Kinetics of Materials

Syllabus

Spring 2025

Course details:

3 credits

Course code:	MTEN 311
Course title:	Kinetics of Materials

In person classes:

Location:	Faculty Memorial Hall (FMH) 203
Time:	Tuesdays and Thursdays, 2:30 to 3:50 pm

Course Instructor and Office hours:

Instructor:	Asst. Prof. Kerri-lee Chintersingh, Tiernan 376
Office hours:	Please email to make appointment. I am also available on campus on Tuesdays and Thursdays from 10 am to 5 pm.
Email address:	kerri.lee.chintersingh@njit.edu
Office number:	973-642-4468

Virtual office hours

Virtual meeting times can be arranged, subject to the instructor's availability week by week. To make these arrangements, please email the instructor to find a mutually convenient time. Once the time, date and mode (in-person or virtually) has been confirmed, the instructor will provide you with the Zoom meeting link and details.

Course description:

Kinetics of materials is an undergraduate core materials engineering course that focuses on applying engineering principles to describe how "fast" reactions take place and/or atoms move, in the case of diffusion. Students will be able to build upon past theory in thermodynamics and physical chemistry to better describe chemical reactions and solid-state diffusion phenomena in the hope to better understand and design novel materials. Fundamental kinetic processes and driving forces will be derived and described and students will be able to qualitatively and quantitatively apply concepts learnt to actual real-life examples and be exposed to current research and the latest methods and models relevant to materials. Because materials engineers most often deal with solids, we focus primarily on gas-solid, liquid-solid, and solid-solid kinetic processes.

Course organization:

The course is designed to bridge the concepts learnt in theory to application. It is also organized to encourage class discussion and participation. The class session includes a lecture and in-class problem solving facilitated by the instructor. This focuses on traditional core theoretical concepts and calculations relevant to solid state diffusion, phase transformations and kinetics. There will also be a mini project to expose students to research and current methods utilized to determine kinetic parameters such as activation energy using thermogravimetric analyses of materials.

Lecture slides and auxiliary notes (chapters, journal articles, review papers, etc.) will be available on CANVAS before each class session. Solutions for the assignment problems will be posted after in-class work sessions. Resources provided should be used as a guide for studying. Taking notes is strongly encouraged.

Required software:

Microsoft Word, Excel and PowerPoint software will be required. These are available for download from NJIT software webpage: https://ist.njit.edu/software-available-download#v.

Suggested/supportive texts:

There are several textbooks that can be utilized to support knowledge on kinetics for material science and engineering. Please note that you are NOT required to purchase textbooks for this course. The textbooks listed below may be useful in strengthening core materials science and engineering concepts and practicing problems relevant for this course and is available online through the library.

The recommended text is:

- R. O'Hayre, *Materials Kinetics Fundamentals: Principles, Processes and Applications,* Wiley, NY, 2015. ISBN-13: 978-1118972892

Other additional textbooks/handbooks and useful resources are:

- R. W. Ballufi, S.M. Allen, W. C. Carter, Kinetics of Materials, Wiley, NY, 2005. ISBN-13: 978-0-471-24689

Course goals/ objectives:

At the end of the course, student should be able to:

- State and apply concepts of core engineering principles such as thermodynamics and kinetics and identify situations where kinetics can be used to understand/ model materials phenomena.
- Explain the difference between equilibrium, steady-state, and time-dependent (non-steady state) processes related to material kinetics and behavior.
- Quantitatively apply conservation laws, transport laws, and reaction rate laws to model kinetic processes including chemical reactions, diffusion and transport, phase transformations, nucleation and growth, and microstructural evolution.
- Explain the atomistic mechanisms of reactions, diffusion, and phase transformation and predict how these processes change with temperature, pressure, concentration, or other external variables.
- Describe materials technology-relevant examples of gas-phase, gas-solid, liquid-solid, and solid-solid kinetic processes and critically analyze concrete real-world experience of physical phenomena to understand and describe more abstract kinetic principles.

Assignments and Grading Policies:

The breakdown for grades is as follows:

Table 1. Grade breakdown for MTEN 311-Kineics of Materials

Assignments	15%
Quizzes/Student- led tutorial session	15%

Mini-project	15%
Mid semester Exam	25%
Final Exam	30%

Assignments (15%)

Assignments will be given and uploaded on CANVAS to be completed throughout the duration of the course. Students are required to submit individual assignments either in person at the start of class or via CANVAS on the due date following the proposed schedule in Table 3 below. Graded assignments will be returned one week after they are submitted. Assignments will cover concepts discussed in classes. Assignment solutions will be posted for students to review and improve their performance. Collaboration on assignments is encouraged, although each person must turn in his or her own set of solutions. Complete work, including answer sheets and diagrams (where necessary), must be provided to support responses in detail. Points will be deducted for late homework, up to a week after the due date. **No assignments will be accepted after a week past the due date.**

Quizzes/Student-led tutorial sessions (15%)

Quizzes covering conceptual content from each lecture will be conducted weekly at the start of classes held on Thursday at 2:30 pm. Students will be able to complete the quiz within the first 15 minutes of class, afterwards, a student will be assigned to lead in-class discussion and problem solving and review the quiz solution prior to the start of the lecture. Students are encouraged to participate and to solve problems prior to the start of class. Extra credit will be given to students who can solve additional homework problems during these tutorial sessions.

Mini-Project (15%)

Students will be required to work as a team to select **one** research paper published between 2005 and 2023 that focuses on performing kinetic computations in materials using thermal analysis data or determining kinetic parameters for materials using thermal analysis. The team will prepare a 10–15-minute presentation with a summary of the method, accomplishments, limitations and constructive criticism of the conducted experiment or developed model/method. Each student will also be required to submit a 1-page individual critique of the paper submission. A copy of the reviewed paper, the critique and the 10-15 minute power point presentation should be submitted on the mini-project due date as outlined in Table 3. The presentations will be given during class time, as outlined by the instructor. If time allows, by the end of the course, students will collect, process and analyze thermal analysis data from materials research and examine different methods for determining kinetic parameters currently used in research in comparison to the paper selected. More details will be provided during class.

Mid-semester test (25%) and Final exam (30%)

The first written exam will be a 1- hour 20 minutes long written test assessing student problem solving and application of knowledge of topics covered up to spring break. The test will be conducted in-class during Week 10. The final exam will be comprehensive and cover concepts from Weeks 1 to the end. It will be administered on the final exam date set by the registrar. It will be 2 hours long. Both tests will be open book/open notes. Students will be assigned 3-4 problems to complete for each test. More details on the exam format and procedure will be provided during the first week of class.

Grading Scale (changes may apply):

Table 2. Grade scale assignment for MTEN 311 Spring 2025

A	> 90
B+	80-90
B	75-80
C+	70-75
C	60-70
D	50-60
F	<50
I	Incomplete

Re-grade/Make-up policy:

Opportunities to improve grade score or complete assignments to improve overall grade can be discussed with the instructor on a case-by-case basis. For discrepancies or questions related to grades received during the semester, you can discuss and request a regrade or makeup for quizzes, assignments, and mid-semester tests within 1 week after the material was graded and returned to you. The new grade will be the final grade. If there are concerns with your final overall course grade and a grade change is requested, this will be done following University guidelines as outlined in the catalog: https://catalog.njit.edu/undergraduate/academic-policies-procedures/

University policies: Accommodation

If you need accommodation due to a disability or challenge please contact Scott Janz, Associate Director of Office of Accessibility Resources & Services (OARS), Kupfrian Hall 201 to discuss your specific needs. A Letter of Accommodation Eligibility from the OARS authorizing your accommodations will be required. Other resources for special support services can be found here: https://www.njit.edu/studentsuccess/support-services-and-accommodations

Academic Integrity

Academic Integrity is the cornerstone of higher education and is central to the ideals of this course and the university. **Cheating is strictly prohibited and devalues the degree that you are working on**. As a member of the NJIT community, it is **your responsibility** to protect your educational investment by knowing and following the **academic code of integrity policy.** More details on this is provided at the following link:
https://www5.njit.edu/policies/sites/policies/files/NJIT-University-Policy-on-Academic-Integrity.pdf

Please note that it is my professional obligation and responsibility to report any academic misconduct to the Dean of Students Office. Any student found in violation of the code by cheating, plagiarizing or using any online software inappropriately will result in disciplinary action. This may include a failing grade of F, and/or suspension or dismissal from the university. If you have any questions about the code of Academic Integrity, please contact the Dean of Students Office at dos@njit.edu

COVID policy:

Based on the NJIT memo regarding Course Requirements and Expectations for Spring 2023, dated January 11, 2023 from the Interim Provost and Senior Executive Vice President:

"Although not mandated, both students and instructors are free to wear facemasks in the classroom, if they so desire. Instructors are not allowed to set their own rules on this issue. The university will be actively monitoring the situation and if the conditions call for it, the policy may be changed."

If you are feeling unwell and experiencing any of the COVID- like symptoms, please follow University guidelines as stipulated at the following website: https://www.njit.edu/healthservices/. Any student who has tested positive, should inform the relevant University authorities at **covid.notify@njit.edu** so that proper contact tracing and COVID recovery measures can be completed. If he/she is unable to attend class sessions, measures for making up or conducting the presentations at a later date will be discussed on a case by case basis. This should be reported to the Dean of Students. More resources on COVID can be found here: https://www.njit.edu/counseling/c-caps-covid-19-bulletin

Attendance Policy

All students are required to attend all classes. If a student is unable to attend a class session, the instructor should be informed via email of your absence prior to the start of the class.
Class attendance will also be recorded by instructor.

Withdrawal

Student requests for withdrawals after the deadline *(end of the 10th week of classes)* will not be permitted unless extenuating circumstances are documented **through the Office of the Dean of Students**. If you are considering withdrawing, please contact the course instructor and the Dean of Students.

Course Schedule:

Table 3.Table showing week by week class schedule and topics for Spring 2025. This will be used as a guide for the course.

WEEK 1: Jan. 21 & 23	**Course Introduction:** What is kinetics? Importance of studying kinetics Classifying kinetic processes; Homogeneous vs heterogeneous; Quantifying reaction and diffusion rates; Reactions vs Diffusion Kinetics vs Thermodynamics
WEEK 2: Jan. 28	**Driving forces and thermodynamics** Dynamic equilibrium, enthalpy, entropy, Gibbs free energy Chemical potential, reaction quotient and equilibrium constant, K Temperature dependence of K Ideal Gas Law Deviation from equilibrium **HOMEWORK #1 DUE**
WEEK 2: Jan. 30	**NO CLASS (Conference trip) ****
WEEK 3: Feb. 4 & 6	**Reaction kinetics** Homogeneous vs heterogeneous reactions Reaction rate equations

	Rate constant; order of reactions Zero ,1st and 2nd order rate laws
WEEK 4: Feb. 11 & 13	**Reaction kinetics** Incomplete reactions Equilibrium reactions Effect of temperature- Arrhenius equation **HOMEWORK #2 DUE**
WEEK 5: Feb. 18 & 20	**Reaction kinetics** Heterogeneous chemical reactions: catalysts and gas- solid surface reactions
WEEK 6: Feb. 25 & 27	**Diffusion kinetics** What is diffusion? Diffusion flux; Steady state diffusion Fick's first law; mass transfer Atomistic mechanisms for diffusion -kinetic theory of gases
WEEK 7: March 4 & 6	**Diffusion kinetics** Generalized flux equation: mobilities and driving forces Solid- state diffusion **HOMEWORK #3 DUE**
WEEK 8: March 11 & 13	**Diffusion kinetics** 1D and 2D transient diffusion **REVIEW**
WEEK 9: March 18 & 20	**SPRING BREAK**
WEEK 10: March 25 & 27	**MID-TERM TEST** **Gas- solid kinetics** Adsorption/Desorption Precipitation from gas Gas corrosion **MINI-PROJECT DUE**
WEEK 11: April 1	**Gas-solid kinetics** CVD & ALD Production and Oxidation of Silicon Oxidation of metals
WEEK 11: April 3	**WELLNESS DAY**
WEEK 12: April 8 & 10	**Solid- Liquid & Solid- Solid kinetics** Phase transformation **HOMEWORK #4 DUE**
WEEK 13: April 15 & 17	**Solid- Liquid & Solid- Solid kinetics** Surface & Interface energies
WEEK 14: April 22 & 24	**Solid- Liquid & Solid- Solid kinetics** Homogeneous & heterogeneous nucleation Nucleation & growth Solidification
WEEK 15: April 29 & May 1	**Solid- Liquid & Solid- Solid kinetics** Overall transformation rate TTT diagrams **HOMEWORK #5 DUE**
WEEK 16: May 6	**Microstructural Evolution** Surface smoothing and evolution Coarsening & grain growth Sintering

	REVIEW
WEEK 17: **FINAL EXAM DATE**	