NORTHERN ARIZONA UNIVERSITY

Department of Chemistry and Biochemistry

DEPARTMENT OF CHEMISTRY AND BIOCHEMISTRY

CHM 599 (1 units) CONTEMPORARY DEVELOPMENTS - Nuclear and Radiochemistry Spring 2022

PRE- REQUISITE (3 UNITS): CHM 342 (Physical Chemistry I) Instructor consent required for enrollment.

Instructor:
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COURSE PURPOSE: This advanced chemistry course extends the fundamental knowledge developed in the Inorganic Chemistry I (CHM 350) and Physical Chemistry I (CHM 342) courses. Specifically, CHM 599 offers in-depth study of Nuclear Chemistry, one of the key areas of chemistry. Success in this course requires mastery of chemical vocabulary, principles, and concepts as stated in the degree program's learning outcomes. In CHM 599, students learn how nucleons interact within the nucleus, half-lives, decay pathways and mechanisms, and nuclear cross-sections and understand the importance of the sub-atomic particles in the nucleus. Students become aware of the quantum nature of the nucleus, and how spectroscopic techniques can guide an understanding of unusual physical behaviour. (Learning Outcome 2). As such, CHM 599 is situated in the *Science and Applied Science* distribution block in Liberal Studies. CHM 599 fosters further development of the Liberal Studies essential skill of *Scientific Inquiry* because students formulate hypotheses on the basis of observations, obtain and analyze data to test (i.e., refute or confirm) hypotheses, and explain phenomena by means of accepted principles, theories or laws. CHM 599 affords students the opportunity to demonstrate all of the Degree Program's Student Learning Outcomes (http://catalog.nau.edu/Catalog/details?plan=CHMBS&catalogYear=1516.)

INTENDED COURSE STUDENT LEARNING OUTCOMES: As a result of taking this course, students will gain an understanding of, and facility with, the methods of nuclear chemistry. Students will apply the results of mathematical approaches to understand the organization of the nucleus. Students will learn that the language and methods of quantum mechanics are the basis for half-lives and other key atomic effects. Finally, students will see that topics in nuclear chemistry such as fission and fusion are derived from quantum mechanical theories that yield the outcomes with a relevance to recent technological applications. They will appreciate that the chemical properties of nuclear species influence how such isotopes can be used in disparate fields including nuclear medicine. All of the following are situated within the Liberal Studies distribution block, *Science and Applied Science* distribution block.

Specifically:

A. Students will gain a deeper understanding of nuclear chemistry and to demonstrate the relationship between nuclear chemistry and other chemical disciplines.
B. Students will be introduced basic concepts to nuclear chemistry, including fission, fusion and other topics.
C. Students will demonstrate the ability to describe the relationship between nuclear and physical/quantum chemistry. (*Scientific Inquiry-LS)*
D. Students will apply mathematical descriptions to explain the components and structure of the nucleus, with a focus of the concept of the nuclear shell model. (1,10)
E. Students will apply the equations to predict half-lives and nuclear energy barriers in gamma ray and related spectroscopic techniques. (2) (*Scientific Inquiry-LS)*
F. Students will demonstrate higher-order thinking to recognize and explain the utility of nuclear chemistry concepts in the design of nuclear weapons and nuclear reactors. Students will demonstrate knowledge of how radioisotopes can be used in nuclear medicine and safe handling of hazardous materials. (2, 4) (*Scientific Inquiry-LS)*
G. Students will gain a deeper understanding of the importance of the types and application of analytical instruments in this field and how it impacts current research and development. (11, 13)
H. Students will demonstrate the ability to bring together relevant material on recent developments in the field of nuclear chemistry and effectively communicate these results to the audience. (8)

(Numbers refer to Degree Learning Outcomes for the BS Chemistry which can be viewed at http://catalog.nau.edu/Catalog/details?plan=CHMBS&catalogYear=1516.)

ASSESSMENTS OF INTENDED COURSE STUDENT LEARNING OUTCOMES:

Homework will be assigned at regular intervals to give students practice with the concepts covered in lecture and in readings. A typical homework assignment will consist of selected end of chapter questions or from the reading material and course hand outs.

Pre-lecture Quizzes will be given at regular intervals to help students prepare for upcoming course material. They will consist of both quantitative and qualitative questions that have been discussed in class.

To assess student learning, students will be asked to do the following:

- complete weekly quizzes at the beginning of the lecture period that require the application of specific student learning objectives to solve problems in inorganic chemistry. These assignments will be evaluated by the instructor to assess the extent to which students are grasping the concepts and to assess students' facility with applying the mathematical tools to solve problems. (Used to assess Course Learning Outcomes C, E, F, G, and H)
- apply the skills learned on the quizzes to solve problems on written reports and assessments specific for this course. When grading the assessments, the instructor will provide feedback to the students to help improve their understanding of the concepts and the methods. (Used to assess Course Learning Outcomes C, E, F, G, and H)
- apply the skills learned during the semester to solve problems on a comprehensive final presentation specific for this course. This is the final opportunity to assess student understanding of the concepts and student facility with the application of concepts in nuclear chemistry to relevant problems. This assessment will be compared with the assessment of homeworks and lecture period quizzes to obtain a measure of the evolution of student understanding. (Used to assess Course Learning Outcome F)

LECTURE SCHEDULE:

Wednesday 9:10 am – 10 am, Room 433, Building 36

OFFICE HOURS:

Thursday 1 pm – 4 pm, or by appointment

Grading:

I.	Abstract	5%
II	Report	15%
III.	Final presentation	30%
IV.	Ten pre-class quizzes	40%
V.	Participation	10%
	Total:	100 %

Make-up or re-tests for quizzes are not allowed under any circumstance. I will attempt an accommodation for a make-up exam under extreme circumstances (e.g. Emergency room bill, official obituary or vehicle towing receipt required, no exceptions). If the final presentation is cancelled due to circumstances beyond our control (e.g. due to a blizzard, *force majeure*, etc) your grade will be based on your points going into the final presentation.

Abstract, Report and Final Presentation:

During the semester you will be required to prepare a formal report on a specific topic in nuclear chemistry. You will be required to submit a one-page abstract document (minimum 400 words, 10%) on the Friday of Week 6 of the semester by 4 pm. You will then submit a full written report (minimum 5 full pages, diagrams and figures in a separate appendix, 20%) on the Friday of Week 9 of the semester by 4 pm. Finally you will give a 25 minute presentation (30 %) in the lecture session during weeks 14 (and if required Week 15). This presentation must be substantially (great than 70%) complete by the lecture session of Week 12 of the semester for checking by the course instructor. Presentations that are insufficiently complete will receive substantial grade deduction. Additional details and reminders regarding the report and presentation will be given during the semester.

Abstract and reports are to be turned into the Chemistry office (Room 400, Building 36) and signed and dated upon receipt. Reports must be typed in 12 pt Times New Roman or Arial fonts, 1.5 line spacing, left and right justified, with 2 cm margins, and a cover sheet including your name, student number, report title and any other pertinent information. Spelling mistakes and grammatical errors will result in loss of points. **Hand written reports will not be accepted.** Structures must be drawn clearly with either: Chemdraw, or Chemsketch software.
Failure to turn in the abstract or report, or to give the final presentation will result in a grade of F for the course.

Text books

No specific text book is assigned, but the following are recommended and a pdf version can be found online.

Gerhart Friedlander, Joseph W. Kennedy, Edward S. Macias, Julian M. Miller. *Nuclear and Radiochemistry, 3rd Edition*, (**1981**) ISBN: 978-0-471-86255-0

Bernard G. Harvey. *Nuclear Chemistry* (**1965**) Prentice-Hall, Englewood Cliffs, N. J.,

Course Website

http://www.inorganic-chem.com or the NAU Blackboard Learn (BBL) portal

CHM 599 Lecture Plan (Fall 2018)

Week #	Course Content	Week #	Course Content
1	Introduction to Course and Nuclear Science	**9**	Biological Effects of Nuclear Species
2	Half Lives, Decay Mechanisms and Decay Chains	**10**	Biological Effects of Nuclear Species
3	The Theory of the Nuclear Shell Model	**11**	Medical Applications of Radioisotopes
4	Quantum Effects inside the Nucleus	**12**	Student Presentations
5	Stellar Nucleosynthesis and the Mass Defect	**13**	Student Presentations
6	Nuclear Fusion and Nuclear Fission	**14**	Student Presentations
7	Design of Nuclear Reactors and Nuclear Weapons	**15**	Student Presentations
8	Analytical Techniques for Nuclear Species	**16**	Finals Week – No lecture

Official Code of Academic Conduct for CHM 599

In previous years there have been several incidences of academic misconduct in lower division lectures, including plagiarism and cheating. This is not acceptable because:

1) This devalues their education of students who do study (i.e. most of you).
2) Cheating on assignments disadvantages students who are not good at exams, by skewing the grading towards exams. Would you like to be operated on by a doctor who cheated their way through medical school?
3) It is a failure of "moral courage" to stand up for honesty and integrity.

First Offence: Verbal warning to student and receive grade of zero on the assignment or exam.
Referred to Head of Department and name recorded.

Second Offence: Receive grade of zero on the assignment or exam.
Referred to Referred to Head of Department and Dean of Students.
Grade of "F" for the course.
Asked to leave course.

Cell phones may not be used during quizzes.
Bags, notes, cell phones, smart watches, and hats must be left in your bag for quizzes.
You may be required to show identification to confirm your enrollment in the course.
Lectures, quizzes and presentations may be recorded electronically.

NAU Policy on Academic Dishonesty

POLICY ON ACADEMIC DISHONESTY

Violations of the Student Code of Conduct which **exclusively** involve issues of Academic Dishonesty are normally dealt with by faculty and academic administrators, rather than the Dean of Students. Allegations of academic dishonesty may be initiated by both students, and faculty or where appropriate, by administrative personnel. Informal procedures (see sections I and II of this Appendix) apply when the student has no previous record of academic dishonesty after an examination of the records by the Associate Provost for Academic Administration, and when the proposed sanctions do not include suspension or expulsion of the student. Formal procedures (see section III of this Appendix) apply when there is a record of previous academic dishonesty, or when there are other aggravating circumstances or when recommended sanctions include suspension or expulsion.

ACADEMIC INTEGRITY means that students and faculty jointly agree to adhere to a code of conduct appropriate to the mutually trusting relationship that must exist between student and teacher. Those values will not allow either to take credit for work not their own, or to be deceitful in any way, or to take unfair advantage of other students or of each other, or to be other than totally truthful and straightforward in all that they do.

ACADEMIC DISHONESTY is a form of misconduct that is subject to disciplinary action under the Student Code of Conduct and includes the following: cheating, fabrication, fraud, facilitating academic dishonesty and plagiarism.

1. **Plagiarism:** any attempt to pass off other's work as your own
2. **Cheating:** any attempt to gain an unfair, hidden advantage over one's fellow students
3. **Fabrication:** any attempt to present information that is not true
4. **Fraud:** any attempt to deceive an instructor or administrative officer of the university

Furthermore, any attempt to facilitate any act of academic dishonesty on the part of oneself or others shall constitute a violation of this policy.

Classroom Management Statement

Membership in the academic community places a special obligation on all members to preserve an atmosphere conducive to a safe and positive learning environment. Part of that obligation implies the responsibility of each member of the NAU community to maintain an environment in which the behavior of any individual is not disruptive.

It is the responsibility of each student to behave in a manner that does not interrupt nor disrupt the delivery of education by faculty members or receipt of education by students, within and/or outside the classroom. The determination of whether such interruption and/or disruption has occurred must be made by the faculty member at the time the behavior occurs. It becomes the responsibility of the individual faculty member to maintain and enforce the standards of behavior acceptable to preserving an atmosphere for teaching and learning in accordance with University regulations and the course syllabus. Visitors are not permitted in class without the express permission of the individual faculty member.

At a minimum, a student will be warned if his/her behavior is considered by the faculty member to be disruptive. Serious disruptions, as determined by the faculty member, may result in immediate removal of the student from the instructional environment. Significant and/or continued violations of this policy may result in an administrative withdrawal of the student from the class. Additional responses by the faculty member to disruptive behavior may include a range of actions from discussing the disruptive behavior with the student to referral to the appropriate academic unit and/or the Office of Student Life for administrative review, in an effort to implement corrective action up to and including suspension or expulsion.

http://www4.nau.edu/stulife/handbookcode.htm

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Chemistry B.S : Foundational outcomes for all Emphases.

1. Atomic Theory: Recognize that modern chemical science is based upon the idea of atoms, their combination in compounds, and their recombination in the course of chemical reactions.

2. Quantum Nature of the Atom: Realize that physical and chemical properties of matter result from subatomic particles that behave according to physical rules not apparent in the behavior of macroscopic objects, and they must realize the importance of spectroscopy in establishing this behavior.

3. Thermodynamics: Understand the principal laws of thermodynamics and how these dictate the behavior of chemical substances. Students must also understand how the thermodynamic information about chemical and physical changes helps to shape understanding of interactions between atoms, molecules, and other ensembles of particles.

4. Frequently Encountered Elements, Compounds and Reactions: Possess a mental library of common substances, their physical properties, and reactions that they undergo. The major classes of organic chemicals and their reactions, the characteristic reactions of other elements of the periodic table, solubility, acid/base, and redox chemistry all must be familiar to students. Students must also be aware of the hazards, both personal and environmental, associated with elements and compounds.

5. Mechanisms of Reactions: Understand how the study of the rates of chemical reactions and the structures of the products of these reactions can lead to knowledge of the detailed atomic-level behavior of chemical substances and elucidation of their chemical and physical properties.

6. Synthesis: Use their knowledge of chemical reactivity to plan and execute the preparation of compounds from common starting materials.

7. Skills and Techniques: Work independently using their own hands and intellect to solve chemical problems with traditional and modern laboratory tools. Students must also learn how to work together in teams, sharing tasks, results and interpretations without compromising the integrity of the investigation.

8. Communication of Scientific Results: Know how to retrieve detailed information about chemical and physical properties of substances and accounts of other experimental or theoretical research. Students must know how to communicate their own results in writing and speaking using appropriate scientific formats and language. Students must also be aware of the global context in which results and theories are formulated, communicated, and debated.

Chemistry B.S- Variable In-depth outcomes depending on Emphasis

9. Kinetic Molecular Theory: Understand that atomic, molecular and ionic particles are in constant motion. Ensembles of these particles have a characteristic distribution of kinetic energies based on the temperature of the sample, and this distribution can be used to predict chemical and physical properties of the sample.

10. Structure and Bonding: Understand how atoms combine in covalent molecules, coordination complexes and ionic solids, and understand the importance of the 3-D arrangements of atoms and ions in these molecules. Students should also be aware of the interactions between ions, atoms, molecules and other bonded collections of atoms.

11. Chemistry Analysis: Have the necessary knowledge and strategies for the separation, identification and quantification of compounds and elements from complex mixtures. Students must also be able to identify uncertainties associated with these measurements.

12. Measurement of Chemical and Physical Properties: Use traditional and modern laboratory equipment to measure chemical and physical properties of substances and be able to correlate the resulting data with chemical models of structure and reactivity.

13. Chemical Instrumentation: Understand the fundamental physical and chemical principles involved in instrumental chemical analyses. Students must understand the chemistry relevant to sampling and sample preparation and must apply these to the successful operation of instruments regardless of model or manufacturer.

14. Empirical basis of chemical knowledge: Students must demonstrate the essential laboratory skills to make accurate measurements and the ability to organize and interpret the resulting data. Students should also have the inductive and deductive reasoning skills necessary to arrive at conclusions from these data. They must also know of the appropriate use of modern, sophisticated instrumentation and proper interpretation of the data resulting from the use of these instruments. Students must be aware of key experiments that have led to the development of chemical theories and models.

15. Biosynthesis and Bioactivity: Understand the biosynthetic pathways and modes of action of biomolecules. Understand the importance of the 3-D arrangements of atoms and ions in these molecules. Students should also be aware of the relationship between structure and bioactivity of molecules.

Emphasis: Certified by the American Chemical Society

Foundation learning outcomes: 1–8

In-depth Learning Outcomes: 9–14

Emphasis: Biochemistry- Certified by the American Chemical Society

Foundation learning outcomes: 1–8

In-depth Learning Outcomes: 9, 11–15