Geology - Planetary Science GL/PS 9510B: Cosmochemistry: Origin and formation of the Solar System and planets

Cross listed with Geology and Planetary Sciences. Open to graduate students in Geology, Physics and Astronomy, and Chemistry at Western, as well as to external graduate students from the same fields, and, with a registration fee, to academic and industrial professionals. Undergraduate students may also enrol, but only with the permission of the instructor based on their individual curriculum, as well as permission from the Academic Dean. For chemistry, astronomy and astrophysics students, it should be a useful introduction to the concepts of geology. For geology students, it will be a new application of their knowledge towards astrophysical phenomena. This course provides a foundation to a whole new cross-disciplinary field.

Instructor: Dr. Audrey Bouvier (audrey.bouvier@uwo.ca; +1-519-661-2111 x.88516; room 1081 B&G)

When: February 20 – February 25, 2018 in class, and for now April 4th 2018 for presentations (in class or remote) to be confirmed in class with all students.

Where: Western University, London, Canada (rooms TBD)

Prerequisites:

Students taking this course must be familiar with chemistry, nuclear chemistry, calculus, and planetary formation. A course in inorganic chemistry, nuclear chemistry, astronomy or meteorite studies is desirable.

Recommended - ES3312A/B Genesis of Meteorites and Planetary Materials and Planetary Sciences short course 9602A/B

Course Description

This is a graduate level, semester course with assigned readings beginning on January 11, 2018.

The course requires on-campus attendance for 6 days for in-class lectures and labs during reading week, Tuesday February 20 - Sunday February 25, 2018, 9:30 am to 5:30 pm, and one day of oral presentations on April 4th in class or remotely.

Homework assignments will be due in March and April.

This course covers:

- Petrography and Classification of meteorites
- Origin, history and transformation of planetary matter in the Solar System and the formation of planetary objects

- Origin, chemical evolution and timescales of planetary formation
- Use of stable and radiogenic isotopes as tracers and chronometers of these planetary processes
- Understanding the basics of cosmochemistry, which is the goal of this class, allows us to interpret results from space probes and astrophysical observations
- Fundamentals of mass spectrometry for isotope measurements of metals

We will survey the various forms in which this matter occurs as primitive bodies (meteorites) and planets, and then focus on the chemical evolution and chronology of these processes. The course begins with the basic concepts of meteorite classification, nuclear chemistry and nucleosynthesis (the origin of elements) and will devote this knowledge to the chemistry and mineralogy of the planets and meteorites. Mineralogy is an important aspect of this class, thus we will explore asteroidal and planetary meteorites in laboratory classes, the most common and more unusual minerals that are commonly mentioned in papers and books in cosmochemistry. This work provides the door to understanding the histories of planetary objects. The course will be based on lecture notes and readings prior to attending the lectures. You are also required to acquire the textbook Cosmochemistry by McSween and Huss (Cambridge Univ. press, 2010). This book is available new, used, in bookstores or as an online version.

Laboratory problems will provide useful exercises to explore cosmochemical and technical topics, and that reinforce readings and lectures. Supplementary texts and reading assignments will be made available as needed. The lecture week will be busy and students will need to be prepare for a first presentation given on the last day of the week. For credits, the evaluation will be based on class and OWL course site participation such as students' questions and answers in class and forum (which is important and will make the class more exciting especially with students from different backgrounds), homework assignment and presentation, and for students only, a final research paper with a topic of your choice in Cosmochemistry. Lab exercises and homework are the same for everybody. I encourage you to discuss topics and work together, however, the answers you submit need to be your own. Announcements will also be made of forthcoming colloquia and other public events of cosmochemical interest as they appear on schedules and mailing lists. I encourage the students enrolled at Western to attend the CPSX forum, although attendance to these events is not required.

Registration by January 8th 2018

For students not enrolled at Western, to register: email cpsx@uwo.ca

In the email please include:

- Subject Line: 2018 Cosmochemistry Course (Your Name)
  If you are an external applicant, please attach a one page resume
- In the body of the message, please include:
  - Your name

- Your supervisor's name (if applicable)
- Your position (faculty, post-doc, graduate student, undergraduate student)
- If you have any accessibility requirements (please describe

Your registration email will be reviewed, and once approved, you will receive a confirmation email with a link to the payment site.

Registration Fees: *(all prices include taxes)*
Students outside Ontario = $500.00
Students outside Canada = $800.00
Professionals = $1300.00
Ontario Students = no fee

Course Resources

An OWL page will be created for posting announcements, forum questions/answers, and materials. Students are thus required to access regularly the OWL course site throughout the Winter semester.

There is a required textbook: − Cosmochemistry: H. McSween and G. Huss, Cambridge, 2010.

The instructor will send by January 11th selected textbook chapter numbers and handouts. These readings are required prior to the lectures.

Additional materials will be distributed during the course as needed.

A number of other useful books are also available and highly recommended. − Planetary Materials, MSA Reviews in Mineralogy, Volume 36, J. J. Papike Editor, 1998. − Meteorites: R. Hutchison, Cambridge Planetary Sciences, 2004. − Geochemistry (or online lecture notes) by William White, Wiley-Blackwell, 2014.

Course Planned Schedule

Required Reading: January 11 - February 19, 2018

Lectures and labs: Tuesday February 20 - Sunday February 25, 2018. Daily lectures 9:30 am - 12:30 pm followed by daily labs from 2:30 pm - 5:30 pm.

Lecture Schedule

Day 1: Welcome & Overview of the week – Basics of Meteorites

Lecture - Introduction to Planetary Materials. Classification and chemistry of meteorites, and Moon, Mars and Earth materials. Learning bases of meteorites and their mineralogy, relationship to the chemical and physical conditions of planetary formation.

Lab - hand samples and thin sections of meteorites for major groups, basics of petrography of meteorites. Distribution of an unknown meteorite of the Western meteorite collection to each student to start establishing the petrography and mineralogy of their own meteorite at the microscope.

Each student start searching literature articles related to its object in preparation for their presentation on Sunday.

Day 2: Isotope Cosmochemistry. Part I: stable isotopes

Lecture - Isotopes come to life! Information about the history of the isotopes is obtained from their abundance in stars, the interstellar medium, and the Solar System, to an important extent represented by meteorites. We will discuss how we use stable isotopes as tracers of planetary processes and to decipher the stellar heritage of the Solar System.

In class exercise - Datasets and calculations relevant to planetary processes (e.g., mass fractionation, Rayleigh equations).

Lab: Students get the electron microprobe elemental dataset for their own meteorite, and may select additional mineral phases to analyze or image at the microprobe on Thursday. Note: depending on the number of students, not all requests may be accepted. The instructor will have to evaluate and select requests based on justifications for classification.

Guest lecturer: Dr. Tony Withers will discuss electron microprobe data processing.

Day 3: Isotope Cosmochemistry. Part II: long-lived radiogenic isotopes

Lecture - Using long-lived radiogenic isotopes as chronometers of planetary processes and fingerprints of internal reservoirs. Equations for isochrons, initials, reservoirs, and

major systems used in cosmochemistry (U-Pb, Sm-Nd, Rb-Sr, and Lu-Hf). Relevant topics.

Lab - Depending on class size, visit of the microprobe lab by groups of maximum 4 students and clean chemistry labs in the Biotron, and analyzes of the whole-rock samples at the ICP-MS while others are regressing and summarizing microprobe and/or ICP-MS data.

Day 4: Isotope Cosmochemistry. Part II: short-lived radiogenic isotopes

Lecture - Using short-lived radiogenic isotopes as tracers of recent nucleosynthesis events, high resolution chronometers of planetary processes and radiogenic heat sources. Equations for isochrons, initials, reservoirs, and major systems used in cosmochemistry (e.g., ^{146}Sm-^{142}Nd). Relevant topics to early Solar System chronology.

Lab - Datasets and age calculations.

Day 5: Instrumentation and techniques of mass spectrometry

Guest lecturer: Dr. Bastian Georg, Trent University.

Lecture and Lab – Nuts and bolts of mass spectrometers, instrumentation for cosmochemistry, isotopic fractionation principles and normalization corrections for measurements.

Day 6: Review and short presentations

Class - 20 minutes per student for presentation (12-15mn) and questions (5-8mn) about each meteorite classification and report of the observation so far of the unknown meteorite and incorporation of literature materials.

Homework assignments:

Meteorite report: data reduction and report of the meteorite analyzed by each group ready for submission to the Nomenclature Committee of the Meteoritical Society. **Due on March 12th 2017.**

Individual assignment: for students consists on writing a 3,000 words (excluding references and figure captions) research proposal on a topic either chosen by the student or discussed with the professor (details on format will be given in class) and will be **due on April 2nd 2017**. 20 minutes presentations of their proposals will take place on campus and with videoconference for off-campus students on **April 4th 2017**.

Course Evaluation

10% class participation
15% lab exercises
20% meteorite report
10% first presentation
35% research proposal
10% final presentation

Learning outcomes:

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

- Explain the major concepts of elemental and isotopic cosmochemistry based on their participation and individual and group assignments.
- Analyze information and data related to meteoritics and cosmochemistry through the integration of relevant literature and data sets into a specific research product.
- Answer fundamental scientific questions in the area of cosmochemistry.
- Apply learned organization and presentation skills developed from written reports and oral presentations.

Attendance

More than 1 day of absence during the class portion of the course will require withdrawal from the course, unless previous arrangements have been made with the course instructor.

Student's responsibilities in the event of a medical issue: If you are unable to meet a course requirement due to illness or other serious circumstances, you must provide valid medical or other supporting documentation to a Counselor in the Office of the Dean of your Faculty as soon as possible and contact your instructor immediately. It is the student's responsibility to make alternative arrangements with their instructor once the accommodation has been approved and the instructor has been informed.

In the event of a missed assignment, a "Recommendation of Special Examination" form must be obtained from the Dean's Office immediately. For further information please see: http://www.uwo.ca/univsec/handbook/appeals/medical.pdf A student requiring academic accommodation due to illness, should use the Student Medical Certificate when visiting an off-campus medical facility or request a Records Release Form (located in the Office of the Dean) for visits to Student Health Services. The form can be found here: https://studentservices.uwo.ca/secure/medical_document.pdf

Graduate Student Credit and Registration

This course will correspond to the University of Western Ontario PLANETSC 9603A. Students from any university are eligible to take the course and may receive credit in their respective institutions, subject to approval from their home Department. Students

enrolled at ONTARIO universities wishing to transfer credit for this course to their home institution must complete an Ontario Visiting Graduate Student form available here. For instructions on submission of this form, please contact Amy Wickham, Academic Program Coordinator, Department of Earth Sciences, Western University, awickham@uwo.ca, t. 519.661.2111 ext. 84523 regarding course enrollment and transcript records for students.

Please contact cpsx@uwo.ca with any questions regarding external registration.

Travel & Accommodation

The course will take place on the Western University in London, Ontario. A map showing the location of the Physics & Astronomy building, the Biological & Geological Sciences building and the Social Science parking lot is available here. Western visitor information can be found here.

Accommodation options near campus include The Guest House on the Mount, Windermere Manor and the Ivey-Spencer Leadership Centre.