ENCH 445 -- Problem Set #2

Problem 1. The Antoine equation for the vapor pressure of component *i* as a function of the temperature can be expressed as:

$$\mathrm{Log}_{10}(P_{i,sat}) = A_i - B_i/(T + C_i)$$

With the pressure given in millimeters of mercury (760 mm Hg = 1 atm) and the temperature in °C, the Antoine constants for n-hexane and benzene are as follows:

	n-hexane	benzene
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A_i	7.0105	7.201
B_i	1246.33	1415.08
C_i	232.988	248.03

Assume that the liquid phase activity coefficients can be described by regular solution theory and that the vapor phase is an ideal gas. Note that parameters needed to employ regulation solution theory are given in a table on page 4 of this document. You may neglect the effect of temperature on regular solution theory parameters.

Perform the following calculations:

a. Construct an *y*-*x* equilibrium diagram for n-hexane and benzene at 40.4 kPa (0.4 atm) where *x* denotes the mole fraction of hexane in the liquid and *y* denotes the mole fraction of hexane in the vapor.

b. Construct an *y*-*x* equilibrium diagram for n-hexane and benzene at 70 °C.

Problem 2. If a mixture containing 20 mole-% isopropanol and 80 mole-% water at 340 K and 60 kPa is heated at constant pressure:

a. At what temperature does it first begin to boil? What is the composition of the first bubble of vapor?

b. At what temperature would it stop boiling (assume no material is removed)? What is the composition of the last droplet of liquid?

c. At 350 K, what fraction of the original mixture is still liquid?

d. When 80% of the original mixture has been vaporized, what is the temperature, and what are the liquid and vapor compositions?

Use the experimental vapor-liquid equilibrium data on page 3 of this document to solve this problem.

Problem 3. A storage tank contains n-butane, n-pentane, and n-hexane at 45°C and 140 kPa. Under these conditions separate liquid and vapor phases exist and are in equilibrium. If the liquid phase contains 0.17 mole fraction of n-butane, find the composition of the liquid and vapor phases. Use the DePriester charts in the Wankat textbook (see Figs. 2-11 and 2-12) to obtain any needed equilibrium data.

Problem 4. We wish to partly separate a mixture that is 45 mole-% benzene and 55 mole-% toluene in a single stage flash unit. The feed rate to the unit is 700 moles/hr. Equilibrium data for the benzene-toluene system can be approximated with a constant relative volatility of 2.5 where benzene is more volatile. The flash unit operates at 1 atm.

a. Use the relative volatility value given above to plot a y-x diagram for this system, where y and x indicate the mole fraction of benzene in the vapor and liquid, respectively.

b. If 60 % of the feed introduced to the unit is vaporized (i.e., V/F = 0.6), find the liquid and vapor compositions.

c. If we desire a vapor composition of 60 mole % benzene, what is the corresponding liquid composition, and what are the liquid and vapor flow rates?

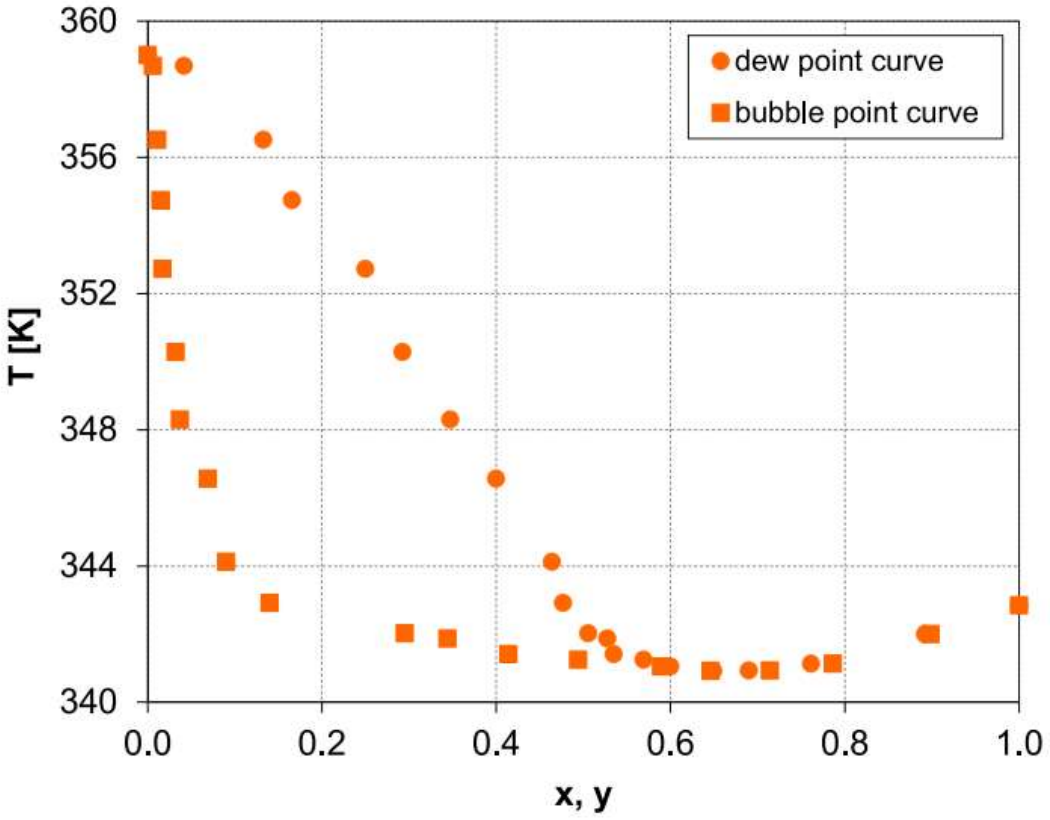
Do the following problems from Chapter 2 of the Wankat textbook (4th ed.):

Problem 5. Chapter 2: D8

Problem 6. Chapter 2: D18

Problem 7. Chapter 2: D19

Note that some or all of these final three problems may require a computer solution. If you are using an older edition of the Wankat textbook, make sure you are working on the correct problems.



Vapor-liquid equilibrium data for the isopropanol and water binary system at 60 kPa. Note that x and y refer to the mole fractions of isopropanol in the liquid and vapor phases, respectively.

Table 14-6 Values of solubility parameters at 298 K† (data from Hildebrand et al., 1970, and Gardon, 1966)

	V, cm^3/mol	δ, $(cal/cm^3)^{1/2}$		V, cm^3/mol	δ, $(cal/cm^3)^{1/2}$
Water	18	23.2	Ethyl bromide	76	8.9
Ethylene glycol	56	15.7	Carbon tetrachloride	97	8.6
Phenol	88	14.5	Ethyl chloride	73	8.5
Methanol	40	14.5	Cyclohexane	109	8.2
Dimethyl sulfoxide	71	13.4	Cyclopentane	95	8.1
Nitromethane	54	12.6	Perfluorobenzene	115	8.1
Acetic acid	57	12.6	*n*-Hexadecane	295	8.0
Dimethyl formamide	77	12.1	Ethylene (169 K)	46	7.9
Acetonitrile	53	11.9	Methylcyclohexane	128	7.85
Furfural	83	10.9	CF_4 (145 K)	45	7.7
Aniline	91	10.8	*n*-Nonane	180	7.65
Benzaldehyde	101	10.8	Ethane (184 K)	55	7.6
Pyridine	81	10.7	Propylene (225 K)	69	7.6
Acrylonitrile	67	10.5	*n*-Octane	164	7.55
n-Butanol	92	10.4	Diethyl ether	105	7.5
Carbon disulfide	61	10.0	*n*-Heptane	147	7.45
Dioxane	86	10.0	*n*-Hexane	132	7.3
Acetone	74	9.9	*cis*-2-Butene	91	7.2
Nitrobenzene	108	9.9	Butadiene	88	7.1
Naphthalene	123	9.9	*n*-Pentane	116	7.05
1,2-Dichloroethane	79	9.8	*trans*-2-Butene	91	7.0
Chlorobenzene	102	9.5	Isooctane	166	6.85
Ethyl iodide	81	9.4	Methane (112 K)	38	6.8
Chloroform	81	9.3	2-Methylbutane	117	6.75
Styrene	115	9.3	Isobutene	94	6.7
Benzene	89	9.15	1-Butene	95	6.7
Ethyl acetate	99	9.1	Neopentane	122	6.25
o-Xylene	121	9.0	Perfluorocyclohexane	170	6.0
Toluene	107	8.9	Perfluoro-*n*-heptane	227	5.7