# MSE 316: Thermodynamics and Kinetics of Materials

*Course description:* Laws of thermodynamics, solution thermodynamics, free energy composition diagrams, mechanisms and kinetics of diffusion; solidification behavior, interfaces and phase boundaries, phase transformations in solids, oxidation and corrosion.

*Number of credits:* 3. This course is required.

*Course Coordinator:* Qizhen (Katherine) Li

*Prerequisites by course:* MSE 201

*Prerequisites by topic:* Phase equilibrium and phase diagram interpretation, physical chemistry, introductory materials science, differential equations.

*Postrequisites:* None

*Textbooks/other required materials:*

1. Easterling, E. and Porter, D. *Phase Transformations in Metal and Alloys.* CRC Press

*Course objectives:*

1. Introduction to laws of thermodynamics.
2. Introduction to solution thermodynamics applied to chemical and phase equilibrium.
3. Introduction to free energy composition diagrams.
4. Derivation of diffusion equations, description of diffusion sources, boundary conditions, temperature dependence.
5. Mechanisms of diffusion.
6. Introduction to solidification behavior of metals and alloys.
7. Applications -- Czochralski crystal growth.
8. Isothermal transformation diagrams, mechanisms promoting C-type isothermal behavior.
9. Analysis of continuous cooling behavior, CT diagrams, quench factor.
10. Diffusional and diffusionless phase transformations.
11. Stages in precipitation -- GP zones, coherency, overaging.
12. Introduction to oxidation mechanisms of materials.
13. Introduction to electrochemical reactions -- half cell reactions, electrode potantials.
14. Analysis of electrode polarization -- polarization diagrams.
15. Treatment of the exchange current density and the Tafel equation.
16. Introduction to the mixed potential theory of corrosion.

*Topics covered:*

1. Laws of thermodynamics.
2. Solution thermodynamics for chemical and phase equilibrium.
3. Free energy composition diagrams.

4. Rate equations of homogeneous and heterogeneous reactions.
5. Diffusion.
6. Solidification behavior: Nucleation and growth.
7. Phase transformations in materials.
8. Precipitation hardening in aluminum alloys.
9. Oxidation of materials.
10. Electrochemical reactions and polarization diagrams.
11. Mixed potential theory of corrosion.

*Expected learning outcomes:*

1. Knowledge of enthalpy, entropy and free energy.
2. Knowledge of ideal and regular solutions and free energy of mixing.
3. Knowledge of the type of variable that affects heterogeneous reaction rates -- nucleation, interfacial energy, interface equilibrium, diffusion, defects and impurities, temperature.
4. An understanding of the effect of diffusion rates, types of source, sinks, mechanisms, on composition changes.
5. Recognition and understanding of solute redistribution during solidification and its significance in practical applications.
6. Knowledge of the mechanisms and behavior of important transformations --- decomposition of austenite, formation of bainite and martensite, formation of strengthening precipitates.
7. Commercial application of these principles in heat treatment.
8. An understanding of oxidation behavior of materials.
9. An understanding of the nature of polarized electrochemical reactions and an introduction of their application in corrosion behavior of metals.

*Class schedule:* Three 50-minute lecture sessions per week, for one semester

*Laboratory schedule:* None

*Contribution to meeting the professional component:* Engineering Topics

*Relationship of course to student outcomes:*
3 strongly supported; 2 supported; 1 minimally supported

Student Outcomes Pre-Fall 2018 (ABET EC2000)

| a | b | c | d | e | f | g | h | i | j | k | l | m | n | o |
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Student Outcomes Fall 2018 forward (ABET EC2019)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
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| 3 | 1 | | 1 | | | 2 | 3 | | | |

*Prepared by:* Andrea Butcherite and Dr. Katherine Li *Date:* May 30, 2018