

## Homework 5B: Multiple species in vapor liquid equilibrium

This homework requires the use of excel. All your final answers should be written and boxed in the PDF of your written homework document. In your “how to solve” be sure to reference the steps you took in excel. Remember – the excel spreadsheet is just a calculator. You will be graded based on the solutions provided on your written document. Submit your explanation of your excel spreadsheet as a Media File on Canvas.

**Problem 1:** Herbal oils are used for broad applications; culinary, cosmetics, and pharmaceutical. Peppermint oil is produced in a three-step process. First, the oil from the plant is extracted using steam. Second, the oil is separated from the water in a condenser. Finally, the vapor phase leaving the condenser is enriched in menthol and is later cooled to become the final liquid product. The primary component of peppermint oil is menthol. The normal boiling point of menthol is 63 °C. The Antoine constants are listed below and can be used in **equation 1**.

$$\log_{10} P^{sat}(\text{bar}) = A - \frac{B}{T(K)+C} \quad (\text{Equation 1})$$

Table 1: Antoine constants for menthol.

A	B	C	Temperature Range (K)
5.38347	2405.946	111	329 – 485

The menthol/water mixture leaves the extractor at a temperature of 110°C as a super-heated vapor. The mixture is cooled to 95°C and pressure of 1 atm before entering the condenser. The molar fraction of the water vapor in the stream exiting the extractor is 0.20. The flowrate of the condensate leaving the condenser is 100 mol/hour.

- A) Draw and fully label a process flow diagram. Write all additional information from the problem statement as algebraic expressions using variables from your PFD.
  - B) Generate a Txy diagram using for the water/menthol system for a system pressure of 1 atm.
  - C) If the condenser is operating at 72°C, what are the mol fractions of menthol and water in the liquid and vapor streams exiting the condenser? To solve—you MUST use the Txy plot generated in part A. Show your work by drawing lines directly on the Txy plot (you may print and scan, annotate in excel/on your table, save a picture and draw on it in powerpoint, etc.).
  - D) What is the production rate of the menthol-enriched vapor phase? To solve—return to the general procedure: DOF, material balances, how to solve.
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- E) Consider the same menthol production process. Now, the buyer requests that the contamination of water in the menthol product line (vapor stream) be less than 0.05 mol fraction. If the condenser operates at 1 atm, what is the maximum allowable operating temperature of the condenser that will meet the buyer’s specification? **\*To solve—Do not use the Txy plot\*** Instead, use the solver function in Excel.
  - F) **Reflection:** Discuss the pros and cons of using Solver in excel vs. an already generated Txy diagram.