

## Syllabus (*draft*) for Earth Sciences 4431a (v. 1.0, Public Version, June 19, 2024)

### 1. Course Information

#### Earth Sciences 4431a. Stable Isotope Geochemistry in Earth & Environmental Sciences

- Fall Term
- In person

#### List of Prerequisites

- Earth Sciences 2230A/B or 3341A/B or completion of any 2000 level half-course in Chemistry; or registration in the third or fourth year of an Environmental Sciences module; or permission of the Instructor/ Department/Faculty.
- Unless you have either the requisites for this course or written special permission from your Dean's Designate (Department/Program Counsellors and Science Academic Counselling) to enroll in it, you may be removed from this course and it will be deleted from your record. This decision may not be appealed. You will receive no adjustment to your fees in the event that you are dropped from a course for failing to have the necessary prerequisites.

### 2. Instructor Information

- Instructor: Fred J Longstaffe, Dept. Earth Sciences, [flongsta@uwo.ca](mailto:flongsta@uwo.ca)
- Graduate Teaching Assistant: [To be announced](#)
- Students must use their Western (@uwo.ca) email addresses when contacting their instructors.
- Weekly office hours with Graduate Teaching Assistant:
  - [To be announced](#); format virtual
  - [To be announced](#); format in personWhen known, details will be provided via the OWL Brightspace course site.
- office hours with Fred – always welcome but by appointment  
Contact [flongsta@uwo.ca](mailto:flongsta@uwo.ca) to arrange.

### 3. Course Syllabus, Schedule, Delivery Mode

*Lay Summary:* You will learn that you are what you eat – isotopically. You will learn that your hair and teeth retain isotopic signals of where you have lived. You will learn that it is not all about you. Minerals have a history too, and you will learn how to decode that history using stable isotopes, in terms of temperatures and fluids involved in mineral formation. You will learn what sorts of water-rock-organic interaction might make you rich and at what cost to Earth. Stable isotopes hold the key to understanding much of past climate change, paleo-ecological shifts and extinctions. You will learn to think like an *Isotopist*. Your life will never be the same thereafter.

*Technical Summary:* Atoms of many elements come in different varieties known as isotopes. Isotopes of an atom have the same number of protons and electrons, but a different number of neutrons. Stable isotopes of an atom do not decay to form another element. Because of the difference in mass arising from different numbers of neutrons, stable isotopes of a given element behave (“fractionate”) in slightly different ways during reactions such as (i) evaporation of water, (ii) carbon dioxide fixation during photosynthesis, (iii) crystallization of a magma, and (iv) transfer of a donut’s isotopic signature to your fingernails and hair. This course addresses the principles governing the fractionation of stable isotopes, and focuses on how the stable isotopes of oxygen, hydrogen, carbon, nitrogen and sulphur allow us to trace interactions within the atmosphere-hydrosphere-biosphere-lithosphere Earth System.

### Learning Outcomes

Upon successful completion of this course students will be able to:

1. Use the oxygen- and hydrogen-isotope compositions of water to determine its source and the hydrological processes that have shaped the water’s isotopic composition, as evaluated through assignments, tests and written examination
  2. Identify the sources (mantle, crust) that have contributed to magma generation, and recognize the nature of rock-water interaction that may have affected an igneous rock after its crystallization, as evaluated through assignments, tests, and oral and written examinations
  3. Calculate the stable isotope fractionation factor between two phases (e.g., mineral and water), use these data to establish whether the system is in equilibrium, and for equilibrium systems, determine the temperature at which equilibration occurred, as evaluated through assignments, a written test, interview and written examination
  4. Use the oxygen- and hydrogen-isotope composition of clay minerals to determine conditions of weathering and hydrothermal alteration, and interpret these results within the larger framework of diagenesis, ore mineralization and / or climate change over Earth history, as evaluated through assignments, a written test, interview and written examination
  5. Identify photosynthetic pathways in vegetation using stable carbon-isotope compositions, recognize land use changes based on stable carbon-isotope compositions of organic matter, and determine the diet and trophic level of animals based on the stable carbon- and nitrogen-isotope compositions of their tissues, as evaluated through a written test, interview and written examination
  6. Use the stable carbon- and oxygen-isotope compositions of Earth’s biosphere, atmosphere and hydrosphere to identify changes in Earth’s carbon and water cycles at geological and Anthropocene time-scales, as evaluated through a written test, interview and written examination
  7. Devise methods using light stable isotope signatures to trace Earth System interactions across the lithosphere, pedosphere, hydrosphere, biosphere and atmosphere continuum, as evaluated through interview and written examination.
- Classes are in person

*This vast amount of space is reserved for  ${}^2\text{H}^{16}\text{O}^{15}\text{N}^{238}\text{U}^3\text{H}^{32}\text{S}$   
(First one to solve the riddle and tell Fred by e-mail gets 1 bonus mark)*

## Course Outline

This outline is a guide only. *Stable Isotope Science* is a dynamic tool applied to research and scholarship in many different fields. Course content may change depending on class feedback and current topics. If you have interest in a subject not covered here, please contact Fred.

### **1. Introduction**

Importance to earth and environmental sciences, isotopes of interest, some general principles, the atom, chart of the nuclides, atomic mass units, atomic weight, binding energy, nuclear stability, abundance of the elements in the solar system, brief history of stable isotope geochemistry, definitions ( $\delta$ ,  $\alpha$ ,  $10^3 \ln \alpha$ ,  $\Delta$ ), standards, introduction to analytical methods and instruments (extraction techniques, mass spectrometry), virtual laboratory tour.

### **2. Stable isotopes in the atmosphere and hydrosphere**

Equilibrium fractionation of isotopes, kinetic processes, O and H isotopes in water and water vapour, Rayleigh distillation, Global Meteoric Water Line, kinetic isotope fractionation and  $d$ -excess, evaporation line, regional effects (latitude, altitude, continentality, temperature, precipitation amount), Kuhn, in-cloud processes and O and H isotopes of precipitation, shallow ground water, atmospheric oxygen and carbon dioxide, juvenile water, geothermal water, rock-water ratio, oceanic pore water, formation water, brines (SW Ontario examples), ocean water (salinity, evaporation, dilution, ice-cap effects, ocean currents, climatic effects), snow and ice, marine paleoclimate reconstruction (ice cores, marine foraminifera), terrestrial and lacustrine paleoenvironmental reconstruction (speleothems, mammalian teeth and bones, ostracodes, diatoms), plant phytoliths, tree rings.

### **3. Stable isotopes in igneous rocks**

Introduction to igneous rocks, oxygen reservoirs (water, sediments, mantle and derivative rock types), mineral ordering, fractional crystallization, O-isotope geochemistry of granitoid rocks (normal  $^{18}\text{O}$ , low- $^{18}\text{O}$ , meteoric water interaction, high  $^{18}\text{O}$ , role of sediments, isotopic exchange with country rocks), O-isotope geothermometry, high temperature concordancy, retrograde isotopic exchange and disequilibrium, Pegmatite Paradise; meteorites, mass independent fractionation.

### **4. Stable isotopes in sedimentary rocks, weathering and diagenesis**

Chemical sediments (carbonate, chert), clastic sediments, submarine weathering (halmyrolysis), O-isotope composition of the ocean through time and its significance, clay mineral structures, controls on clay mineral isotopic compositions during weathering and diagenesis, clay isotope geothermometry, O- and H-isotope variation in soil and weathering clays.

### **5. Stable carbon and nitrogen isotopes in organic matter**

Introduction to stable C isotopes on Earth, photosynthesis ( $\text{C}_3$ ,  $\text{C}_4$ , CAM and aquatic plants), C-isotope fractionation during photosynthesis (diffusive, enzymatic), fractionation during organic synthesis, C-isotope behaviour during vegetation shifts and climate change, isotopic alteration of soil organic matter (oxidation, microbial), humic substances, tracking carbon storage in soils (Maya examples), N-isotope variations in air, soil, plants and animals, diet and paleodiet (collagen,

structural carbonate in bioapatite, keratin), C- and N- isotope trophic effects, food webs, N-isotope baselines, *are you what you eat?*

## 6. Stable carbon isotopes in the carbon cycle

Carbon cycle (long- versus short-term), carbon reservoirs ( $\delta$  and fluxes), long-term carbon cycle, carbonates, equilibrium C-isotope fractionation, vital effects, coal, petroleum, natural gas, biogenic methane, tracing hydrocarbon leaks, short-term carbon cycle (atmospheric CO<sub>2</sub>, atmosphere-biosphere-hydrosphere transfer, ice-cores, biological pump, ocean productivity), Phanerozoic C-isotope secular variations (atmospheric oxygen, extinction events, Strangelove Ocean, PETM), Earth C-isotope budget.

## 7. Sulphur isotopes

Introduction to S isotopes, fractionation in abiotic and biotic systems, Rayleigh distillation, Recent sediments, ocean water, secular variation, atmospheric sulphur, petroleum, coal, S isotopes as a tracer (petroleum migration, air pollution), mass independent S-isotope fractionation, S isotopes in ore deposits, crystal chemistry and bond-strength controls on S isotopic fractionation, speciation effects on sulphur isotopic compositions ( $f[O_2]$  and pH), comparison with C-isotope system.

## 8. Thinking like an Isotopist

### Key Sessional Dates:

Classes begin: Friday, September 6, 2024

National Day for Truth and Reconciliation (no class): Friday, September 30, 2024

Reading Week (no classes): Saturday, October 12, 2024 to Sunday, October 20, 2024

Classes end: Friday, December 6, 2024

### **Contingency plan for an in-person class pivoting to 100% online learning**

Although the intent is for this course to be delivered in person, should any university-declared emergency require some or all of the course to be delivered online, either synchronously or asynchronously, the course will adapt accordingly. The grading scheme will **not** change. Any assessments affected will be conducted online as determined by the course instructor.

## 4. Course Materials

- Text Book: Sharp, Z. (2<sup>nd</sup> Edition) Principles of Stable Isotope Geochemistry, Electronic Edition.

*You can obtain a copy at **no cost** from: [csi.unm.edu](http://csi.unm.edu) under the web site's publications tab.*

There are assigned readings from this textbook associated with most lectures.

- As needed, other materials for this course will be placed on-line on OWL: <http://owl.uwo.ca> .
- Students are responsible for checking the course OWL site ( <http://owl.uwo.ca> ) on a regular basis for news and updates. This is the primary method by which information will be disseminated to all students in the class.

- All course material will be posted to OWL: <http://owl.uwo.ca> .
- If students need assistance with the course OWL site, they can seek support on the OWL Help page. Alternatively, they can contact the Western Technology Services Helpdesk. They can be contacted by phone at 519-661-3800 or ext. 83800.

### Technical Requirements (*only in case of shift to on-line status*)

- Computer and stable internet connection
- If possible, computer with working microphone and/or webcam
- Patience

## 5. Methods of Evaluation

The overall course grade will be calculated as listed below:

Assignments (5)	20 %
Midterm Test	30 %
Interview	15 %
Final Examination	35 %

- Assignments and their due dates will be delivered and received via OWL. Normally one week is allowed to complete each assignment. For a few assignments, two weeks are allowed.
- *Topics to be included on the Mid-term Test:* All material up to the lecture before the Mid-term Test.
- The Mid-term Test will occur during regular class time on **Wednesday, October 23, 2024**. In case of a shift back to ‘on-line’ learning, the Mid-term Test will still be administered during the regularly scheduled class time. Those details would follow on the course’s OWL site.
- Student interviews (15 minutes in length) will be scheduled individually and take place between Monday, **November 11, 2024** and **Friday, November 15, 2024**.
- *Topics to be included on the Final Examination:* Entire course but with emphasis on material covered after the Mid-term Test.
- The Final Examination date and location will be scheduled by the Registrar’s Office during the normal December examination period. In case of a shift back to ‘on-line’ learning, the final examination will be administered in a ‘take-home’ format. Those details would follow on the course’s OWL Brightspace site.

## 6. Student Absences

If you are unable to meet a course requirement due to illness or other serious circumstances, please follow the procedures below.

### **Assessments worth less than 10% of the overall course grade:**

- There are no ‘make-up’ options for missed Assignments (each worth 4%). Ten percent per day is deducted for late assignments, and assignments received more than five days late will not be accepted. In case of extenuating circumstances, students should contact the instructor at [flongsta@uwo.ca](mailto:flongsta@uwo.ca) .

### **Assessments worth 10% or more of the overall course grade:**

For work totaling 10% or more of the final course grade, you must provide valid medical or supporting documentation to the Academic Counselling Office of your Faculty of Registration as soon as possible. For further information, please consult the University’s medical illness policy at

[https://uwo.ca/univsec/pdf/academic\\_policies/appeals/academic\\_consideration.pdf](https://uwo.ca/univsec/pdf/academic_policies/appeals/academic_consideration.pdf) .

The Student Medical Certificate is available at

[https://www.uwo.ca/univsec/pdf/academic\\_policies/appeals/medicalform.pdf](https://www.uwo.ca/univsec/pdf/academic_policies/appeals/medicalform.pdf) .

- The Mid-term Test date is firm and make-up Mid-term Tests are not offered. If your Faculty’s Academic Counselling Office has approved your circumstances, then the value of the Mid-term Test will be shifted to the Final Examination. Please ensure that the instructor is informed of this approval using [flongsta@uwo.ca](mailto:flongsta@uwo.ca) .
- Ten percent per day is deducted for a late Review Paper, and a Review Paper received more than five days late will not be accepted. If your Faculty’s Academic Counselling Office has approved your circumstances that caused an up to five-day delay in submission of your Review Paper, then the late penalty will be waived. Please ensure that the instructor is informed using [flongsta@uwo.ca](mailto:flongsta@uwo.ca) .
- There are no ‘make-up’ options for a missed Review Paper. If your Faculty’s Academic Counselling Office has approved your circumstances, then the value of the Review Paper will be shifted to the Final Examination. Please ensure that the instructor is informed of this approval using [flongsta@uwo.ca](mailto:flongsta@uwo.ca) .

### **Absences from Final Examinations**

If you miss the Final Examination, please contact the Academic Counselling office of your Faculty of Registration as soon as you are able to do so. They will assess your eligibility to write the Special Examination (the name given by the University to a makeup Final Examination).

You may also be eligible to write the Special Examination if you are in a “Multiple Examination Situation” (e.g., more than 2 exams in 23-hour period, more than 3 exams in a 47-hour period).

- Special final examinations will be held as mandated by the University on *To be determined*, with details to be provided by the Registrar.

If a student fails to write a scheduled Special Examination, the date of the next Special Examination (if granted) normally will be the scheduled date for the final exam the next time this course is offered. The maximum course load for that term will be reduced by the credit of the course(s) for which the

final examination has been deferred. See the Academic Calendar for details (under [Special Examinations](#)).

**Note:** missed work can only be excused through one of the mechanisms above. Being asked not to attend an in-person course requirement due to potential COVID-19 symptoms is **not** sufficient on its own.

## 7. Accommodation and Accessibility

### Religious Accommodation

When a course requirement conflicts with a religious holiday that requires an absence from the University or prohibits certain activities, students should request accommodation for their absence in writing at least two weeks prior to the holiday to the course instructor and/or the Academic Counselling office of their Faculty of Registration. Please consult University's list of recognized religious holidays (updated annually) at

<https://multiculturalcalendar.com/ecal/index.php?s=c-univwo> .

### Accommodation Policies

Students with disabilities are encouraged to contact Accessible Education, which provides recommendations for accommodation based on medical documentation or psychological and cognitive testing. The policy on Academic Accommodation for Students with Disabilities can be found at:

[https://www.uwo.ca/univsec/pdf/academic\\_policies/appeals/Academic\\_Accommodation\\_disabilities.pdf](https://www.uwo.ca/univsec/pdf/academic_policies/appeals/Academic_Accommodation_disabilities.pdf) .

## 8. Academic Policies

The website for Registrarial Services is <http://www.registrar.uwo.ca> .

In accordance with policy,

[https://www.uwo.ca/univsec/pdf/policies\\_procedures/section1/mapp113.pdf](https://www.uwo.ca/univsec/pdf/policies_procedures/section1/mapp113.pdf) ,

the centrally administered e-mail account provided to students will be considered the individual's official university e-mail address. It is the responsibility of the account holder to ensure that e-mail received from the University at their official university address is attended to in a timely manner.

Scientific calculators are allowed for both the Mid-term Test and the Final Examination.

**Scholastic offences** are taken seriously and students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence, at the following Web site:

[http://www.uwo.ca/univsec/pdf/academic\\_policies/appeals/scholastic\\_discipline\\_undergrad.pdf](http://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_undergrad.pdf) .

All required papers may be subject to submission for textual similarity review to the commercial plagiarism detection software under license to the University for the detection of plagiarism. All papers submitted for such checking will be included as source documents in the reference database for

the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between The University of Western Ontario and Turnitin.com ( <http://www.turnitin.com> ).

## 9. Support Services

Please visit the Science & Basic Medical Sciences Academic Counselling webpage for information on adding/dropping courses, academic considerations for absences, appeals, exam conflicts, and many other academic related matters: <https://www.uwo.ca/sci/counselling/> .

Students who are in emotional/mental distress should refer to Mental Health@Western (<https://uwo.ca/health/>) for a complete list of options about how to obtain help.

Western is committed to reducing incidents of gender-based and sexual violence and providing compassionate support to anyone who has gone through these traumatic events. If you have experienced sexual or gender-based violence (either recently or in the past), you will find information about support services for survivors, including emergency contacts at

[https://www.uwo.ca/health/student\\_support/survivor\\_support/get-help.html](https://www.uwo.ca/health/student_support/survivor_support/get-help.html) .

To connect with a case manager or set up an appointment, please contact [support@uwo.ca](mailto:support@uwo.ca) .

Please contact the course instructor if you require lecture or printed material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Accessible Education at

[http://academicsupport.uwo.ca/accessible\\_education/index.html](http://academicsupport.uwo.ca/accessible_education/index.html)

if you have any questions regarding accommodations.

Learning-skills counsellors at the Student Development Centre ( <https://learning.uwo.ca> ) are ready to help you improve your learning skills. They offer presentations on strategies for improving time management, multiple-choice exam preparation/writing, textbook reading, and more. Individual support is offered throughout the Fall/Winter terms in the drop-in Learning Help Centre, and year-round through individual counselling.

Western University is committed to a thriving campus as we deliver our courses in the mixed model of both virtual and face-to-face formats. We encourage you to check out the Digital Student Experience website to manage your academics and well-being: <https://www.uwo.ca/se/digital/> .

Additional student-run support services are offered by the USC, <https://westernusc.ca/services/> .

