UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

**The Grainger College of Engineering**
Department of Nuclear, Plasma, & Radiological Engineering
Suite 100 Talbot Laboratory, MC-234
104 S. Wright St.
Urbana, IL 61801

# NPRE 498 – Nuclear Chemical Engineering | Course Syllabus (Spring 2025)

**Instructors**

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**Schedule**

Mon Wed Fri 11:00-11:50 PM
106B6 Engineering Hall

**Credit**

Undergraduate: 3 credit hours, Graduate: 4 credit hours.

**Prerequisite**

CHEM102, ME200 (credit or concurrent enrollment), MATH285 (credit or concurrent enrollment). Instructor's approval required in absence of prerequisite.

**Office Hours**

To be determined according to students' and instructor's availability.

**Description**

The course will provide an introduction to the chemical engineering aspects for the design and operation of advanced nuclear reactors, focusing on theoretical elements, analytical techniques, and practical applications to new generation fusion and reactors. Topics in this course include chemical thermodynamics, electrochemistry, corrosion, and gas analysis. Topics will be presented using case studies relevant to nuclear technology, with a focus on systems employing high-temperature, non-aqueous liquids. The material developed in this course constitutes a foundation for students interested in conducting experimental research in the field of chemistry of advanced blankets and coolants.

**Grading**

The class is not graded on a curve. The class grade is composed of a weighted sum of your assignment grades, quiz grade, paper grade (only graduate students), midterm grade, and final grade. The weight of each partial grade is determined by how many assignments you decide to submit during the course. The more assignments you submit, the less the midterm and exam grade will count towards your final grade. This grading approach is chosen to let you focus only on the assignments that you are mostly interested in working on.

**Midterm and Final:**
One midterm exam is scheduled for the 8$^{h}$ week of instruction (one single-side letter-sized note sheet is allowed). The final exam is planned for finals week (one two-side letter-sized note sheet is allowed). Each test will be graded on a 0-100 scale. The length of the exams and the allotted time will be calibrated to prevent lack of time to be impacting your grade.

**Quizzes:**
Quizzes are small post-class assignments that are marked for completion (they do not receive a grade or grading comments, but submissions are read by me). The

format of the quizzes will vary across lectures and will based on the book "Classroom Assessment Techniques", by Dr. Cross and Dr. Angelo. For a full quiz grade, you must earn a total of 40 points. There are a total of 43 lectures, each with a 1-point quiz.

**Assignments:**
A total of 10 assignments will be released throughout the course. Assignments will be composed of a small set of problems to be solved individually and must be submitted electronically, as pdf file, on Canvas by 11:59pm on the due date (see course schedule below). Each assignment is graded on a 1-100 scale. In grading your assignments, the instructor pays attention to the logical solution process, and substantial credit is assigned if the solution steps are correct, but the final numerical results are off. As such, make sure that your arguments are transparent and reproducible; for example, your assumptions must be stated, always indicate units, etc.

**Paper (only graduate students):**
Graduate students will be divided in groups of 2/3 students and each group will work towards writing a literature review paper on a topic that leverages the themes introduced in this course. A list of topics will be provided during the course, and groups will be able to pick a topic from the list or propose a different one. You will start working on the paper on the second part of the course, and the paper will be due at the end of finals week. Grading rubrics will be provided ahead of time.

**Grade Breakdown:**
Each assignment has a weight of 5% on your final grade. You can decide how many assignments you want to submit. If you submit $n$ assignments ($5 \leq n \leq 10$) , your final grade will be composed of:

Undergraduates: 10% Quiz Grade, $n$•4% Assignment Grade, 45% - $n$•2% Midterm Grade, 45% - $n$•2% Final Grade.
Graduates: 10% Quiz Grade, $n$•4% Assignment Grade, 30% - $n$•2% Midterm Grade, 35% - $n$•2% Final Grade, 25% Paper Grade.

*Note: a minimum of five assignments are required to obtain a 100% mark. If you submit n < 5 assignments, a grade of 0 will be assigned to the missing assignments. Also note that the assignments are designed to help you prepare for the exams, and the problems in the midterm and exam will require knowledge from multiple modules of the course.*

| Letter Grade | Percentage | Letter Grade | Percentage |
|---|---|---|---|
| A+ | [95 - 100] | C | [70 - 74) |
| A | [90 - 95) | C- | [67 - 70) |
| A- | [87 - 90) | D+ | [65 - 67) |
| B+ | [84 - 87) | D | [62 - 65) |
| B | [80 - 84) | D- | [60 - 62) |
| B- | [77 - 80) | F | <60) |
| C+ | [74 - 77) | * | |

**Workload**

One credit hour corresponds to 3 hours of work per week (including lectures, reading, studying, and homework). The workload for undergraduate students in this class is of 3 credit hours, which corresponds to 3 hours of lecture and 6 hours of

independent work per week. The workload for graduate students in this class is 4 credit hours, which corresponds to 3 hours of lecture and 9 hours of independent work per week.

**Textbooks**

**[1]** Lecture notes on Canvas
**[2]** D. Olander, *General Thermodynamics,* CRC Press, 2007
**[3]** A. Bard, L.R. Faulkner, *Electrochemical Methods*, Wiley, 2001
**[4]** P. Atkins, *Physical Chemistry,* Oxford 2018

**Canvas**

Digital textbooks for this class are available free-of-charge through the university library. The rest of the course material will be made available through Canvas. Students are required to review all the materials (video presentations, pdf handouts, readings, assignments descriptions) added by the instructor for each class. Each student will review the online asynchronous material when required.

**Academic Integrity**

Students should pay particular attention to University of Illinois at Urbana-Champaign Student Code Article 1, Part 4: Academic Integrity. Read the Code, http://studentcode.illinois.edu/. Academic dishonesty may result in a failing grade. Every student is expected to review and abide by the Academic Integrity Policy: https://studentcode.illinois.edu/article1/part4/1-401/. Ignorance is not an excuse for any academic dishonesty. It is your responsibility to read this policy to avoid any misunderstanding. Do not hesitate to ask the instructor(s) if you are ever in doubt about what constitutes plagiarism, cheating, or any other breach of academic integrity.

**COVID Safety**

The most updated policy on Covid is at the following link: https://covid19.illinois.edu/on-campus/on-campus-students/.

**Absences due to illness**

Students who feel ill must not come to class. In addition, students who test positive for COVID-19 or have had an exposure that requires testing and/or quarantine must not attend class. These students are judged to have excused absences for the class period and should contact the instructor via email about making up the work. If you are absent, it is your responsibility to check on Canvas, contact the instructor or other students, to determine what was missed, including announcements made during class and/or any class meeting or assignment modifications. If you know that you need to miss class for an important reason (e.g., presenting a paper at a professional meeting; family emergency), please contact the instructor as soon as possible ahead of time. If you become ill and need to miss class, please e-mail the instructor.

**Students w/ Disabilities**

To ensure equity for each student's educational experience, those with documented disability and required accommodations should contact me early in the semester so that all learning needs may be appropriately met. If you have not yet contacted DRES, please do so as soon as possible.

To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor and the Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES, you may visit 1207 S. Oak St., Champaign, call 333-4603, e-mail disability@illinois.edu or go to https://www.disability.illinois.edu.

If you are concerned you have a disability-related condition that is impacting your academic progress, there are academic screening appointments available that can help diagnosis a previously undiagnosed disability. You may access these by visiting the DRES website and selecting "Request an Academic Screening" at the bottom of the page.

**Plagiarism**

Plagiarism is not admitted, there can be severe consequences such as reduction of the grade, fail of the course, and reporting to the College. Participants in University of Illinois courses retain copyright of all assignments and posts they complete; however, all materials may be used for educational purposes within the given course. In group projects, only the portion of the work completed by a particular individual is copyrighted by that individual. The University of Illinois may request that students' materials be shared with future courses, but such sharing will only be done with the students' consent. The information that students submit during a course may, however, be used for the purposes of administrative data collection and research. No personal information is retained without the students' consent.

**Student Behavior**

Students are expected to behave in accordance with the penal and civil statutes of all applicable local, state, and federal governments, with the rules and regulations of the Board of Regents, and with University regulations and administrative rules.

**Anti-Racism and Inclusivity**

This classroom is a place where you will be treated with respect. I welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, national origins, religious affiliations, sexual orientations, abilities - and other visible or non-visible differences. All members of this class are expected to contribute to a respectful, welcoming and inclusive environment for every other member of the class.

The intent is to raise student and instructor awareness of the ongoing threat of bias and racism and of the need to take personal responsibility in creating an inclusive learning environment. The Grainger College of Engineering is committed to the creation of an anti-racist, inclusive community that welcomes diversity along a number of dimensions, including, but not limited to, race, ethnicity and national origins, gender and gender identity, sexuality, disability status, class, age, or religious beliefs. The College recognizes that we are learning together in the midst of the Black Lives Matter movement, that Black, Hispanic, and Indigenous voices and contributions have largely either been excluded from, or not recognized in, science and engineering, and that both overt racism and micro-aggressions threaten the well-being of our students and our university community.

The effectiveness of this course is dependent upon each of us to create a safe and encouraging learning environment that allows for the open exchange of ideas while also ensuring equitable opportunities and respect for all of us. Everyone is expected to help establish and maintain an environment where students, staff, and faculty can contribute without fear of personal ridicule, or intolerant or offensive language. If you witness or experience racism, discrimination, micro-aggressions, or other offensive behavior, you are encouraged to bring this to the attention of the course director if you feel comfortable. You can also report these behaviors to the Bias Assessment and Response Team (BART) (https://bart.illinois.edu/). Based on your report, BART members will follow up and reach out to students to make sure they have the support they need to be healthy and safe. If the reported behavior also violates university policy, staff in the Office for Student Conflict Resolution may

respond as well and will take appropriate action.

**Sexual Misconduct Reporting Obligation** The University of Illinois is committed to combating sexual misconduct. Faculty and staff members are required to report any instances of sexual misconduct to the University's Title IX Office. In turn, an individual with the Title IX Office will provide information about rights and options, including accommodations, support services, the campus disciplinary process, and law enforcement options. A list of the designated University employees who, as counselors, confidential advisors, and medical professionals, do not have this reporting responsibility and can maintain confidentiality, can be found here: wecare.illinois.edu/resources/students/confidential. Other information about resources and reporting is available here: wecare.illinois.edu.

**Religious Observances** Illinois law requires the University to reasonably accommodate its students' religious beliefs, observances, and practices in regard to admissions, class attendance, and the scheduling of examinations and work requirements. You should examine this syllabus at the beginning of the semester for potential conflicts between course deadlines and any of your religious observances. If a conflict exists, you should notify your instructor of the conflict and follow the procedure at https://odos.illinois.edu/community-of-care/resources/students/religious-observances/ to request appropriate accommodations. This should be done in the first two weeks of classes.

**FERPA** Any student who has suppressed their directory information pursuant to Family Educational Rights and Privacy Act (FERPA) should self-identify to the instructor to ensure protection of the privacy of their attendance in this course. See https://registrar.illinois.edu/academic-records/ferpa/ for more information on FERPA.

**Personal and Grade-related Questions**
Questions of a personal nature should first be sent to the instructor's e-mail address (vergari@illinois.edu). When sending e-mail, include a subject that identifies the course number and nature of your question.

**Emergencies**
If you have an emergency that will keep you from participating in the course, please notify your instructor by using the instructor's e-mail address (vergari@illinois.edu). Provide callback information in your e-mail (if necessary). You should also notify your program director of any emergencies.

**Syllabus Change Policy**
The course outline in the syllabus is a guide and is subject to change at the discretion of the instructor. Any changes in due dates will be publicly announced in class and on Canvas.

## Course Schedule

An updated schedule will be maintained during the course. A reading guide will be added to each module.

| W | Lec. | D | Module | Content | Assignment |
|---|---|---|---|---|---|
| 1 | L1 | 1/22 | Introduction | Course intro. Syllabus discussion. Surveys. | |
| | L2 | 1/24 | Intro to Advanced Reactors | Nuclear 101. Reactor engineering. | |
| 2 | L3 | 1/27 | | Nuclear materials. Operating conditions. Material requirements. | |
| | L4 | 1/29 | Chemical Thermodynamics | Thermodynamic fundamentals. First and second law. | HW 1 released |
| | L5 | 1/31 | | Equilibrium. Phase equilibria in one phase. Multi-component systems: ideal and non-ideal mixtures | |
| 3 | L6 | 2/3 | | Chemical potentials, activity coefficients, binary phase equilibria | |
| | L7 | 2/5 | | Chemical reactions. Law of mass action | |
| | L8 | 2/7 | | Tools in chemical thermodynamics: Ellingham diagrams | HW 1 due<br>HW 2 released |
| 4 | L9 | 2/10 | | Exercises on chemical thermodynamics | |
| | L10 | 2/12 | | *Module Recap session* | |
| | L11 | 2/14 | Electrochemistry and Mass Transport | Electrochemical cells, half-cell reaction, redox reaction, Nernst equation | |
| 5 | L12 | 2/17 | | Redox reactions in a molten salt | HW 2 due<br>HW 3 released |
| | L13 | 2/19 | | Electrode kinetics, B-V Equation | |
| | L14 | 2/21 | | B-V Equation, Tafel kinetics | |
| 6 | L15 | 2/24 | | Intro to mass transfer, Fick's laws. Mass diffusion. | |
| | L16 | 2/26 | | Mass diffusion: mathematical formulation. Boundary conditions | HW 3 due<br>HW 4 released |
| | L17 | 2/28 | | Solution of diffusion problems. Diffusion profiles | |
| 7 | L18 | 3/3 | | Analytical electrochemistry: CA, CP | |
| | L19 | 3/5 | | Analytical electrochemistry: CV | |
| | L20 | 3/7 | | Exercises on electrochemistry | HW 4 due<br>HW 5 released |
| 8 | L21 | 3/10 | | *Module Recap Session* | |
| | L22 | 3/12 | *Midterm Recap Session* | | |
| | L23 | 3/14 | **Midterm** | | |
| 8 | - | 3/17 | *Spring break* | | |
| | - | 3/19 | | | |
| | - | 3/21 | | | |
| 9 | L24 | 3/24 | Corrosion | Intro to corrosion. Types of corrosion | HW 5 due<br>HW 6 released |
| | L25 | 3/26 | | Techniques to study corrosion | |
| | L26 | 3/28 | | Corrosion in nuclear reactors: molten salts | |
| 10 | L27 | 3/31 | | Corrosion in nuclear reactors: molten metals | |
| | L28 | 4/2 | | Exercises on corrosion | HW 6 due<br>HW 7 released |
| | L29 | 4/4 | | Non-metallic corrosion | |
| 11 | L30 | 4/7 | | Exercises on corrosion | |
| | L31 | 4/9 | | *Module Recap Session* | |
| | L32 | 4/11 | Gas – Solid Interactions | Reaction kinetics | HW 7 due<br>HW 8 released |
| 12 | L33 | 4/14 | | Adsorption, absorption, desorption | |
| | L34 | 4/16 | | Adsorption isotherms | |
| | L35 | 4/18 | | Adsorption and mass transport | |
| 13 | L36 | 4/21 | | Desorption, rate limiting steps | HW 8 due<br>HW 9 released |
| | L37 | 4/23 | | Thermal desorption spectroscopy | |
| | L38 | 4/25 | | Case study: tritium adsorption in graphite | |
| 14 | L39 | 4/28 | | Case study: tritium removal from fusion blankets | |
| | L40 | 4/30 | | Exercises on gas-solid interactions | HW 9 due<br>HW 10 released |
| | L41 | 5/2 | | *Module Recap Session* | |
| 15 | L42 | 5/5 | | *Final Recap Session – Theory* | |
| | L43 | 5/7 | | *Final Recap Session – Exercises* | HW 10 due |