CHE407: Separation Processes

Tutorial-3 **Due: 15/06/1440**

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QUESTION (1)

(i) A saturated liquid feed of 200 mol/h at the bubble point containing 42 mol% heptane and 58 mol% ethyl benzene is to be fractionated at 1.0 atm to give a distillate containing 97 mol% heptane and a bottoms containing 1.1 mol% heptanes. Calculate the following:

(a) Moles per hour distillate and bottoms.

(b) Minimum reflux ratio Rm.

(c) Minimum theoretical trays at total reflux Nm.

(d) The theoretical number of trays for an operating reflux ratio of 2.5 :1.

(ii) Repeat part (i) if the feed enters the tower partially vaporized so that 40 mol% is liquid and 60 mol% vapor.

(iii) Compare the results.

Temperature				Temperature			
K	°C	x_H	y_H	K	°C	x_H	y_H
409.3	136.1	0	0	383.8	110.6	0.485	0.730
402.6	129.4	0.08	0.230	376.0	102.8	0.790	0.904
392.6	119.4	0.250	0.514	371.5	98.3	1.000	1.000

QUESTION (2)

A feed of 0.30 mol fraction of benzene and the rest toluene is fed to a continuous distillation column at 1.0 atm to give a top product of 0.90 mol fraction benzene and a bottom product of 0.95 mol fraction toluene. If the reflux ration is 5.0, how many plates are required:

(a) If the feed is saturated vapor?

(b) If the feed is saturated liquid?

(c) If the feed is liquid at 283 K, of specific heat 1.84 kJ/kg K? The molar latent of benzene and toluene may be taken as 30 MJ/kmol.

QUESTION (3)

A continuous fractionating column is to be designed to separate 227 kg/min a mixture of 40 mass% benzene and 60 mass% toluene into an overhead product containing 97 mass% benzene and a bottom product containing 98 mass% toluene. A reflux ratio of 3.5 and an average relative volatility of 2.5 are to be used. The molar latent heat of benzene and toluene are 7360 and 7960 cal/gmol. Assuming the feed has a bubble point temperature of 95 ^oC at a pressure of 1.0 atm.

(a) Calculate x_D, x_F, x_W in mole fraction.

(b) The molar flow rate of the distillate and bottom product in lbmol/h.

(c) The average latent heat of the feed in Btu/lb.

(d) Determine the number of ideal plates, the position of the feed plate , N_m, R_m for the following cases:

(i)The feed is saturated liquid.

(ii) The feed is liquid at 20 ^oC (specific heat=0.44 Btu/lb. ^oF).

(iii) The feed is a mixture of two-thirds vapor and one-third liquid.

(e) If saturated steam at 20 lb_f/in^2 gauge is used for heating, how much steam is required per hour for each of the above three cases ($\dot{m}_s \lambda_s = \bar{V} \lambda_{mix}$) , neglecting heat losses? And complete the following Table:

Case	q	Steam $\dot{m}_s$ (lb/h)	Number of ideal plates (N)	R_m	N_m
(i)					
(ii)					
(iii)					

(f) If cooling water enters the condenser at 80 ^oF and leaves at 150 ^oF, how much cooling water is required ($V \lambda_{mix} = \dot{m}_w C_{pw} (T_{out} - T_{in})$), in gallons per minute and assuming the reflux is a saturated liquid?

(g) Is the water needed the same in all cases?

QUESTION (4)

(CHE 202, Chapter 8, page 420)

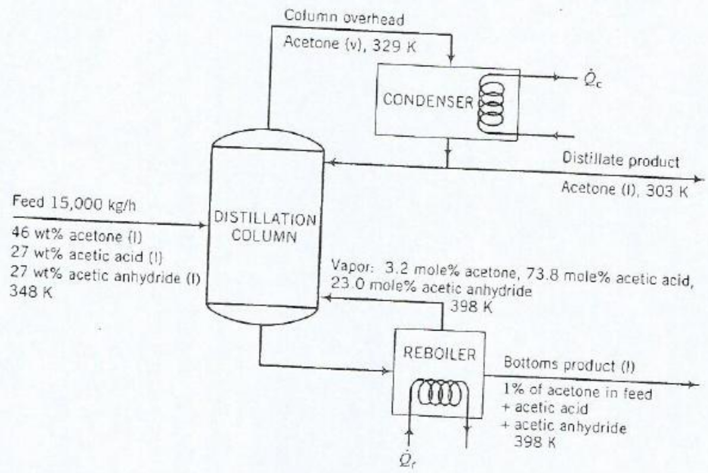
8.57. A mixture that contains 46 wt% acetone (CH_3COCH_3), 27% acetic acid (CH_3COOH), and 27% acetic anhydride [$(CH_3CO)_2O$] is distilled at $P = 1$ atm. The feed enters the distillation column at $T = 348$ K at a rate of 15,000 kg/h. The distillate (overhead product) is essentially pure acetone, and the bottoms product contains 1% of the acetone in the feed.

The vapor effluent from the top of the column enters a condenser at 329 K and emerges as a liquid at 303 K. Half of the condensate is withdrawn as the overhead product, and the remainder is refluxed back to the column. The liquid leaving the bottom of the column goes into a steam-heated reboiler, in which it is partially vaporized. The vapor leaving the reboiler is returned to the column at a temperature of 398 K, and the residual liquid, also at 398 K, constitutes the bottoms product. A flowchart of the process and thermodynamic data for the process materials follow.

(a) Calculate the molar flow rates and compositions of the product streams.

(b) Calculate the condenser cooling requirement $\dot{Q}_c$(kJ/h).

(c) Use an overall energy balance to determine the reboiler heating requirement $\dot{Q}_r$(kJ/h).



Thermodynamic Data (All temperatures are in kelvin)

Acetone: $C_{pl} = 2.30$ kJ/(kg·K)

C_{pv}[kJ/(kg·K)] $= 0.459 + 3.15 \times 10^{-3}T - 0.790 \times 10^{-6}T^2$

$\Delta\hat{H}_v(329\text{ K}) = 520.6$ kJ/kg

Acetic acid: $C_{pl} = 2.18$ kJ/(kg·K)

C_{pv}[kJ/(kg·K)] $= 0.688 + 1.87 \times 10^{-3}T - 0.411 \times 10^{-6}T^2$

$\Delta\hat{H}_v(391\text{ K}) = 406.5$ kJ/kg

Acetic anhydride: C_{pl}[kJ/(kg·K)] = ? (Estimate it—see Section 8.3c.) 2.26 kJ/kg·K

C_{pv}[kJ/(kg·K)] $= 0.751 + 1.34 \times 10^{-3}T - 0.046 \times 10^{-6}T^2$

$\Delta\hat{H}_v(413\text{ K}) = ?$ (Estimate it—see Section 8.4b.)