# Department of Chemical and Biomolecular Engineering
# North Carolina State University

**CHE 446** **Design and Analysis of Chemical Reactors** **Parsons, Fall 2009**

**Time:** 9:35 – 10:25 MWF Classroom: EB1 – 1007


**Instructor:** Professor Gregory Parsons
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Office hours: W 10:30 -11:30

**Assistants:**

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**Required Text:**

G.W. Roberts "Chemical Reactions and Chemical Reactors" Wiley, 2009.

**Course purpose:**

This course is an introduction to characterization and measurement of the rates of homogeneous and heterogeneous reactions. The concepts also include fundamental engineering principles associated with the design and analysis of chemical reactors.

**Course objectives:**

By the end of the course, you should be able to:

a) Develop a rate equation from experimental kinetic data.
b) Analyze various reactor design options for carrying out multiple reactions.
c) Utilizing knowledge of reaction kinetics, size various ideal reactors to carry out a specific job and produce a specific product.
d) Derive the form of a rate equation based on the sequence of elementary reactions involved.
e) Use the energy balance to calculate the required heat-transfer area in an isothermal reactor and the required reactor size under adiabatic conditions.

**Prerequisites:** C or better in CHE 316. CHE 312 is a co-requisite.

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**ABET Accreditation Outcomes (http://www.abet.org)** Our ABET goal is to demonstrate that students attain the following outcomes:

(a) an ability to apply knowledge of mathematics, science, and engineering

*All assignments and work in this class supports this outcome.*

(b) an ability to design and conduct experiments, as well as to analyze and interpret data

(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

*Work in this class that supports this outcome includes: Chemical reactor design, including sizing ideal reactors to carry out a specific job and analysis of various reactor design options for carrying out multiple reactions.*

(d) an ability to function on multi-disciplinary teams

(e) an ability to identify, formulate, and solve engineering problems

*Work in this class that supports this outcome includes: Identification and solution of engineering problems related to the design of chemical reactors and the characterization of reaction rates and reaction mechanisms.*

(f) an understanding of professional and ethical responsibility

(g) an ability to communicate effectively

(h) a broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

(i) a recognition of the need for, and an ability to engage in life-long learning

(j) a knowledge of contemporary issues

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

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## Policies and Procedures

### Instructor and Classroom

- Your instructor's primary goal is to provide the opportunity and environment for your highest quality education. Your instructor will be courteous, respectful, and punctual, and will be well organized and prepared for the lectures. Questions will be answered promptly and in a positive tone. The instructor will make himself available to meet you outside of class time as needed, and he will respond promptly when you indicate your desire to meet him. He will inform you ahead of time regarding his plans for travel or time out of the office, and will provide a suitable guest lecturer when needed. The instructor will also assure a grading process that is fair, uniform and consistent. He will also listen carefully and give attention to your comments and suggestions for improving the class or overall learning environment.

- The classroom environment is to be maintained to promote concentration and learning of the course subject matter, and all students are expected to maintain this positive environment for fellow students. Cell phones and other electronic devices are to be kept turned off during class and during exams, and students are expected to refrain from any activity that distracts the class's attention from the course materials. Text-messaging during class or exams is strictly forbidden.

### Tests

- There will be three tests and a final exam, all **closed book**, and will be scheduled during class time. Other short quizzes may also be given, and will be announced at least one class ahead of time. Use of homework solutions, notes, any reference materials, sharing of calculators, or any electronic communication during examinations or quizzes is strictly forbidden.
- If you have a reasonable excuse for not being able to take a test or quiz at the assigned time, you must inform the instructor before the exam, and arrangements will be made.
- If you miss a test with prior approval from the instructor, or certified (i.e. doctor's) excuse, arrangements will be made to make up the test grade on an individual basis. If you miss a test or quiz without instructor's prior approval or certified excuse, you will receive a zero for that test or quiz. In extreme circumstances, at the discretion of the instructor, a retest may be given. If you miss the final exam for any reason, a zero will be averaged into your grade. For a full statement of the university attendance policy, see http://www.ncsu.edu/policies/academic_affairs/pols_regs/REG205.00.4.php
- In-class quizzes may be assigned periodically. They will be announced at least one class period ahead. Quizzes will be graded and counted as one homework problem.

### Required Homework

- Homework will be done individually. You may discuss homework problems with your classmates, but copying solutions from any current or previous student or any other source is not allowed. If the instructor or TA suspects a problem is copied, serious consequences will also be pursued in accordance with the University's student code of conduct (see link given below).
- Homework is generally due every week. Problem sets must be handed in at the beginning of class on the due date. Use engineering paper, write only on the front side. Staple the pages and fold them vertically before handing them in. Clearly box your solutions. Neatness counts on the homework. Neatly presented homework solutions make the papers easier to grade, and it makes it more likely that the grader will find areas to give you partial credit. Also, if the homework cannot be easily read and understood by the grader, the grader is permitted to return it to you ungraded. To receive credit, you can rewrite it and turn it in as "Late" homework.
- Late homework can be turned in up to 2 weeks after the due date. It will receive only cursory grading, with a maximum of 50% credit possible.

- **Dead Week:** Tests will not be assigned during the last week of class.

**Consulting with instructor and TA on tests, homework and grading**

- You are strongly encouraged to discuss questions related to homework or exams directly with the TA. E-mail questions regarding hints how to solve the homework problems should be addressed to only the TA. Any questions regarding exam grading should also be addressed to the TA. If you disagree with the TA's decision regarding grading, the instructor will review the situation and make the final decision.

**Academic integrity**

- Students should refer to the University policy on academic integrity found in the Code of Student Conduct (found in *Appendix L of the Handbook for Advising and Teaching*). http://www.ncsu.edu/policies/student_services/student_discipline/POL11.35.1.php It is the instructor's expectation that the student's name on any test or assignment means that they neither gave nor received unauthorized aid. Similarly, *the homework assignments should be prepared individually*. Authorized aid on an individual assignment includes discussing the interpretation of the problem statement, sharing ideas or approaches for solving the problem, and explaining concepts involved in the problem.
- Any computer work submitted must be completed on your own personal computer or from your own account. No sharing of files in any way is allowed.
- Sharing of any course material with third parties (i.e. anyone outside this class section), posting any materials on the internet, or allowing others to post materials on the internet or in any other public area is strictly forbidden.

**Grading**

- The responsibility for grading tests and homework assignments reside with the teaching assistant. The final grades are decided by the instructor.
- The course grades will be calculated as follows: Tests 18% each; Homework 15%; Final exam 31%. Homework sets will be graded at 10 points per problem. Therefore, the value of the homework set will depend on the number of problems assigned. It is possible for every student in the class to earn an A. Plus/minus grading will be used.

**Disabled students**

- North Carolina State is subject to the Department of Health, Education, and Welfare regulations implementing Section 504 of the Rehabilitation Act of 1973. Section 504 provides that: "No otherwise qualified handicapped individual in the United States. . . shall, solely by reason of his handicap be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance." This regulation includes students with hearing, visual, motor, or learning disabilities and states that colleges and universities must make "reasonable adjustments" to ensure that academic requirements are not discriminatory. Modifications may require rescheduling classes from inaccessible to accessible buildings, providing access to auxiliary aids such as tape recorders, special lab equipment, or other services such as readers, note takers, or interpreters. It further requires that exams actually evaluate students' progress and achievement rather than reflect their impaired skills. This may require oral or taped tests, readers, scribes, separate testing rooms, or extension of time limits. The instructor abides by all these regulations and is supportive of students requiring any special accommodations. The instructor also respectfully treats any personal situation that effects the class or student learning with strict privacy.

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*Class Schedule*

| Week # | Dates | Subject | Reading: |
|---|---|---|---|
| 1 | 8/19 - 21 | Introduction to Reactions and Reaction Rates | Ch. 1 |
| 2-3 | 8/24 – 9/4 | Reaction Rates and Rate Equations<br>Ideal Reactors – Batch Reactors | Ch. 2<br>Ch. 3 |
| 4 | 9/7 – 11 | *No Class 9/7*<br>Ideal Reactors, cont'd<br>Ideal Continuous Reactors | <br><br>Ch. 3 |
| 5 | 9/14 - 18 | **In-class Exam Wed 9/16**<br>Graphical Interpretation of Design Equations | <br>Ch. 3 |
| 6 | 9/21 – 25 | Sizing of Ideal Reactors<br>Homogeneous Reactions<br>Heterogeneous Catalytic Reactions | Ch. 4 |
| 7 | 9/28 – 10/2 | Systems of Continuous Reactors<br>*Last day to drop, Friday 10/16* | Ch. 4 |
| 8 | 10/5 - 7<br>*10/8–9* | Reaction Rate Fundamentals<br>*Fall Break* | Ch. 5 |
| 9 | 10/12 - 16 | **In-class Exam Wed 10/14**<br>Use of the Steady State Approximation | Ch. 5 |
| 10 | 10/19 - 23 | Analysis of Experimental Kinetic Data | Ch. 6 |
| 11 | 10/26 – 30 | Multiple Reactions | Ch. 7 |
| 12 | 11/2 – 6 | Multiple Reactions, cont'd | Ch. 7 |
| 13 | 11/9 – 13 | Energy Balance in Reactor Sizing | Ch. 8 |
| 14 | 11/ 16 – 20 | **In-class Exam Wed 11/19**<br>Heterogeneous Catalysis | <br>Ch. 9 |
| 15 | 11/23<br>*11/25-27* | Heterogeneous Catalysis, cont'd<br>*Thanksgiving Break* | Ch. 9 |
| 16 | 11/30 – 12/4 | Non-Ideal Reactors<br>Review | Ch. 10 |
| | | **Final Exam (Comprehensive)**<br>**Friday Dec 11, 8-11AM** | |