

Astrochemistry

General Information:

Department: Department of Astronomy and Planetary Science

Course: AST 470/570, Class Number 9533 (Graduate), 11771 (Undergraduate)

Term: Spring 2025

Meeting Time: Monday/Wednesday; 2:20 p.m. – 3:35 p.m. Liberal Arts 306

Mode of Instruction: Face-to-face

Credit Hours: 3

Course Prerequisites:

Graduate students: Admission to Astronomy and Planetary Science PhD program or permission from Instructor

Undergraduate students: AST-280

Instructor: Mark Loeffler

Office: Physical Science (Building #19), Room 311. Phone: 523-0369. Email:
mark.loeffler@nau.edu

Laboratory: Physical Science (Building #19), Room 313/313A.

Office Hours: 1:00 – 2:00 PM. Monday and Wednesday. You are welcome to come by my office/lab at another time.

Career Ready Resources.

LinkedIn:

CEFNS Career Development

www.linkedin.com/in/cefns-career-development-072715233

NAU Career Development

<https://www.linkedin.com/company/nau-career-development/>

Handshake:

<https://nau.joinhandshake.com/login>

Udemy: Online courses and career searching advice

<https://in.nau.edu/its/udemy/>

Log in with your NAU email account and search 'NAU Career Steps'

O*net Online: Occupation exploration reports

<https://www.onetonline.org/>

Course Purpose:

Compared to basic scientific disciplines, the topic of astrochemistry is a relatively new field of study, based heavily on chemistry and astronomy. Given that the topic is somewhat interdisciplinary, drawing on concepts from a variety of other disciplines, such as physics, biology, geology, and materials science, many of the concepts and principles studied in this field are often missing from the curricula of PhD degree programs in Astronomy and Planetary Science. The intention of this course is to introduce and solidify the student's understanding of astrochemistry by studying and predicting the physical and chemical processes that are important for the formation of new species in different extraterrestrial environments. This course will use specific examples to emphasize the diversity of environments that exist both inside and outside our Solar System and to show how different astrochemical approaches can be combined to gain a more realistic picture of the likely chemical history and evolution of any object under study. Letter grade only.

Co-Convening of AST 470 and AST 570:

This course is co-convened between AST 470 and AST 570. The goal of the undergraduate offering (AST 470) is to ensure that students have a strong foundational background in the chemical makeup of our Universe, and how chemical processes subsequently shaped other astronomical and planetary features. Graduate students will be expected to develop a deeper understanding of cosmochemical principles and to critically evaluate peer-reviewed research at a level that is not expected by the undergraduate students enrolled in AST 470. This will be manifested through the class presentation and associated write-up that will be required for graduate students. In some cases, it will also be in the additional homework problems given to graduate students.

NACE Career Readiness Competencies

The National Association of Colleges and Employers (NACE), the leading source of information on the employment of the college educated, have identified eight Career Readiness Competencies (CRC), a foundation from which to demonstrate requisite core competencies that broadly prepare the college educated for success in the workplace and lifelong career management. More information regarding these competencies can be found at: <https://www.naceweb.org/career-readiness/competencies/career-readiness-defined>

The CRC's are listed below:

- 1) **Career & Self-Development:** Proactively develop oneself and one's career through continual personal and professional learning; awareness of one's strengths and weaknesses
- 2) **Communication:** Clearly and effectively exchange information, ideas, facts, and perspectives with persons inside and outside of an organization
- 3) **Leadership:** Recognize and capitalize on personal and team strengths to achieve organizational goals.
- 4) **Critical Thinking:** Identify and respond to needs based upon an understanding of situational context and logical analysis of relevant information
- 5) **Equity & Inclusion:** Demonstrate the awareness, attitude, knowledge, and skills required to equitably engage and include people from different local and global cultures.
- 6) **Professionalism:** Knowing work environments differ greatly understand and demonstrate effective work habits, and act in the interest of the larger community and workplace
- 7) **Teamwork:** Build and maintain collaborative relationships to work effectively toward common goals, while appreciating diverse viewpoints and shared responsibilities

- 8) Technology:** Understand and leverage technologies ethically to enhance efficiencies, complete tasks, and accomplish goals

All learning outcomes are meant to develop your CRCs. Below are the learning outcomes with the numerated CRC listed at the end.

Learning Outcomes:

Undergraduate and Graduate Students:

Understand role of Astrochemistry plays the formation and evolution of objects in the Interstellar Medium and in our Solar System (CRC: 4, 8)

Become proficient in the scientific techniques (modeling, laboratory, theoretical) that are used to study astrochemistry throughout our Solar System and the Interstellar Medium (CRC 4, 7, 8)

Become proficient in how some of the basic processes (sputtering, radiolysis, photochemistry, and thermally-driven chemistry) drive the chemical evolution of objects throughout our Solar System and the Interstellar Medium (CRC 4, 7, 8)

Be able to make calculations to help quantify astrochemical effects on objects throughout our Solar System and the Interstellar Medium (CRC 2, 4, 8)

Be able to apply astrochemical principles to different environments throughout our Solar System and the Interstellar Medium to understand, explain and predict general outcomes (CRC 1, 4, 8)

Graduate Students Only:

Critically evaluate relevant studies that investigate the chemical composition of our solar system, galaxy, and universe (CRC 1, 2, 4, 7, 8)

Describe and develop key investigations to study outstanding questions and hypotheses in astrochemistry (CRC 1, 2, 4, 8)

Be able to answer more detailed homework/exam problems specially designed for the graduate students enrolled in the course (CRC 2, 4, 7, 8)

Learn to effectively lead both large (entire class) and small group discussions (assigned homework group) (CRC 2, 3, 5, 6, 7, 8)

Course Structure:

Required Textbook: There is no required textbook for this course. However, reference books that will be used to varying degrees in this class are:

Astrochemistry: From Astronomy to Astrobiology, by Andrew Shaw

Introduction to Astrochemistry: Chemical Evolution from Interstellar Clouds to Star and Planet Formation, by Satoshi Yamamoto

The Physics and Chemistry of the Interstellar Medium, by A.G.G.M. Tielens

Assessment/Grading:

Grades will be determined from the following categories:

Graduate Students:

Homework (30%): Assignments will be given approximately every week; the student will typically have a week to complete the assignment. The homework will be due at the beginning of class, unless otherwise specified. The assignments must be turned in by their stated due dates; 10% point deduction will be applied for every day assignment is late. NACE CRCs: **Communication, Critical Thinking, Professionalism**

Mid-Term Exam (25%): One written exam will be given in class roughly halfway through the semester. It will be based on lectures and homework assignments. Graduate students may receive additional/higher level questions during the examination. NACE CRCs: **Communication, Critical Thinking, Professionalism**

Class Project (15%): In the class project, the student will find a topic related to astrochemistry in which they are interested. After approval from the professor, they will research the topic, write a short paper that includes from key graphic from the article (~1000 words) and give a short in-class presentation (10 - 15 minutes). The paper has to be turned in by the end of the week that the presentation is made in class but can be completed earlier if so desired by the student. The student will also be required to turn in questions prior to other students presentations; these questions will be worth 1/5 of the project grade. NACE CRCs: **Communication, Critical Thinking, Professionalism**

Final Examination (30%): A cumulative written final exam will be given on May 6th, 3:00 – 5:00 PM. Again, graduate students may receive additional/higher level questions during the examination. NACE CRCs: **Communication, Critical Thinking, Professionalism**

Undergraduate Students:

Homework (40%): Assignments will be given approximately every week; the student will typically have a week to complete the assignment. The homework will be due at the beginning of class, unless otherwise specified. In some cases, the undergraduate assignment may be shorter than the assignments for graduate students. The assignments must be returned by their stated due dates; 10% point deduction will be applied for every day assignment is late.

Mid-Term Exam (25%): One written exam will be given in class roughly halfway through the semester. It will be based on lectures and homework assignments.

Class Project Questions (5%): The student will be required to turn in questions prior to other students' presentations. NACE CRCs: **Communication, Critical Thinking, Professionalism**

Final Examination (30%): A cumulative written final exam will be given on May 6th, 3:00 – 5:00 PM.

Approximate Grading Scale for 470/570:

≥ 90% A
≥ 80 – 90% B
≥ 70 – 80% C
≥ 60 – 70% D
< 60% F

Makeup Work:

A student must obtain permission in advance of a regularly scheduled examination in order to take a make-up examination. Make up examinations will be different than the in-class examination.

Academic Dishonesty:

A finding of academic dishonesty will result in a zero for the assignment and a record of the student's offense in NAU Academic Dishonesty Database. A repeat of a finding of academic dishonesty will result in a failing grade for the class.

Course Outline:

The schedule and topics shown below are tentative and are subject to change.

Week Beginning	Day 1	Day 2
1/13	Overview of Astrochemistry	ISM environment
1/20	MLK Day/no class	ISM Environment
1/27	Energy Sources	Ions vs. Photons
2/3	Observational Techniques	Observational Techniques
2/10	Reactions - Gas Phase	Reactions - Gas Phase
2/17	Catch up	Solid Phase Processes
2/24	Solid Phase Processes	Solid Phase Processes
3/3	Applications	Exam 1
3/10	Spring Break	
3/17	Applications	Solar System Formation/Chemical Time Line
3/24	Overview of Solar System Environments	Applications: Jupiter
3/31	Application: Outer Solar System Ices (not Jovian)	Applications: Mars
4/7	Applications: Venus	Applications: Icy Satellites
4/14	Applications: Icy Satellites	Applications: Moon
4/21	Applications: Comets	Applications: Asteroids
4/28	Applications: Meteorites	Catch up
5/6	Final Exam	Tuesday 3 - 5 pm

University and Course Policies:

Safe Environment Policy: NAU's Safe Working and Learning Environment Policy prohibits discrimination and promotes the safety of all individuals within the University. The goal of this policy is to prevent the occurrence of discrimination on the basis of sex, race, color, age, national origin, religion, sexual orientation, disability, or veteran status and to prevent sexual harassment, sexual assault or retaliation by anyone at this University.

Students With Disabilities: If you have a documented disability, you can arrange for accommodations by contacting Disability Resources (DR) at 523-8773 (voice) or 523-6906 (TTY), dr@nau.edu (e-mail) or 928-523-8747 (fax). Students needing academic accommodations are required to register with DR and provide required disability related documentation. Although you may request an accommodation at any time, in order for DR to best meet your individual needs, you are urged to register and submit necessary documentation (www.nau.edu/dr) 8 weeks prior to the time you wish to receive accommodations. DR is strongly committed to the needs of student with disabilities and the promotion of Universal Design. Concerns or questions related to the accessibility of programs and facilities at NAU may be brought to the attention of DR or the Office of Affirmative Action and Equal Opportunity (523-3312).

Academic Integrity: The university takes an extremely serious view of violations of academic integrity. As members of the academic community, NAU's administration, faculty, staff and students are dedicated to promoting an atmosphere of honesty and are committed to maintaining the academic integrity essential to the education process. Inherent in this commitment is the belief that academic dishonesty in all forms violates the basic principles of integrity and impedes learning. Students are therefore responsible for conducting themselves in an academically honest manner. Individual students and faculty members are responsible for identifying instances of academic dishonesty. Faculty members then recommend penalties to the department chair or college dean in keeping with the severity of the violation. The complete policy on academic integrity is in Appendix G of NAU's Student Handbook <http://www4.nau.edu/stulife/handbookdishonesty.htm>. In short, anyone cheating on an assignment will receive a zero and possibly a failing grade in the course. Also, this incident would have to be reported to the Dean of Students and a written copy of any such incident may be attached to your official NAU file.

Academic Contact Hour Policy: The Arizona Board of Regents Academic Contact Hour Policy (ABOR Handbook, 2-206, Academic Credit) states: "an hour of work is the equivalent of 50 minutes of class time...at least 15 contact hours of recitation, lecture, discussion, testing or evaluation, seminar, or colloquium as well as a minimum of 30 hours of student homework is required for each unit of credit."

The reasonable interpretation of this policy is that for every credit hour, a student should expect, on average, to do a minimum of two additional hours of work per week; e.g., preparation, homework, studying.

Sickness or Hospitalization: Northern Arizona University has an official authorized absence policy that is administered by the Office of Student Life. Institutional excuses can be issued to authorize absences. If a student is hospitalized or has been directed by a physician to remain confined to his or her place of residence because of illness, Fronske Health Center staff or private physicians may issue a statement providing the dates of the student's confinement.

Disruptive Behavior: Membership in NAU's academic community entails a special obligation to maintain class environments that are conducive to learning, whether instruction is taking place in the classroom, a laboratory or clinical setting, during course-related fieldwork, or online. Students have the obligation to engage in the educational process in a manner that does not breach the peace, interfere with normal class activities, or violate the rights of others. Instructors have the authority and responsibility to address disruptive behavior that interferes with student learning, which can include the involuntary withdrawal of a student from a course with a grade of "W". For additional information, see NAU's disruptive behavior policy at <https://nau.edu/university-policy-library/disruptive-behavior>.

Nondiscrimination and Anti-Harassment: NAU prohibits discrimination and harassment based on sex, gender, gender identity, race, color, age, national origin, religion, sexual orientation, disability, or veteran status. Due to potentially unethical consequences, certain consensual amorous or sexual relationships between faculty and students are also prohibited. The Equity and Access Office (EAO) responds to complaints regarding discrimination and harassment that fall under NAU's Safe Working and Learning Environment (SWALE) policy. EAO also assists with religious accommodations. For additional information about SWALE or to file a complaint, contact EAO located in Old Main (building 10), Room 113, PO Box 4083, Flagstaff, AZ 86011, or by phone at 928-523-3312 (TTY: 928-523-1006), fax at 928-523-9977, email at equityandaccess@nau.edu, or via the EAO website at <https://nau.edu/equity-and-access>.

Title IX: Title IX is the primary federal law that prohibits discrimination on the basis of sex or gender in educational programs or activities. Sex discrimination for this purpose includes sexual harassment, sexual assault or relationship violence, and stalking (including cyber-stalking). Title IX requires that universities appoint a "Title IX Coordinator" to monitor the institution's compliance with this important civil rights law. NAU's Title IX Coordinator is Pamela Heinonen, Director of the Equity and Access Office located in Old Main (building 10), Room 113, PO Box 4083, Flagstaff, AZ 86011. The Title IX Coordinator is available to meet with any student to discuss any Title IX issue or concern. You may contact the Title IX Coordinator by phone at 928-523-3312 (TTY: 928-523-1006), by fax at 928-523-9977, or by email at pamela.heinonen@nau.edu. In furtherance of its Title IX obligations, NAU will promptly investigate and equitably resolve all reports of sex or gender-based discrimination, harassment, or Academic Policy 100227 / Syllabus Requirements and Template Page 2 of 2 sexual misconduct and will eliminate any hostile environment as defined by law. Additional important information about Title IX and related student resources, including how to request immediate help or confidential support following an act of sexual violence, is available at <http://nau.edu/equity-and-access/title-ix>.

