CE 407 Separations
Happy #1

Instructions: Please read over the entire exam first thing so that you can make a rational decision about how to budget your time. Please think calmly and logically, and work slowly, so that your answers reflect your true knowledge untinged by panic-induced irrationality and careless errors. More than enough data to answer all the questions are supplied on the attached sheets.

1. (35 points) An 80 mol/h contaminated air stream (98 mole percent air, 2 mole percent ethylbenzene) is to be cleaned up by countercurrent contact with mineral oil in an absorption tower operating isothermally at 35 °C and atmospheric pressure. Oil enters the tower pure.

(a) (10 points) Assuming availability of an effectively infinite number of stages, what is the lowest possible ethylbenzene mole fraction in the exiting air (y_a) that can be achieved using 3 mol/h of oil. A brief statement of reasoning and/or qualitative sketch is required for credit.

(b) (25 points) How many ideal stages are required to remove 95 percent of the ethylbenzene in the air if the tower operates with an entering oil flow rate of 2 mol/h? Base your answer on an operating diagram drawn on the graph paper supplied. In order to receive full credit, you must account for possible curvature of the operating line by calculating one intermediate point thereon.

Assume validity of Raoult's law.

2. (65 points) This problem addresses fractionation of a mixture comprising 55 mole percent benzene and 45 mole percent ethylbenzene by continuous distillation at atmospheric pressure in a sieve-tray column. It is desired to have 94 percent recovery of benzene in the distillate and 97 percent recovery of ethylbenzene in the bottom product. The column is fitted with a total condenser. Feed enters as saturated liquid. The top two trays in the column behave as ideal stages, and all other trays have Murphree efficiencies equal to 75 percent. The operating reflux ratio is $R = 0.6$.

(a) (25 points) How many trays are required to perform the separation? Use the graph paper supplied.

(b) (25 points) What is the required rate of heat removal q_c in the condenser?

(c) (15 points) What is the temperature of the vapor (V_2) stream rising from stage 2 and entering stage 1?

Elroy counts stages starting from the top. Please do as Elroy does.

Elroy-matic™ vapor pressure data

T (°C)	P^{sat} of benzene (mm Hg)	P^{sat} of ethylbenzene (mm Hg)
20	75.2	7.08
25	95.2	9.50
30	119.3	12.61
35	148.3	16.55
40	182.8	21.49
45	223.5	27.61
50	271.3	35.15

Elroy-matic™ heat capacity data

C_P of liquid benzene = 159 J/(mol °C)

C_P of liquid ethylbenzene = 231 J/(mol °C)

C_P of vapor benzene = 104 J/(mol °C)

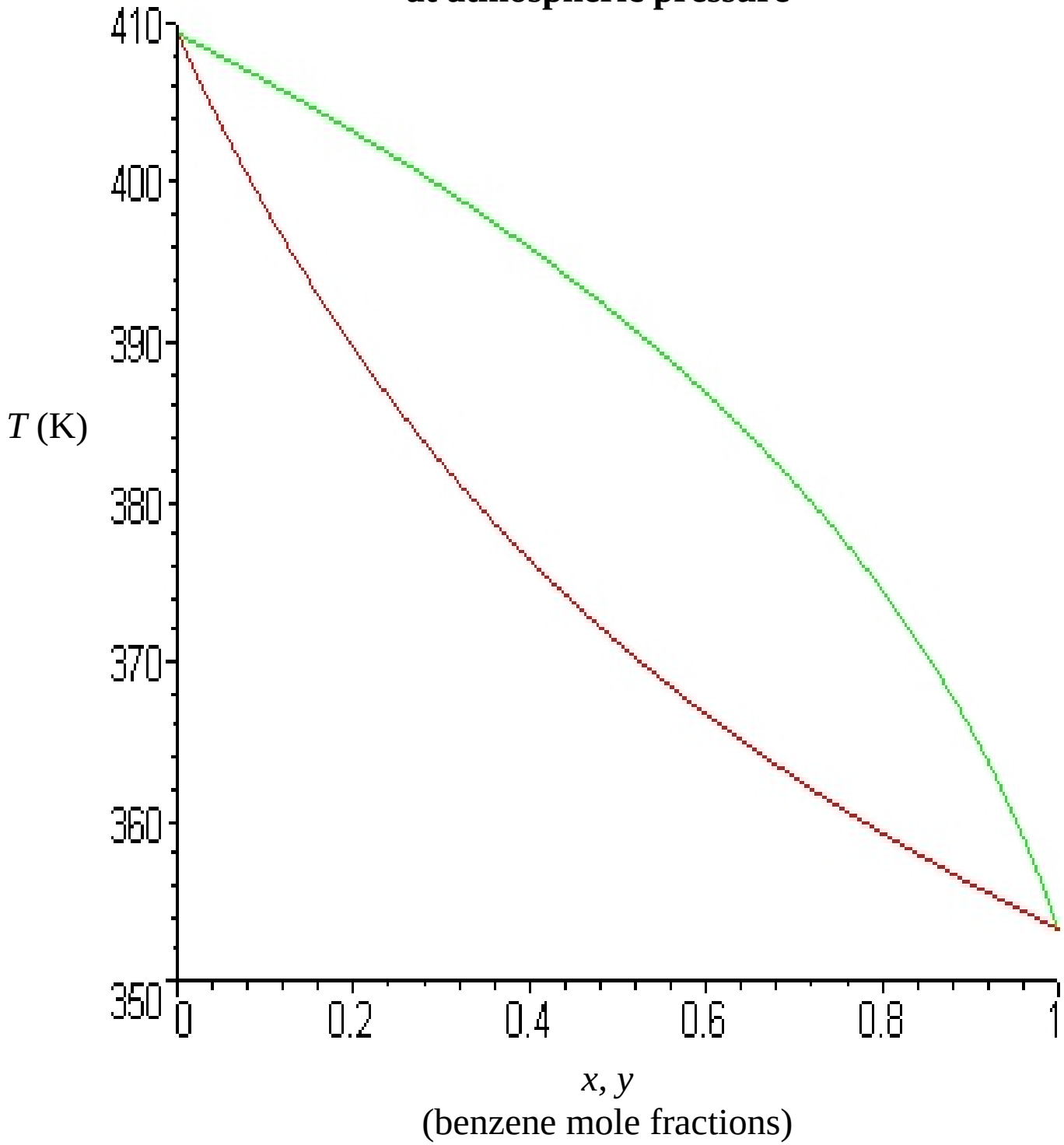
C_P of vapor ethylbenzene = 160 J/(mol °C)

Elroy-matic™ heat of vaporization data

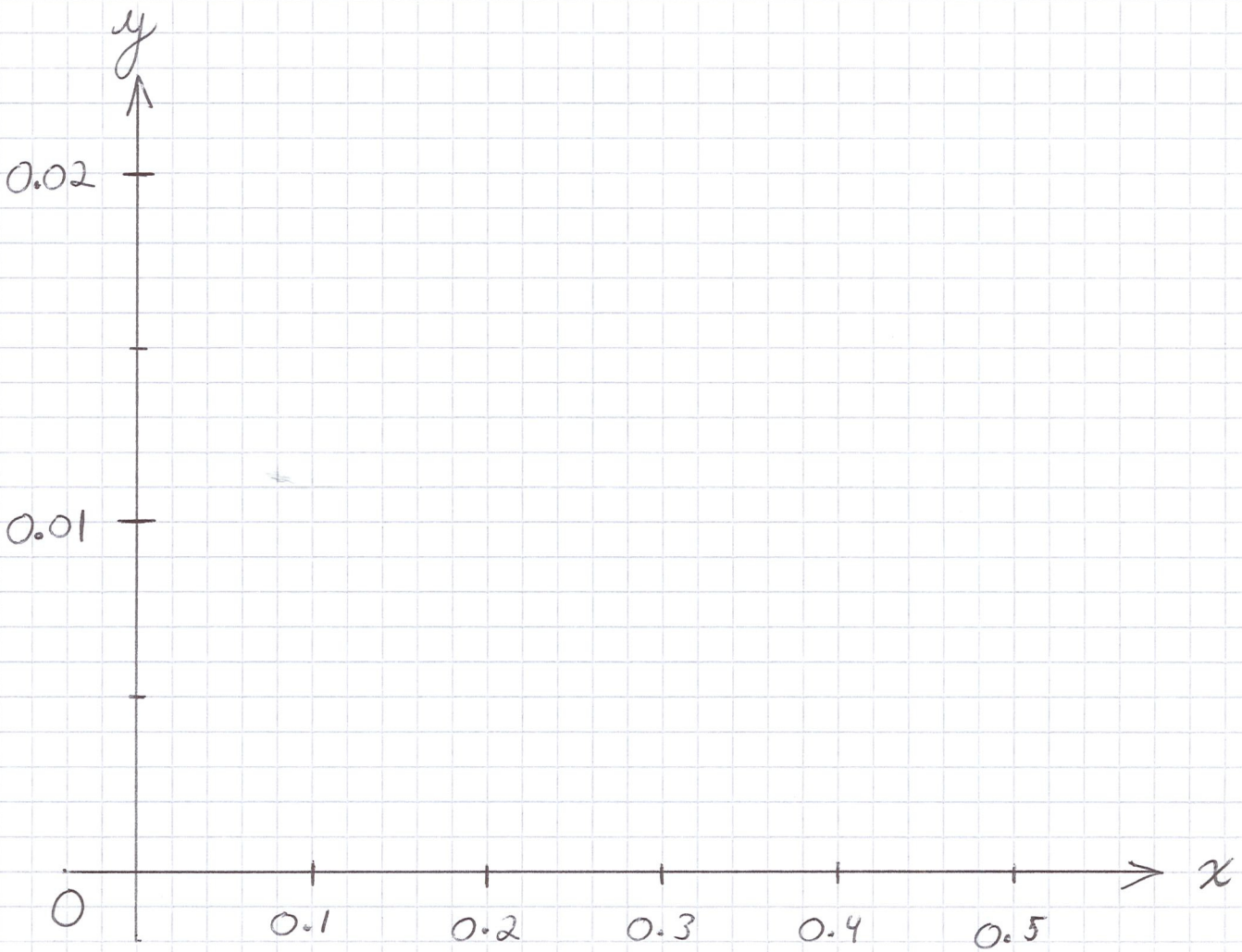
ΔH^{vap} of benzene at its normal boiling point = 30,794 J/mol

ΔH^{vap} of ethylbenzene at its normal boiling point = 35,815 J/mol

Phase diagram for
benzene(1) + ethylbenzene(2)
at atmospheric pressure



Graph paper for #1



Graph paper for #2