Recap

For this chapter, it is important to understand the concepts of thermodynamics before balancing. You can also use these concepts to see if your work/answer make sense in the end.

1.At which conditions can you assume ideal gas?

a.Low temperature and low pressure
b.High temperature and low pressure
c.High Pressure and low temperature
d.High temperature and high pressure

2.What does it mean if a vapor is superheated?

a.Its temperature is above the bubble point
b.Its temperature is above the dew point
c.Its temperature is below the bubble point
d.Its temperature is below the dew point

3.What is gauge pressure relative to?

a.Full vacuum
b.atmospheric
c.absolute zero
d.standardized pump

4.If a gas is assumed incompressible, what is its density a function of?

a.Nothing (it is constant)
b.Temperature only
c.Pressure only
d.Both temperature and pressure

5.What does a compressibility factor of >1 mean?

a.Ideal gas law can be used
b.Ratio of PV/RT is > 1
c.Ratio of PV/RT is < 1
d.None of the above

Gibbs Phase Rule

$$F = 2 + (c - r) - \pi$$

where c is the number of chemical species, r is the number of chemical reactions, and π is the number of phases

Clausius-Clapeyron Equation

Look at its derivation and its approximations.

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1. 3 approximation and the reasoning behind them
2. derivation from differential form to algebraic
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This was on the second midterm and also on the final for last years exam.

In [1]:

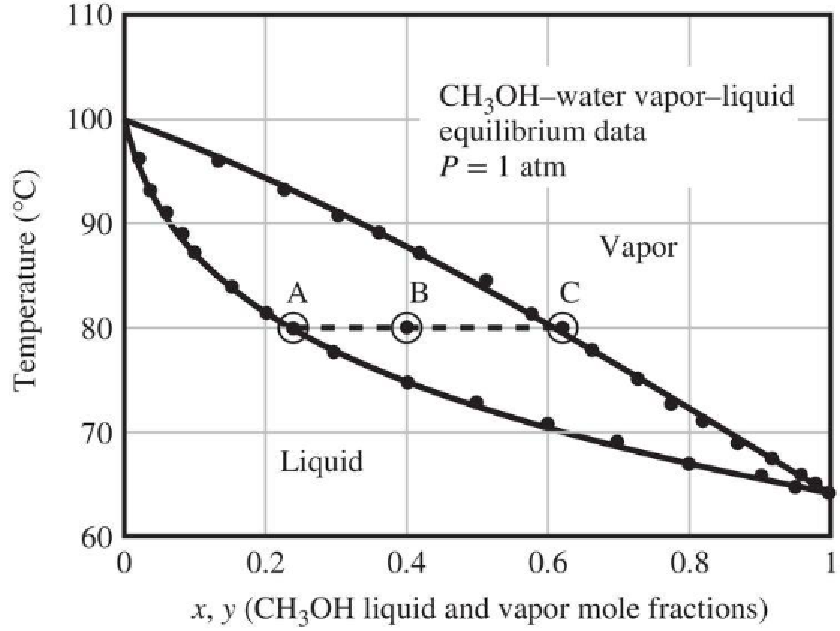
```python
from IPython.display import YouTubeVideo

YouTubeVideo('Adr9_2LnQdw', width=800, height=300)
```

Out[1]:

Example Problem 1

A methanol–water feed stream is introduced to a vaporizer in which a molar fractionof the feed is vaporized. The feed has a methanol mole fraction of xF=0.4, and the vaporizer operates at a pressure of 1 atm absolute and 80°C. Vapor and liquid leaving the device are in equilibrium at the temperature and pressure of the system and have methanol mole fractions ofyandx, respectively.A Txy diagram for methanol–water mixtures at 1 atm absolute is shown below. The feed to the vaporizer and the liquid and vapor product streams are shown as points B, A, and C, respectively.



a) Prove that f can be determined from the equation:where V: mole of vapor, L: mole of liquid, F: mole of feed. Use this result to determine f for the specific conditions cited above(x_F=0.4,T=80°C).

$$f = \frac{V}{L} = \frac{x_F - x}{y - x_F}$$

b) Use the T_{xy} diagram to estimate the minimum and maximum temperatures at which the given feed stream could be separated into vapor and liquid fractions at 1 atm. In each case, what fraction of the feed would be vaporized?

c) The vapor at C is sent to a condenser operated at constant pressure (1 atm) and temperature 78°C. At this temperature, the pure methanol vapor pressure is 1.66 atm. The liquid(L2) and vapor(V2) product streams leaving the condenser are in equilibrium and in a ratio of 1 mol vapor/1 mol liquid. Estimate the methanol compositions(x2 and y2) in the two streams leaving the condenser.

Solution:

a)

1. write out balances:

   Mole balance: $F = V + L$

   MeOH mole balance: $x_F F = yV + xL$

1. derive equations:

$$x_F F = yV + xL$$

$$x_F(V + L) = yV + xL$$
$$(y - x_F)V = (x_F - x)L$$
$$f = \frac{V}{L} = \frac{x_F - x}{y - x_F}$$

1. Find x and y.

   use T_{xy} diagram to find x and y at T=80°C

1. Solve for f

   plug in $x_F = 0.4$, x, and y to find f

In [1]:

```
xf = 0.4
x = 0.23
y = 0.62
f = (0.4-0.23)/(0.62-0.4)
f
```

Out[1]:

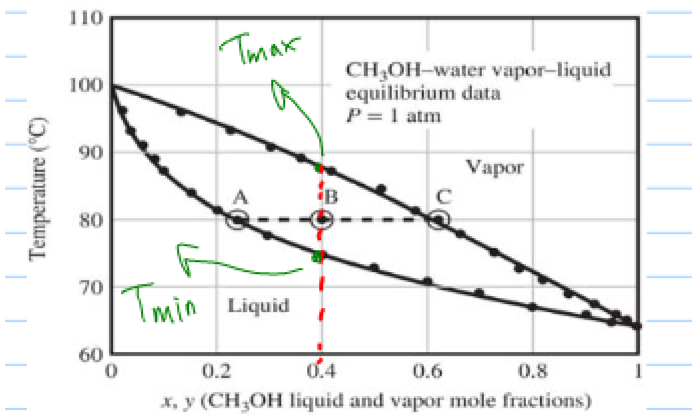
```
0.7727272727272729
```

b)

1. recognize that the two phase must exist in equilibrium since there are both vapor and liquid fractions

   This implies that it has to be within the two-phase region of the T_{xy} diagram

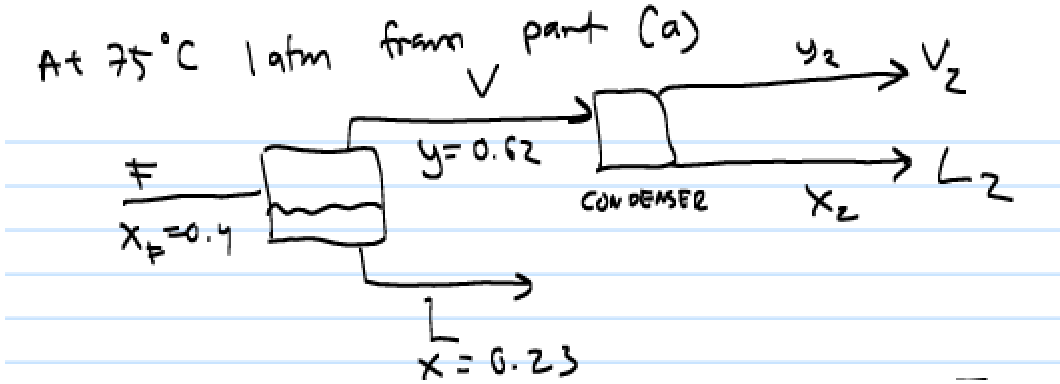
1. use the T_{xy} diagram to find T_{max} and T_{min}



At $T_{max} = 87$, f = 1 and at $T_{min} = 75$, f = 0 for $x_F = 0.4$

c)

1. Draw process diagram



$$\frac{V_2}{L_2} = 1$$
$$V = V_2 + L_2$$
$$\frac{V_2}{V} = 0.5$$

1. Use given condition and derive equation for MeOH balance

$$yV = y_2V_2 + x_2L_2$$
$$y\frac{V}{V_2} = y_2 + x_2\frac{L_2}{V_2}$$
$$y\frac{V}{V_2} = y_2 + x_2 f$$

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plug in values from part a
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$$0.62(2) = x_2(1) + y_2$$

$$1.24 = x_2 + y_2$$

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Two unknowns so we need some law that can relate the two unknowns
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1. Use Raoult's law

$$y_2P = x_2P^*_{MeOH}(T)$$

1. Combine two equations and solve

$$1.24 = x_2 + x_2\frac{P^*_{MeOH}}{P}$$
$$x_2 = \frac{1.24}{1 + \frac{P^*_{MeOH}}{P}}$$
$$x_2 = 0.47$$
$$y_2 = 0.77$$

Mass Balance Question

Sulfur dioxide may be converted to SO3, which has many uses including the production of H2SO4and the sulphonation of fatty acids to make detergent. A gas stream having the molar composition shown in the figure below is to be passed through a two-stage converter (reactor). The single-pass fractional conversion of SO2to SO3in the first stage is 0.77 and in the second stage, 0.63. Toboost the overall process conversion to 0.95, some of the exit gas from stage 2 is recycled back to the stage 2 inlet.

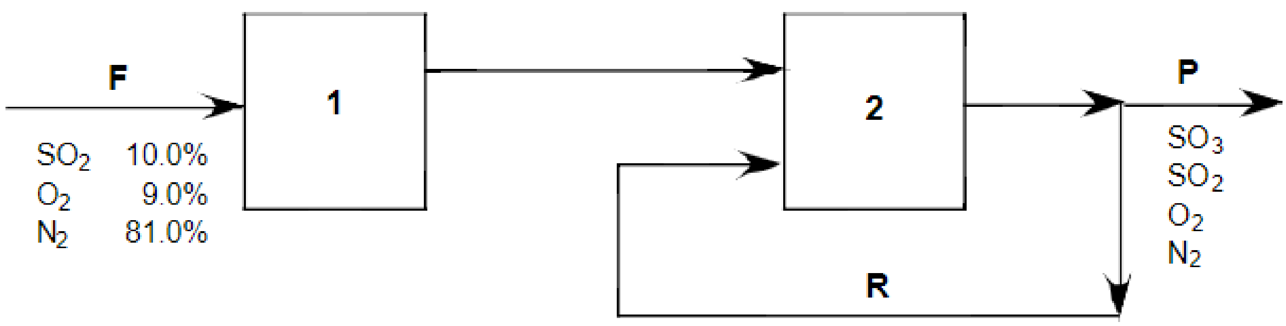
a) Draw and label the flowchart given that 100 kmol/h of feed gas, F, is fed.

b) Write the balanced stoichiometric equation for the SO2reaction with O2to produce SO3.

c) Determine how much gas is recycled in kmol/h.

Solutions

a)



Put the basis of 100kmol/hr at F

At 1, f = 0.77

At 2, f = 0.63

Overall, f = 0.95

b)

SO2:

$$y_{PSO2}P = m_{SO20} - \zeta$$

SO3:

$$y_{PSO3}P = m_{SO30} + \zeta$$

O2:

$$y_{SO2}P = m_{O20} - 0.5\zeta$$

N2:

$$y_{PNO2} = (1 - y_{PSO2} - y_{PSO3} - y_{PO2})$$