Study Guide for CM3120 Transport II
Module 4 Diffusion and Mass Transfer II and Unit Operations
Morrison Spring 2021

Test subjects in this course are cumulative. Anything on a study guide from a prior exam may be the subject of a current exam.

Exam 4 (the final exam) will cover, in addition to Exam 1-3 topics, the topics listed below.

To do well on the test, you should be able to do the following:

Using classical mass-transfer solutions (Part II Equimolar counter diffusion; penetration model)

1. Explain resistance to mass transfer; indicate what chemical engineering processes affected by mass-transfer resistance
2. Explain the "constant molal overflow" assumption in distillation; identify the physics that makes this assumption plausible
3. Apply equimolar counter diffusion model to determine concentration distributions and mass transfer engineering quantities of interest
4. Apply the penetration model to determine concentration distributions and mass transfer engineering quantities of interest
5. Choose among appropriate "classic" mass-transfer models to evaluate the importance of mass transfer in an engineering scenario
6. Continue to demonstrate proficiency with module-3 and other prior study-guide objectives, including applying the mechanical energy balance
7. (optional) Apply pseudo-steady-state solution methods to species A mass transfer problems (macroscopic control volumes)

Linear driving force model for transfers at or across boundaries (film mass transfer coefficients, k_x, k_c, k_p and overall mass transfer coefficients K_L, K_G)

8. Explain the role of chemical equilibrium in identifying the driving force for mass transfer
9. Explain the linear driving force model for mass transfer to an interface (employing film mass transfer coefficient k_x) and compare it to Fick's law of diffusion
10. Explain the linear driving force model for mass transfer from one bulk phase to another (employing overall mass transfer coefficients K_L, K_G) and compare it to the heat exchanger design equation $\dot{Q} = UA\Delta T_{lm}$
11. Calculate engineering quantities of interest with the macroscopic species A mass balance incorporating transfers at boundaries
12. Evaluate predictions of mass transfer coefficient from microscopic models of diffusion and mass transfer
13. Calculate liquid-side-units and gas-side-units overall mass transfer coefficients from associated film coefficients.

Macroscopic species A mass balance-steady and unsteady

14. List the contributions to the macroscopic species A mass balance on unit operations and indicate how each is typically evaluated
15. Explain how mass transfer is accounted for in the macroscopic species A mass balance
16. Simplify and solve the macroscopic species A mass balance for elementary unsteady scenarios such as evaporating liquids or dissolving solids
17. Simplify and solve the macroscopic species A mass balance for elementary steady scenarios such as in gas absorption

Dimensional analysis in mass transfer, conditions at the boundary (complex mass-transfer systems involving bulk convection)

18. Explain the purpose of dimensional analysis in mass-transfer engineering
19. Explain the meaning of *data correlation*; explain where and how we obtain mass transfer data correlations
20. List, define, and explain the use of at least three dimensionless numbers in mass transfer
21. List two examples of data correlations for Sherwood number Sh (give the equation, the name of the correlation if it has one, and identify the symbols, including the material it applies to). Indicate when the correlations apply
22. Identify pairs of unsteady state heat transfer and mass transfer problems that are governed by the same mathematics, including boundary conditions
23. Use heat-transfer results (for example, Heisler charts) to address answers to mass transfer questions
24. Explain the use of the analogy between heat and mass transfer to determine data correlations for Sherwood number Sh
25. Identify analogous $\mathrm{Sh}(\mathrm{Re,Sc})$ correlations from $\mathrm{Nu}(\mathrm{Re,Pr})$ heat-transfer correlations

Unit operations and devices (mass transfer dominated, K_L, K_G)

26. Carry out a McCabe-Thiele analysis to determine the number of equilibrium stages needed to carry out a separation
27. Explain the operating line in mass-transfer unit operations modeling; identify the physics that gives the operating line
28. Explain the equilibrium curve in mass-transfer unit operations modeling; identify the physics that gives the equilibrium curve
29. Compare and contrast the operation and modeling of staged distillation columns and continuous distillation columns
30. Define and explain the meaning and utility of NTU and HTU in mass-transfer unit operations modeling
31. Explain how mass-transfer issues affect the efficiency of a distillation column or a gas absorption column
32. ~~Calculate NTU and HTU for a continuous distillation operation (size a continuous distillation column)~~
33. Calculate NTU and HTU for a gas absorption tower (size a gas absorption tower))
34. Apply macroscopic species A mass balances to unit operations to determine size-related parameters

Unit operations: Distillation (UO Worksheet)

35. Explain in one to three sentences the operating principle of a distillation column
36. List at least two actual engineering processes that employ distillation columns; one should be the most common
37. List three limitations of this unit operation

Unit operations: Gas absorption (UO Worksheet)

38. Explain in one to three sentences the operating principle of a gas absorption column
39. List at least two actual engineering processes that employ gas absorption columns; one should be the most common
40. List three limitations of this unit operation

Unit operations: Membrane separation (UO Worksheet)

41. Explain in one to three sentences the operating principle of membrane separation
42. List at least two actual engineering processes that employ membrane separation; one should be the most common
43. List three limitations of this unit operation

Unit operations: Liquid-Liquid Extraction (UO Worksheet)

44. Explain in one to three sentences the operating principle of a liquid-liquid extraction column
45. List at least two actual engineering processes that employ liquid-liquid extraction columns; one should be the most common
46. List three limitations of this unit operation

Mass transfer troubleshooting

47. Compare and contrast steady and unsteady mass transfer scenarios
48. From among mass transfer tools (microscopic species A mass balance, macroscopic species A mass balance, linear driving force models) identify the method that may result in the missing desired quantity (amount of species A transferred, mass of species A flux, concentration field, etc.) for unsteady state mass transfer scenarios
49. List, in an order that works, steps for determining a quantity with the mass transfer tools at your disposal

<u>References:</u>

- Christie J. Geankoplis, *Transport Processes and Unit Operations*, 4th Edition, Prentice Hall, New York (2003)
- *Perry's Handbook of Chemical Engineering*, 8th Edition (McGraw-Hill Professional, New York, 2007).
- Phillip C. Wankat, *Separation Process Engineering*, 4th edition, Prentice Hall, New York (2017)
- E. L. Cussler, Diffusion: Mass Transfer in Fluid Systems, 3rd Edition, Cambridge University Press, New York (2009).
- James R. Welty, Gregory L. Rorrer, and David G. Foster, "*Fundamentals of Momentum, Heat, and Mass Transfer*," 6th edition (Wiley, New York, 2015).