-874997-4.

4- Jacob D.J. (1999) Introduction to Atmospheric Chemistry. Princeton University Press.

Course Policies and Student Responsibilities

(1) General

You are expected to complete all assigned readings and activities, attend all classes punctually and take all scheduled assignments, reports and tests by due dates. You are expected to take responsibility to follow up with course notes, assignments and course related announcements for seminar sessions they have missed.

(2) Absenteeism

In-class activities make up a significant portion of your course grade. Absence from class without a valid reason will affect your overall course grade. Valid reasons include falling sick supported by a medical certificate and participation in NTU's approved activities supported by an excuse letter from the relevant bodies.

Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email
WANG Xianfeng	N2-01B-26	6592-2614	xianfeng.wang@ntu.edu.sg

Planned Weekly Schedule

Week	Topic (Lecture / Practical)	Course LO	Readings/ Activities
1	Universe, element formation, Earth	1, 2, 4	White: Chap. 10; Albarede: Chap. 1, 12
2	Basic thermodynamics	1, 2, 4	White: Chaps. 2, 4
3	Kinetics and fluxes	1, 2, 4	White: Chap. 5; Albarede: Chap. 1, 12
4	Radiogenic isotopes and geochronology	1, 2, 4	White: Chap. 8; Albarede: Chap. 4
5	Major stable isotopic systems	1, 2, 4	White: Chap. 9; Albarede: Chap. 3
6	Earth's differentiation, magmatic rocks	1, 2, 4	White: Chap. 7; Albarede: Chap. 2
7	Medical and forensic geochemistry	1, 2, 4	White: Chap. 9; Albarede: Chap. 13
Recess			
8	Aquatic geochemistry, element source and sinks	1, 2, 4	White: Chap. 6; Albarede: Chap. 7; Duffy: Chap. 9
9	Carbonate equilibria	1, 2, 4	White: Chap. 6; Albarede: Chap. 9; Duffy: Chap. 11
10	Atmospheric geochemistry, gas species and radiative balance of the Earth	1, 2, 4	Duffy: Chap. 8; Jacob: Chap. 7
11	Photochemistry of atmospheric gas species	1, 2, 4	Duffy: Chap. 3; Jacob, Chap. 9, 10
12	Oxidation-reduction geochemistry	1, 2, 4	White: Chap. 3; Albarede: Chap. 7
13	Research project presentations	1, 3, 4, 5	

Appendix 1: Assessment Criteria for Homework Assignments

Standards	Criteria
A+ to A-	Takes an original approach to the questions, very well structured and focused, and does not deviate from the given question; evidence of excellent ability to apply knowledge taught in the course while thinking outside the box; evidence of deep understanding and not just memorization of key concepts taught in the course.
B+ to B-	Takes a conventional approach to the question, has evidence of structure and focus, and is mostly on-topic; evidence of some ability to apply knowledge taught in the course; some evidence of understanding and not just memorization of key concepts taught in the course.
C+ to C	Takes a conventional (though somewhat unoriginal) approach to the question, has some evidence of structure and focus, and does not deviate substantially from the topic; evidence of some (but not significant) ability to apply knowledge taught in the course; some familiarization of key concepts taught in the course but evidence of deep understanding is limited.
D+ to D	Does a poor to middling job of addressing the question, has limited structure and focus, and frequently strays off topic; limited evidence of ability to apply knowledge taught in the course; limited familiarization of key concepts taught in the course.
F	Inadequate in addressing the question, lacks structure and focus, and is mostly or wholly off topic; inadequate capacity to apply knowledge taught in the course; poor familiarization of key concepts taught in the course. OR failure to submit homework assignments.

Appendix 2: Assessment Criteria for Group Project Presentations

Standards	Criteria
A+ to A-	Demonstrate complete understanding of their project. Connect to the topics covered to solve the problems at hand based on principles and tools of geochemistry. Demonstrate intellectual flexibility and critical thinking, and independently evaluate data quality. Clear description, interpretation and explanation of research process and findings. Convey the problematics and outcomes of their project with clarity and fluency.
B+ to B-	Demonstrate good understanding of their project. Connect to the topics covered and solve most problems. Demonstrate intellectual flexibility and independent thinking and evaluation on research data. Can convey the problematics and outcomes of their project.
C+ to C	Demonstrate incomplete understanding of their project. Partly connect to the topics covered and solve only few problems. Present thinking and evaluation on research data. Incompletely convey the problematics and outcomes of their project.
D+ to D	Demonstrate only basic understanding of their project and lack solution for it. Present some evaluation on research data. Confuse in conveying the problematics of their project.
F	Lack understanding of their project. Cannot convey the problematics.

Appendix 3: Assessment Criteria for Individual Project Report

The individual research report should be ~10 pages (not counting references, but can include figures/tables), double spaced in times font and should include ~15 references. The report will be evaluated using the following rubric.

Standards	**Criteria**
A+ to A-	Clarity: The writing is clear and presented with a strong, coherent, and compelling voice; Structure and information: Presents a focused argument that message that presents intricacies of the science, evaluates them, and offers insightful opinions; Context: Offers a detailed context for the topic that fluidly integrates course themes and language; Evidence: Offers multiple lines of evidence informing the topic and evaluates the merit of their contribution; Sources: Expertly sourced references that include seminal articles that are relevant to the topic being presented.
B+ to B-	Clarity: The writing is clear and is presented with a strong, coherent voice; Structure and information: Presents a focused message that considers alternative opinions and evaluates them; Context: Offers a detailed context for the topic being presented that correctly uses course terms and language; Evidence: Offers multiple lines of evidence and relates them to the topic; Sources: Entirely sourced references that are mostly relevant to the topic being presented.
C+ to C	Clarity: The writing is clear but may contain a few errors that do not detract from the argument; Structure and information: Presents a simple, but focused, message with a clear motivation; Context: Offers a simple context for the topic being presented that uses course terms and language; Evidence: Offers multiple lines of evidence for claims; Sources: Mostly sourced references that are mostly relevant to the topic being presented.
D+ to D	Clarity: The writing is mostly clear but contains a few errors that detract from the argument; Structure and information: Presents a low-level of information with a single point which may wander or not have a message; Context: Offers a simple context for the topic being presented; Evidence: Offers a single line of evidence for claims; Sources: Mostly sourced references.
F	Clarity: Writing is unclear or does not address the assignment; Structure and information: Does not present a clear, logical structure; Context: Does not provide context for the message being presented; Evidence: Does not provide evidence for claims; Sources: Unsourced references.

Appendix 4: ASE Learning Outcomes

At the completion of your course of study in ASE, you will be able to:

1) Apply environmental knowledge and concepts to make sound decisions

- Interpret evidence to give sound environmental advice to stakeholders
- Give advice to industry regarding existing environmental legislation
- Synthesise the views of key stakeholders to make decisions involving environmental issues

2) Demonstrate intellectual flexibility and critical thinking

- Demonstrate intellectual flexibility to view environmental issues from multiple perspectives
- Question assumptions behind current ways of solving environmental problems
- Show willingness to adopt new ways of approaching environmental problems.

3) Demonstrate passion and use advanced communication skills to share that passion

- Learn independently and then share that knowledge with others
- Effectively communicate environmental concepts in writing
- Effectively communicate environmental concepts in speech
- Effectively communicate environmental concepts in various forms of media such as data visualisation, diagrams, animation, video, or podcasts

4) Formulate key scientific questions and develop hypotheses

- Research and formulate questions involving environmental issues
- Express and explain why these questions are important
- Create and evaluate hypotheses to research such questions

5) Conduct research

- Search for relevant scientific literature
- Interpret scientific literature
- Synthesize findings from scientific literature into current laboratory or field work
- Make first-hand observations in order to draw conclusions

6) Solve environmental problems

- Solve environmental problems systematically
- Solve environmental problems creatively
- Solve environmental problems reflexively
- Express and explain why the problems are important

7) Synthesize interdisciplinary approaches to solving problems

- Apply techniques from disciplines beyond your own field to solve environmental problems
- Express and explain how a problem solving approach may impact the environment
- Express and explain how an approach to solving an environmental problem may impact human society

8) Demonstrate the willingness and skills for lifelong learning

- Demonstrate good observation skills and a curiosity about the world
- Demonstrate critical thinking skills such as analysis, discrimination, logical reasoning, prediction and transforming knowledge

9) Demonstrate ethical values

- Use knowledge and skills to contribute to the world
- Debate the ethical implications of scientific processes and results
- Respect regulations involving plagiarism and copyright
- Respect requirements regarding confidentiality, data protection, conflict of interest, and falsification of data

10) Demonstrate collaboration and leadership skills

- Learn collaboratively and be willing to share expertise with peers
- Demonstrate leadership of small teams