Homework 6

Problem 3

Temp \degree$C$	x_A	y_A
78.4	0.00	0.00
77.5	0.015	0.075
75	0.05	0.28
72.5	0.12	0.42
70	0.22	0.54
68.5	0.31	0.60
67.7	0.68	0.68
68.5	0.81	0.73
72.5	0.91	0.82
75	0.95	0.88
77.5	0.98	0.95
80.1	1.00	1.00

problem 3.a and 3.b

Determine the bubble point temperature and composition of the first bubble when $z_A = 0.25$. </br></br> The bubble point temperature is the temperature when $x_A = 0.25$ and the composition of the first bubble is y_A at the bubble point temperature. The following code, similar to problems 1 and 2, interpolates through the data and finds the bubble point temperature and composition of the first bubble.

In [ ]:

```
import matplotlib.pyplot as plt
import numpy as np
from scipy.interpolate import interp1d
```

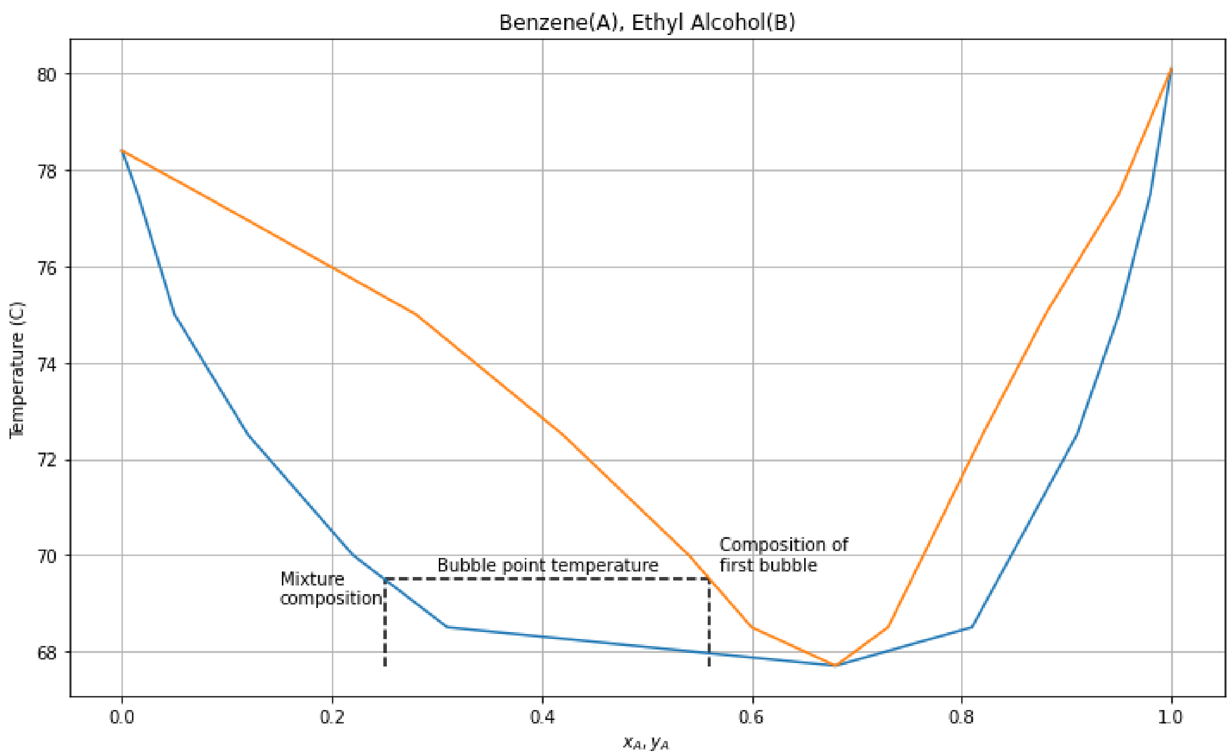
In [ ]:

```
T = np.array([78.4,77.5,75,72.5,70,68.5,67.7,68.5,72.5,75,77.5,80.1])          #
xA = np.array([0,.015,.05,.12,.22,.31,.68,.81,.91,.95,.98,1])
yA = np.array([0,.075,.28,.42,.54,.6,.68,.73,.82,.88,.95,1])

molFrac = np.linspace(0,.6,9999)                                               #
interpX = interp1d(xA[:7],T[:7])                                               #
interpY = interp1d(yA[:7],T[:7])                                               #
interpTx = interp1d(T[:7],xA[:7])                                              #
interpTy = interp1d(T[:7],yA[:7])                                              #
# print(interpX(molFrac))
```

```
zA = .25                                                    #

Tbub = interpX(zA)                                          #
ybub = interpTy(Tbub)                                       #
Tdew = interpY(zA)
xdew = interpTx(Tdew)

plt.figure(figsize=(12,7))
plt.plot(xA,T,label='Saturated liquid')
plt.plot(yA,T,label='Saturated vapor')

plt.vlines(zA,min(T),interpX(zA),linestyles='--',color='k')
plt.hlines(Tbub,zA,ybub,linestyles='--',color='k')
plt.vlines(ybub,min(T),Tbub,linestyles='--',colors='k')

plt.text(.15,69,'Mixture\ncomposition')
plt.text(.3,69.7,'Bubble point temperature')
plt.text(.57,69.7,'Composition of\nfirst bubble')

plt.title('Benzene(A), Ethyl Alcohol(B)')
plt.ylabel('Temperature (C)')
plt.xlabel(r'$x_A,y_A$')
plt.grid()
print('T_bub =',Tbub,'\ny_bub =',ybub)
print('T_dew =',Tdew,'\nx_dew =',xdew)
;
```

```
T_bub = 69.5
y_bub = 0.56
T_dew = 75.36585365853658
x_dew = 0.044878048780487886
''
```

Out[ ]:



The bubble point temperature is about $69.5\degree C$ and the composition of the first bubble is about 56% Benzene.

Problem 3.c

Determine mixture composition when 25% has evaporated. </br></br> This problem can be solved using the inverse lever arm rule which for this problem becomes

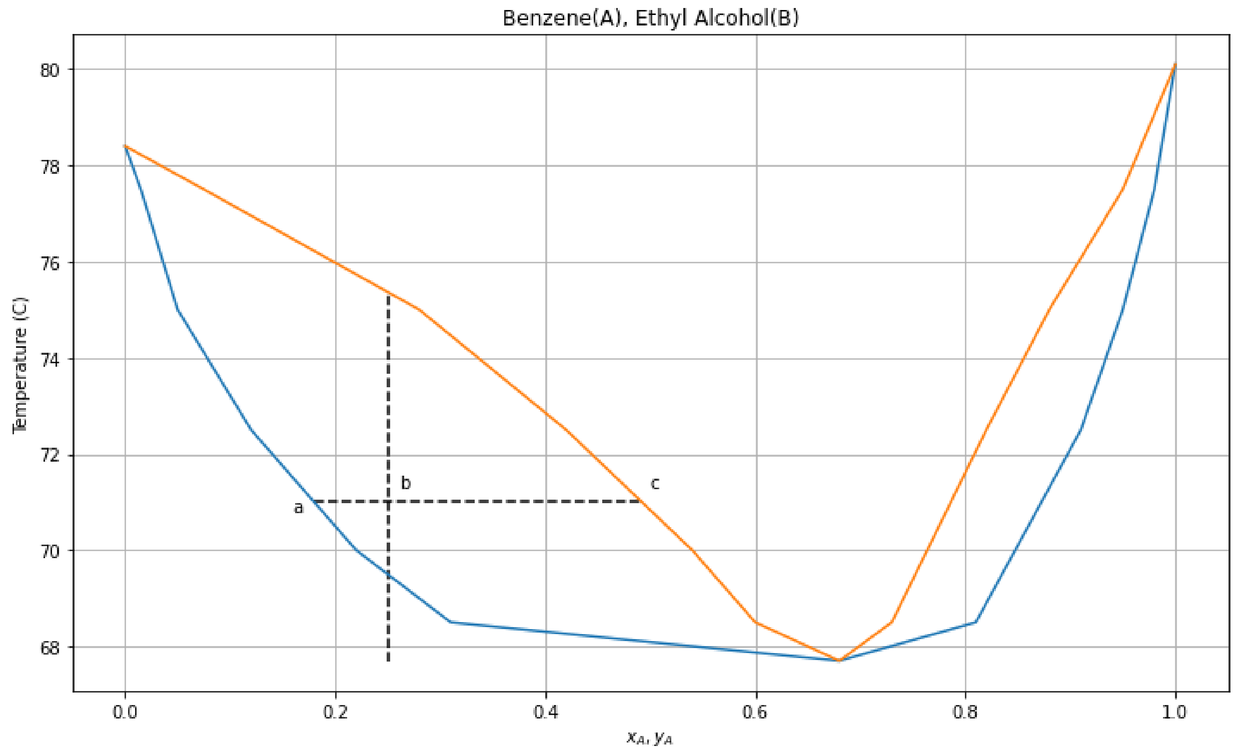
$$0.25 = \frac{0.25 - a}{c - a}$$

where a and c are displayed on the plot below. a and c are found by solving the above equation on $y_A = [0.25, 0.56]$ which is done in the code below.

In [ ]:

```
plt.figure(figsize=(12,7))

plt.plot(xA,T,label='Saturated liquid')
plt.plot(yA,T,label='Saturated vapor')

plt.vlines(zA,min(T),interpY(zA),linestyles='--',color='k')
plt.hlines(71,interpTx(71),interpTy(71),linestyles='--',color='k')

plt.text(.16,70.8,'a')
plt.text(.26,71.3,'b')
plt.text(.5,71.3,'c')

plt.title('Benzene(A), Ethyl Alcohol(B)')
plt.ylabel('Temperature (C)')
plt.xlabel(r'$x_A,y_A$')
plt.grid()

;
```

Out[ ]: ''



In [ ]:

```
possibY = []                                                    #loop to make array of po
for i in range(len(molFrac)):
    if molFrac[i] < ybub and molFrac[i] > zA:
        possibY.append(molFrac[i])
possibY = np.array(possibY)
possibX = interpTx(interpY(possibY))                            #possible x values

sol = (zA-possibX)/(possibY-possibX)                           #solution to eq1
sol = sol.tolist()
```

In [ ]:

```
for i in sol:                                                   #loop to find x,y to achi
    if .25/i >=.9999 and .25/i <=1:
        percVap1 = i
        print(possibX[sol.index(i)],possibY[sol.index(i)],i)
print(interpY(possibY[sol.index(percVap1)]))
```

```
0.17238047609521914 0.4828565713142628 0.2500016107520922
71.19048809761952
```

The composition of the liquid when 25% of the mixture has evaporated is about 17.2% benzene

Problem 3.d

Determine composition of the liquid phase when 90% has evaporated. </br></br> The process to solving this problem is identical to solving problem 3.c but the inverse lever arm rule is

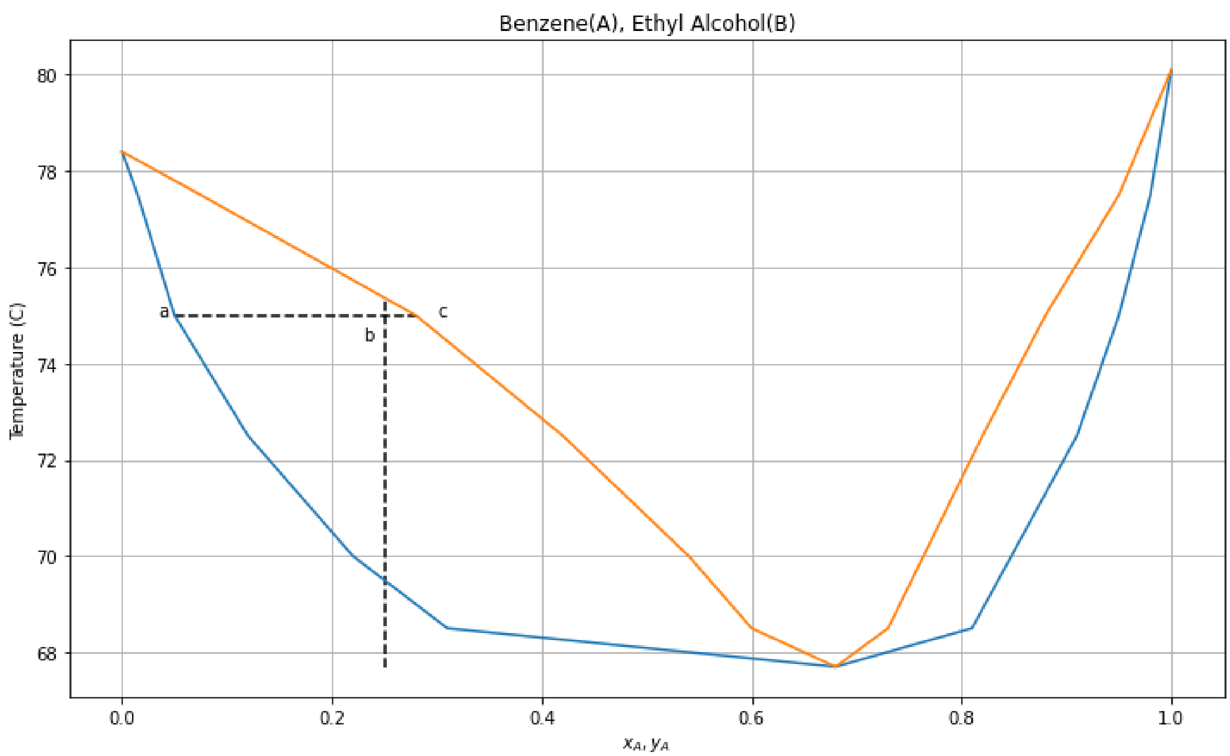
$$0.90 = \frac{0.25 - a}{c - a}$$

In [ ]:

```
plt.figure(figsize=(12,7))
```

```
plt.plot(xA,T,label='Saturated liquid')
plt.plot(yA,T,label='Saturated vapor')

plt.vlines(zA,min(T),interpY(zA),linestyles='--',color='k')
plt.hlines(75,interpTx(75),interpTy(75),linestyles='--',color='k')

plt.text(.035,75,'a')
plt.text(.23,74.5,'b')
plt.text(.3,75,'c')

plt.title('Benzene(A), Ethyl Alcohol(B)')
plt.ylabel('Temperature (C)')
plt.xlabel(r'$x_A,y_A$')
plt.grid()

;
```

Out[ ]: ''



In [ ]:

```
for i in sol:                                    #loop to find x,y to achi
    if .9/i >=.9998 and .9/i <=1:
        percVap2 = i
        print(possibX[sol.index(i)],possibY[sol.index(i)],i)
print(interpY(possibY[sol.index(percVap2)]))
```

```
0.04869125044521096 0.27233446689337865 0.9001334927654514
75.09348211105636
```

When 90% of the mixture vaporizes, the liquid phase is about 4.9% benzene

Problem 3.e

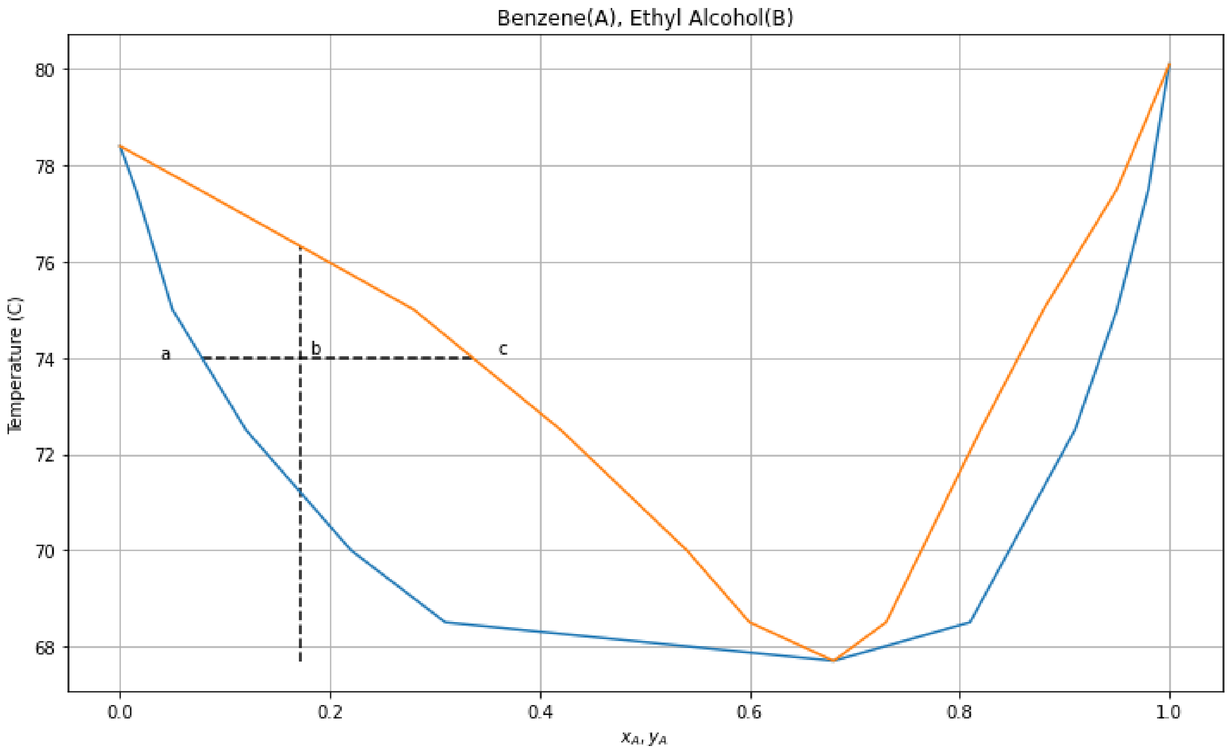
Determine composition of the liquid when 25% of the mixture has vaporized and been removed and then 35% of the remaining mixture is vaporized. </br></br> There are two steps to this problem. The first step is to determine the composition of the liquid phase when 25% has been vaporized. This was found in problem 3.c to be about 17.2% benzene. For the second step, all the vapor has been removed so the mole fraction of benzene in the mixture after the vapor has been removed is the same as the mole fraction of benzene in the residual liquid phase. $\therefore$ the inverse lever arm rule becomes $$ 0.35 = \frac{0.172-a}{c-a}

$$

In [ ]:

```
zAnew = possibX[sol.index(percVap1)]

plt.figure(figsize=(12,7))

plt.plot(xA,T,label='Saturated liquid')
plt.plot(yA,T,label='Saturated vapor')

plt.vlines(zAnew,min(T),interpY(zAnew),linestyles='--',color='k')
plt.hlines(74,interpTx(74),interpTy(74),linestyles='--',color='k')

plt.text(.038,74,'a')
plt.text(.18,74.1,'b')
plt.text(.36,74.1,'c')

plt.title('Benzene(A), Ethyl Alcohol(B)')
plt.ylabel('Temperature (C)')
plt.xlabel(r'$x_A,y_A$')
plt.grid()

;
```

Out[ ]: ''



In [ ]:

```
TbubNew = interpX(zAnew)
ybubNew = interpTy(TbubNew)
possibY2 = []                                             #loop to make array of p
for i in range(len(molFrac)):
    if molFrac[i] < ybubNew and molFrac[i] > zAnew:
        possibY2.append(molFrac[i])
possibY2 = np.array(possibY2)
possibX2 = interpTx(interpY(possibY2))                     #possible x values
```

In [ ]:

```
sol2 = (zAnew-possibX2)/(possibY2-possibX2)                    #solution to eq1
sol2 = sol2.tolist()

for i in sol2:                                            #loop to find x,y to ach
    if i!=0 and .35/i >=.9997 and .35/i <=1:
        percVap3 = i
        print(possibX2[sol2.index(i)],possibY2[sol2.index(i)],i)
print(interpY(possibY2[sol2.index(percVap3)]))
```

```
0.08100420084016804 0.342008401680336 0.3500950366350904
73.89270711285114
```

The composition of the remaining fluid at the end of the process is about 8.1% benzene