Geology and Planetary Sciences 9510A/B/L
Cosmochemistry: Origin and formation of the Solar System and planets

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Format: Semester course with on-campus attendance for 7 Days for in-class lectures and labs (6 hours daily for lecture and lab classes), requested readings before the lectures, and homework assignments. Note: all in-class lectures and labs are taking place during reading week, February 15th to 21st, 2016 but the course runs from January 4th to April 30th.

Open to graduate students in Geology, Physics and Astronomy, Chemistry, and Engineering at Western, as well as to external graduate students from the same fields, and, with a registration fee, to academic or industrial professionals. Undergraduate students may also enroll but only with permission of the instructor based on their individual curriculum, as well as permission from the Academic Dean.

Course Description
This course will discuss the origin, history and transformation of planetary matter in the Solar System and the formation of planetary objects. The subject includes the origin, chemical evolution and timescales of planetary formation. For that, we need to discuss the use of stable and radiogenic isotopes as tracers and chronometers of these planetary processes. We will also have hands-on activities to investigate the mineralogy and chemistry of planetary materials during the laboratory classes as group projects. Understanding the basics of cosmochemistry, which is the goal of this class, allows us to interpret results from space probes and astrophysical observations. This is a graduate level course and students may or may not (although recommended) have taken ES3312A/B Genesis of Meteorites and Planetary Materials and the short course of the collaborative program in Planetary Sciences PS 9602A/B. For 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. For those in other disciplines (engineering, physics & astronomy) it provides a foundation to a whole new interdisciplinary field.

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 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 meteorites in laboratory classes, lunar and Martian meteorites, 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 short course. You are also **required** to acquire the textbook Cosmochemistry by McSween and Huss (Cambridge Univ. press, 2010). This book is available new, used, or in bookstores.

Laboratory problems will provide useful exercises to explore cosmochemical topics, and that reinforce readings and lectures.

Supplementary texts and reading assignments will be made available as needed.

The lecture week will be an intense week and students will need to be prepared for evening group work to prepare for a first presentation given on the last day. 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), group homework assignment and presentation, and for students only, a final research paper with a topic of your choice or a suggested topic in Cosmochemistry. Lab exercises and group homework are the same for everybody. Students, I encourage you to work together on problems, graduates and undergraduates together, in groups. It is crucial, however, that the answers you submit are 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.

Pre-requisites
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.

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 course.** 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 schedule: Lectures and labs during reading week, February 15-21st, 2016.

7 days. Monday-Sunday. Every day will consist of 3 hour lecture (morning 9.30am-12.30pm) and 3 hour lab (afternoon 2.30-5.30pm), to be adjusted in function of activities.

Lab (in class) exercises will be done by groups of 3-4 students and will peer-reviewed at the end of each session with the input of the instructor.

Depending of attendance (fewer than 10), additional lab exercises will be carried out in the chemistry lab and ICP-MS lab. This will require Western online Lab Safety training to be taken prior to the course.

A OWL website will be set up for the course and students are responsible to check regularly for announcements and posts on the Forum.

Day 1:

- Welcome: overview of the week.
- Introduction to Planetary Materials. Classification and chemistry of meteorites, Moon, Mars and Earth materials. Chemistry of planets.
- Lab: hand samples, petrography of meteorites. Goals: learning bases and advanced mineralogy, relationship to chemical and physical conditions of formation and chronometry. Distribution of unknown meteorites of the CPSX meteorite collection to groups: thin section, chip and a chip which will have been dissolved prior to the workshop and will be analyzed during the week at the ICP-MS (Biotron or new installed instrument in Bouvier's laboratory). Students establish the mineralogy at the microscope and select mineral phases to analyze the microprobe. Hand-out thin section to microprobe lab for analysis. Each group searches literature articles related to its object.

Day 2:

- Isotope Cosmochemistry. Part I: stable isotopes.

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.

- Lab: Datasets and calculations relevant to planetary processes (e.g., mass fractionation, Rayleigh equations). Understand chemical reservoirs in the protoplanetary disk, and planetary processes that can be traced.

Day 3:

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

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: Datasets and age calculations. Understanding the dating methods and other nucleosynthetic or irradiation processes affecting isotope abundances in meteorites and their ages.

Day 4:

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

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 (Al-Mg, Fe-Ni, Mn-Cr). Relevant topics to early Solar System chronology.

Lab: Datasets and age calculations.

Day 5:
Instrumentation and techniques of mass spectrometry
Lecture on basic concepts of mass spectrometry and instruments. Mass fractionation and normalization corrections.
Lab: Visit of the microprobe lab and clean chemistry labs in the Biotron, and by groups (half-half) analyzing the samples at the ICP-MS while other groups are regressing and summarizing microprobe and/or ICP-MS data.

Day 6:
Cosmochemistry and Space missions: past, current and future.
Several space missions have brought back space samples to Earth or have brought instrumentation on board to analyze in-situ. We will review the main discoveries and chemical and isotopic measurements used for missions such as on Mars with rovers, or Rosetta on comet 67P.
Lab: Planning the next space mission, "where would you go, what would you bring and why?"

Day 7:
Review and short presentations.
Lecture: Review of major concepts discussed during the week (e.g., planetary accretion, differentiation, Moon formation) and applications to selected topics of interests and current literature in top-ranked journals (two articles will be sent before the workshop).
Lab: 10 minutes group presentation of their observation so far of the unknown meteorite and incorporation of literature materials. Discussion of the presentations and of the group and individual homework assignments.

Homework assignments:

- Group assignment: 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 8th 2016.

- 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 1st 2016. 10 minutes presentations of their proposals will take place on campus and with videoconference for off-campus students at a TBD date in April.

Course evaluation

10% participation
15% lab exercises
20% group assignment
10% group presentation
35% research proposal
10% presentation

Learning outcomes:

Students will learn major concepts of elemental and isotopic cosmochemistry which are fundamentals for a career in space and planetary sciences. Students' learning outcomes will be evaluated by their participation and individual and group assignments.

Undergraduate and graduate students will be able to develop organization and presentation skills. The student will be expected to produce written reports and oral presentations for their assignments that substantiate their research with technical and scientific arguments. Students will work together as a team to synthesize analytical data and literature for meteorites in a timely manner and incorporate these into an oral presentation and written report for submission to the Nomenclature Committee of the Meteoritical Society.

Students will be exposed to new concepts and questions and will write and present an original research plan. Students will analyze information and data related to meteoritics and cosmochemistry through the integration of relevant literature and data sets into a specific research product. This exercise will thus contribute to expending their scientific knowledge to the current state of science on these topics, improving their writing style and elevating their critical thinking**.**

Students will acquire, process and critically evaluate data and information by answering fundamental scientific questions in the area of cosmochemistry. Such knowledge can be further used in other scientific fields such as environmental sciences, forensics, nuclear chemistry, or even medical sciences. This learning outcome will be evaluated based on the student's responses to problems presented during in-class laboratory exercises and the student's responses to in-class questions and discussion."

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 final exam or presentation, 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

More than 1 day absence during the 7 days of the short course will require withdrawal from the course, unless previous arrangements have been made with the course instructor.

Statement on Academic Offenses:

Academic offenses are taken seriously. Students are directed to read the appropriate policy on academic offenses at:
www.uwo.ca/univsec/handbook/appeals/scholoff.pdf

Plagiarism is a serious academic offence. The UWO Senate Academic Handbook defines plagiarism as "The act of appropriating the literary composition of another, or parts or passages of his writings, or the ideas or language of the same, and passing them off as the product of one's own mind." Students must write their assignments in their own words.

Students must write their assignments in their own words. Proper referencing or quotations must be used when taking an idea or passage from another author. This includes websites, papers, books, other students, etc. You are not allowed to copy and paste paragraphs and then change several words. You must gather ideas for your report then write the entire paper in your own words.

Your professor reserves the option to submit your report to turitinit.com. 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 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 Western University and Turnitin.com (http://www.turnitin.com).

Accessibility Statement

Please contact the course instructor if you require material in an alternate format or if you require any other arrangements to make this course more accessible to you. You may also wish to contact Services for Students with Disabilities (SSD) at 661-2111 x.82147 for any specific question regarding an accommodation.
A OWL website will be set up for the course where course materials will be posted. Also access to the lectures via video conference may be made available for students with accommodations and unable to attend lectures on campus.

Health and Wellness

As part of a successful graduate student experience at Western, we encourage students to make their health and wellness a priority. Western provides several on campus health-related services to help you achieve optimum health and engage in healthy living while pursuing your graduate degree. For example, to support physical activity, all students, as part of their registration, receive membership in Western's Campus Recreation Centre. Numerous cultural events are offered throughout the year. For example, please check out the Faculty of Music web page http://www.music.uwo.ca/, and our own McIntosh Gallery http://www.mcintoshgallery.ca/. Information regarding health- and wellness-related services available to students may be found at http://www.health.uwo.ca/. Students seeking help regarding mental health concerns are advised to speak to someone they feel comfortable confiding in, such as their faculty supervisor, their program director (graduate chair), or other relevant administrators in their unit. Campus mental health resources may be found at:
http://www.health.uwo.ca/mental_health/resources.html