Mass Transfer Operations
Instructor: Prof. Jamin Koo
Due on October 4, 2019

Assignment #2

1. **Explain the following equations that calculate the fraction of liquid in the feed.**
증류 공정의 원료 흐름 내 액상 분율인 q 를 계산하는 아래 공식의 의미와 각 q 값 구간(<0, 0, 0<q<1,1, >1)의 물리적인 의미에 대해 설명하시오. (**15 점**)

Cold liquid: $q = 1 + \frac{C_{pL}(T_b - T_F)}{\lambda}$

Superheated vapor: $q = -\frac{C_{pV}(T_F - T_d)}{\lambda}$

where C_{pL}, C_{pV} represent specific heats of liquid and vapor, respectively; T_F, T_b, and T_d are feed, bubble-point, and dew-point temperature; λ denotes heat of vaporization

2. **A continuous fractionating column is to be designed to separate 30,000 kg/hr of a mixture of 40 wt% benzene and 60 wt% toluene into an overheated product containing 97 wt% benzene and a bottom containing 98 wt% toluene. A reflux ratio of 3.5 mol to 1 mol of product is used. The molal latent heats of benzene and toluene are 7,360 and 7,960 cal/mol. Benzene and toluene form a nearly ideal system with relative volatility of about 2.5; the equilibrium curve is shown in below. The feed has a boiling point of 95 ºC @ 1 atm.**

(a) Calculate the moles of overheated product and bottom product per hour.

(b) Determine the number of ideal plates and the position of the feed for three different conditions of the feed.

(c) If steam is used for heating, how much steam is required per hour?

(d) If cooling water enters the condenser at 25 ºC and leaves at 40 ºC, how much cooling water is required per hour?

교재의 예제 21.2 를 풀으시오. 이때, 평형선을 이용하는 과정은 예제풀이의 그래프에 나온 거리비율을 이용하여 직접 만들어 사용하시오. (**20 점**)

3. **A mixture of 50 mol% benzene and toluene is to be separated by distillation at 1 atm into products of 98 % purity using a reflux ratio 1.2 times the minimum value.**

The feed is liquid at the boiling point. Use enthalpy balances (Table in below) to calculate the flows of liquid and vapor at the top, middle, and bottom of the column, and compare these values with those based on constant molal overflow. Estimate the difference in the number of theoretical plates for the methods.

벤젠과 톨루엔의 몰분율이 50%인 혼합물이 대기압에서 순도 98%가 되도록 증류를 통해 분리하고자 하며, 이때 reflux ratio 는 최소값의 1.2 배를 사용하고자 한다. 원료는 끓는 점의 온도까지 가열된 액체이다. 에너지 수지를 이용하여 (아래 표 참조) 증류탑 상단부, 중간, 그리고 하단부에서의 액체와 기체 유량을 계산하라. 계산된 값들을 유량이 일정하다고 가정하고 계산했을 때와 비교하라. 두 방법의 차이에 따른 필요한 단의 차이를 추정하라. (**30 점**)

Component	Enthalpy of vaporization, cal/g mol	Specific heat at constant pressure, cal/g mol · °C		Boiling point, °C
		Liquid	Vapor	
Benzene	7,360	33	23	80.1
Toluene	7,960	40	33	110.6

4. **For a given distillation, answer the following questions using mathematical analysis**.

(a) How does increasing a reflux ratio impact purity of the overhead product?

(b) How does increasing a reflux ratio impact the productivity (flowrates of products, i.e., overhead and bottoms)?

(c) Will the total cost increase or decrease as you increase the reflux ratio? Answer this using physical/mechanical reasoning. Your answer can be qualitative.

증류탑과 관련 다음 질문들을 수학적 분석을 이용하여 답하시오. (**15점**)

(a) 환류비가 증가하면 탑상제품의 순도는 어떻게 변하겠는가?

(b) 환류비가 증가하면 증류탑의 생산성(시간당 생산되는 제품, 즉 탑상제품과 탑하제품의 유량)은 어떻게 변하겠는가?

(c) 환류비가 증가하면 총비용은 어떻게 변하겠는가? 물리적/기계적으로 생각하여 변화를 예측해 보시오 (정성적으로 답하여도 괜찮음).

5. **Is it possible to operate distillation such that both operating lines (rectifying and stripping section) lie above the equilibrium curve? Analyze mathematically.**

두 운전선이 모두 평형선 보다 위가 되도록 증류탑을 운전하는 것이 가능한가? (**20점**)