Quiz 11
Chemical Engineering Thermodynamics
April 4, 2019

A feed stream (F) of $z_1 = 0.7$ ethanol and $z_2 = 0.3$ methanol at 50°C and 0.2 MPa (1520 mmHg) is fed into a flash tank at 0.1 MPa (760 mmHg) resulting in a liquid (L) and a vapor (V) stream.

a) First determine the state (L, V, or L/V) of the feed stream (F) using the bubble point pressure at 50 °C. (*First determine the appropriateness of Antoine's equation.*)
b) Repeat this determination of the state (L, V, or L/V) by finding the bubble point temperature at 0.2 MPa of the feed stream. (*First determine the appropriateness of Antoine's equation.*)
c) Calculate the bubble and dew temperatures at 760 mmHg (0.1 MPa).
d) If the receiving tank were kept at 347K (74°C) what would be the composition and flow rates for the two streams (L and V) based on the feed rate, F?
e) What is the heat flow needed to maintain the receiving tank at 74° C? (*Use the feed stream as the reference point for enthalpy = 0.*)
f) Why is this separation so sensitive to the temperature? (Extra credit.)

Use the Antoine's Equation to calculate the vapor pressure and assume the vapors follow Raoult's law.

$$\log_{10} P^{sat} = A - \frac{B}{T+C}$$

where P^{sat} is in mmHg, and T is in Celsius. Additional Antoine constants are tabulated in

$$\sum_i \frac{z_i(1-K_i)}{1_i + (V/F)(K_i - 1)} = 0$$ For isothermal flash.

Answer Sheet:

a) Bubble Pressure:
   State:

b) Bubble Point Temperature
   State:

c) V/F =
   x1 =
   y1 =

d) Q =

e)

E.3. Antoine Constants

The following constants are for the equation

$$\log_{10} P^{sat} = A - \frac{B}{T + C}$$

where P^{sat} is in mmHg, and T is in Celsius. Additional Antoine constants are tabulated in Antoine.xls.

	A	*B*	*C*	*T* range (°C)	Source
Ethanol	8.11220	1592.864	226.184	20–93	a
Hexane	6.91058	1189.64	226.28	−30–170	a
1-Propanol	8.37895	1788.02	227.438	−15–98	a
2-Propanol	8.87829	2010.33	252.636	−26–83	a
Methanol	8.08097	1582.271	239.726	15–84	a

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		$\Delta H_{f,298.15}$	$\Delta G_{f,298.15}$	Heat Capacity Constants			
		kJ/mol	kJ/mol	A	B	C	D
Liquids, over the temperature range from 273.15 to 373.15 K[a]							
	Ethanol			281.6	-1.435	2.903E-03	
	Ethylene oxide			174.9	-7.184E-01	1.432E-03	
	Methanol			111.7	-4.264E-01	1.090E-03	

Gas state:

1101	Methanol	-200.94	-162.24	21.15	0.07092	2.587E-05	-2.852E-08
1102	Ethanol	-234.95	-167.73	9.014	0.2141	-8.390E-05	1.373E-09

Heat of Vaporization at 760 mmHg

	TbC	DHvap kJ/m	Tb K	DH J/mole
Methanol	64.7	38.278	337.7	38278
Ethanol	78.5	38.58	351.5	38580

Answers Quiz 11
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Answer Sheet:

a) Bubble Pressure: **280 mmHg** (***0.0431 (0.0368)*** MPa) at 50°C
State: L at 1520 mmHg

b) Bubble Point Temperature: **365K** if you used 760 mmHg *and **346K** for 0.1 MPa*
State: Liquid at 323K and 760 mmHg (0.1 MPa)

*If you used 35MPa for the pressure (a typo) you get **636K** (363°C).*

c) Bubble Temperature at 760 mmHg: **346.5K** (***346.2K** at 750 mmHg*)
Dew Temperature at 760 mmHg: **348K** (***348K** at 750 mmHg*)

d) V/F = 0.403 (0.28 to 0.493)
x1 = 0.255 (0.26 to 0.24)
y1 = 0.366 (0.38 to 0.36)

e) Q = 34.7 kJ/(mole feed)

764.2 mmHg	760 mmHg	756 mmHg
33.2 kJ/MolF	34.7 kJ/MolF	53.7 kT/MolF

f) The temperature gap is small because the two components are thermodynamically and chemically very similar. The heat of vaporization differs by 1%, the boiling point differs by about 3%. The densities are 0.789 g/cc and 0.792 g/cc differ by 0.4%. There is not much to distinguish these two alcohols, hence it is very difficult to separate them. This is a big problem since methanol is toxic, causing blindness and other problems, while ethanol can be tolerated in low concentrations.

a) First determine the state (L, V, or L/V) of the feed stream (F) using the bubble pressure at 50 °C. (*First determine the appropriateness of Antoine's equation.*)

Antoine Equation Constants							
	A	B	C				
methanol	8.08097	1582.271	239.726 15-84C				
ethanol	8.1122	1592.864	226.184 20-93 C				
Temp, K	323	Temp, C	50				
Pressure,mmHg	1520	P, Mpa	0.2				
	Feed	Liquid	Vapor	Psat, mmHg	Ki	yi	Feed* Psat
Methanol	0.3			416.584539	0.27406878	0.08222063	124.975362
Ethanol	0.7			221.206843	0.14553082	0.10187157	154.84479
						Pb at 50C =	279.820152 mmHg
						Liquid at 1520 mmHg	

b) Repeat this determination of the state (L, V, or L/V) by finding the bubble point temperature and/or the dew point temperature at 35.0 MPa of the feed stream. (*First determine the appropriateness of Antoine's equation.*)

Antoine Equation Constants						
	A	B	C			
methanol	8.08097	1582.271	239.726 15-84C			
ethanol	8.1122	1592.864	226.184 20-93 C			
Temp, K	365.22978	Temp, C	92.22978			
Pressure,mml	1520	P, Mpa	0.2			
	Feed	Liquid	Vapor	Psat, mmHg	Ki	yi
Methanol	0.3			2062.80715	1.35710997	0.40713299
Ethanol	0.7			1287.36867	0.84695307	0.59286715
					sum yi =	1.00000014
				So stream is a liquid		

c) Calculate the bubble and dew temperatures at 760 mmHg (0.1 MPa).

Antoine Equation Constants						
	A	B	C			
methanol	8.08097	1582.271	239.726	15-84C		
ethanol	8.1122	1592.864	226.184	20-93 C		
Temp, K	346.509194	Temp, C	73.5091944			
Pressure,mml	760	P, Mpa	0.1			
	Feed	Liquid	Vapor	Psat, mmHg	Ki	yi
Methanol	0.3			1070.5003	1.40855303	0.42256591
Ethanol	0.7			626.928161	0.82490548	0.57743383
					sum yi =	0.99999974
				So stream is a liquid		

Antoine Equation Constants							
	A	B	C				
methanol	8.08097	1582.271	239.726	15-84C			
ethanol	8.1122	1592.864	226.184	20-93 C			
Temp, K	348.006835	Temp, C	75.0068352				
Pressure,mml	760	P, Mpa	0.1				
	Feed	Liquid	Vapor	Psat, mmHg	Ki	yi	xi
Methanol	0.3			1131.41923	1.48870951	0.44661285	0.20151682
Ethanol	0.7			666.263449	0.87666243	0.6136637	0.79848294
						Sumxi =	0.99999976
				So stream is a liquid			

d) If the receiving tank were kept at 347K (74°C) what would be the composition and flow rates for the two streams (L and V) based on the feed rate, F?

$$\sum_i \frac{z_i(1-K_i)}{1_i+(V/F)(K_i-1)} = 0$$

Antoine Equation Constants								
	A	B	C					
methanol	8.08097	1582.271	239.726	15-84C				
ethanol	8.1122	1592.864	226.184	20-93 C				
Temp, K	347	Temp, C	74					
Pressure,mm	764.2	P, Mpa	0.1005526					
V/F	0.2840321							
	Feed	Liquid	Vapor	Psat, mmHg	Ki	yi	Test	xi
Methanol	0.3			1090.1578	1.4265347	0.3817157	-0.114133	0.2675825
Ethanol	0.7			639.59912	0.8369525	0.6143162	0.1141332	0.7339917
					sum yi =	0.9960319	4.799E-11	1.0015742
				0.1453544				
				0.0852799				
				Tb	346			
				Td	348			
						Tref C	T Ref K	
						50	323	
Heat Capacity Constants		TK Cp in J/mol-K						
	A	B	C	D		Q=HL+HV-H	HL	HV
methanol ig	21.15	7.09E-02	2.59E-05	-2.85E-08		MeOH	1.44E+04	4.00E+04
ethanol ig	9.014	2.14E-01	-8.39E-05	1.37E-09		EtOH	3.57E+04	4.19E+04
						Total	3.00E+04	4.10E+04
methanl Liq	111.7	-0.4264	1.09E-03			3.32E+04	J/(mole feed)	
ethanol Liq	281.6	-1.435	2.90E-03			3.32E+01	kJ/(mole feed)	
Heat of Vaporization at 760 mmHg								
	TbC	DHvap kJ/m	Tb K	DH J/mole				
Methanol	64.7	38.278	337.7	38278				
Ethanol	78.5	38.58	351.5	38580				

e) What is the heat flow needed to maintain the receiving tank at 74° C? (*Use the feed stream as the reference point for enthalpy = 0.*)

See above.