Materials Engineering 152
Learning Objectives

Prerequisite knowledge:

Knowledge gained during the undergraduate program from MatE 115, MatE 25 and MatE/ChE 151, or equivalent courses for graduate students, is assumed. In particular, it is expected that the student can:

1. Identify the 14 Bravais lattices.
2. Identify what Bravais lattice a crystal belongs to as well as the crystallographic basis.
3. Manipulate the Maxwell relations in thermodynamics.
4. Define and calculate the thermodynamic functions free energy (Gibbs and Helmhotz), internal energy, total energy, heat capacity, specific heat, entropy
5. Utilize an Arrhenius relationship and determine an activation energy from empirical data

MatE 152 Specific Learning objectives:

After successfully completing all course assignments including reviewing lecture notes, participating in class discussions and bluesheets, homework assignments and examinations, the student should be able to:

General Thermo Principles

1. Calculate entropy, enthalpy, and Gibbs free energy of a substance at different temperatures from heat capacity terms.
2. Utilize tables of thermodynamic data to calculate thermodynamic functions at various temperatures and for different reactions.
3. Define entropy and enthalpy in their standard state.
4. Calculate changes in Gibb's free energy as you transform between phases or change temperature or pressure.
5. Calculate molar and total entropy, enthalpy, and Gibb's free energy.
6. Calculate the specific volume.

Solution Thermo

7. Calculate mole fraction in a solution.
8. Calculate entropy, enthalpy and Gibbs free energy of mixing in solution.
9. Calculate chemical potential (partial molar free energy) and activity of components in solution.
10. Distinguish between regular and ideal solutions.
11. Define entropy of mixing and enthalpy of mixing for both regular and ideal solutions.
12. Determine whether a regular solution is exothermic or endothermic from the bond energies.

Phase Diagrams

13. Construct a phase diagram from free energy curves.
14. Predict general shape and type of phase diagram from exothermic and endothermic relationships between atom bonds.

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15. Read a solid state phase diagram and differentiate between areas of phase equilibrium.
16. Determine if a material system will be stable or unstable.
17. Utilize Gibbs Free Energy curves to predict phase equilibrium and compositions of the phases in equilibrium.
18. Determine chemical potential and Gibb's free energy of the pure state from Gibbs Free Energy curves.
19. Determine the number of components in material system.
20. Identify number of degrees of freedom.

Diffusion

21. Identify various point defects and describe diffusion mechanisms.
22. Calculate diffusion coefficients.
23. Determine activation energies from rates of reactions from diffusion data.
24. Describe how random atomic motions result in net diffusion down a concentration gradient.
25. Derive Fick's first and second law
26. Identify the boundary conditions for various solutions to Fick's second law
27. Plot diffusion profiles as a function of temperature and time.
28. Describe the difference between self-diffusion, intrinsic diffusion, and interdiffusion coefficients.
29. Calculate self-diffusion coefficient from radiotracer data.
30. Describe the Kirkendall phenomena.
31. Explain the creation and annihilation of vacancies needed in interdiffusion.
32. Calculate the interdiffusion coefficient or intrinsic diffusion coefficients from marker velocity data.
33. Calculate the interdiffusion coefficient from intrinsic data in a binary solution.
34. Explain the driving force for diffusion in cases where species diffuse up a concentration gradient.

Defects, Surfaces, and Interfaces

35. Calculate equilibrium point defect concentrations as a function of temperature.
36. Discuss the difference between surface tension and surface energy in liquids and solids.
37. Calculate the surface energy for different crystal orientations.
38. Discuss how surface energy affects the driving force for transformation (Gibb's free energy change).
39. Calculate the influence of surface energy on equilibrium properties like composition and melting temperature.
40. Explain the Ostwald ripening phenomena.
41. Discuss ways in which surface energy is measured.
42. Calculate the equilibrium arrangement of surfaces or interfaces based on their interface energy.
43. Calculate the wetting angle of a liquid to a solid using surface energies.
44. Explain grain coarsening.
45. Explain how the interfacial energy affects stability of a phase.

46. Distinguish between coherent, incoherent and semi-coherent interfaces
47. Apply the affect of coherency strain to interface formation.
48. Determine why an interface occurs in a certain shape.
49. Predict precipitate shape from Wulff diagram.

Nucleation

50. Calculate the free energy of formation and critical embryo size
51. Distinguish between heterogeneous and homogeneous nucleation
52. Describe effect of strain on nucleation kinetics
53. Calculate rate of nucleation

Crystallization/ Solidification/ Growth

54. Calculate dendrite growth rate in a solution
55. Determine effect of constitutional supercooling
56. Describe effect of solute partitioning
57. Calculate eutectic solidification rates
58. Recommend materials processing to achieve a desired microstructure
59. Determine the driving force for a transformation
60. Calculate rate and size of precipitation reaction
61. Distinguish between supersaturation and diffusion controlled growths
62. Distinguish between spinodal reaction and precipitation reaction

Kinetics of Transformations

63. Use linear regression to determine transformation kinetics
64. Use "time for constant fraction" technique
65. Use "Change of slope" technique
66. Use rate constant technique
67. Apply the Avrami equation

TTT Curves

68. Estimate the extent of reaction from TTT and IT curves
69. Accurately predict processing solutions from time-temperature-transformation diagrams

Martensitic Reactions

70. Explain martensitic reactions and why they occur
71. Identify parent-child phase relationships in a variety of martenistic transformations

Communication

72. Relate theoretical kinetics topic to current industrial application or problem.
73. Perform a thorough literature review of chosen kinetics topic.
74. Write a clear and concise technical paper.
75. Provide constructive feedback on the writing of colleagues.
76. Work as a team to solve problems in class.