ChEn 3603 Homework #10

Recall that we previously did a homework that calculated the *T-x-y* and *x-y* diagrams for benzene-toluene mixtures at two different pressures. Use the SRK equation of state to determine the phase equilibrium conditions for this system at 1 atm to analyze the following distillation problems. You don't need to submit the python files that generate the *x-y* data with your solution.

Alternatively, you can use the *Txy* data from the csv data file provided as part of this homework assignment. You can load it into python easily with the following:

```
# Load the csv data using Pandas then grab numpy arrays for the Txy data
import pandas as pd
data = pd.read_csv('Txy.csv')
Teq = data['T'].values
xeq = data['x'].values
yeq = data['y'].values

# Plot the Txy data:
plt.figure(figsize=(7,7))
plt.plot(xeq,yeq,'k-',[0,1],[0,1],'k-')
plt.grid()
plt.axis('equal')
plt.axis([0,1,0,1])
plt.xlabel('Liquid Benzene Mole Fraction')
plt.ylabel('Vapor Benzene Mole Fraction')
axes = plt.gca()
axes.set_xticks(np.arange(0, 1.01, 0.1))
axes.set_yticks(np.arange(0, 1.01, 0.1))
```

Problem 1 (15 pts)

We want to separate 45 kg/hr of 55 mol% benzene in toluene entering as a saturated liquid into streams of 80 mol% benzene and 85 mol% toluene.

1. (4 pts) What is the minimum number of theoretical (equilibrium) stages required to achieve this separation?
2. (2 pts) What is the minimum reflux ratio?
3. (5 pts) If 3x the minimum reflux ratio is used, what is the required number of equilibrium stages, and where should the feed stage be located?
4. (4 pts) What is the ***mass*** flow rate of the product streams for the situation given in part 3? Also report the composition of the bottoms stream given the number of equilibrium stages you report in part 3.

Problem 2 (10 pts)

Let's consider a change to problem 1 where the feed is 67 mole% vapor.

1. (4 pts) What is the composition at which the q-line intersects the equilibrium curve?
2. (2 pts) What is the minimum reflux ratio?
3. (4 pts) For $R = 3R_{\text{min}}$, what is the required number of equilibrium stages, and where should the feed stage be located?

Problem 3 (6 pts)

For the same feed as in problem 1, with a distillation column that has 20 trays that operate at 15% efficiency, if we desire a distillate of 80% benzene, what is the *lowest* ***benzene*** composition possible in the bottoms if we have:

1. (2 pts) A total condenser and total reboiler?
2. (2 pts) A partial condenser and total reboiler?
3. (2 pts) A partial condenser and partial reboiler?