Quiz 12 Chemical Engineering Thermodynamics
April 11, 2019

An absorption refrigerator* uses a refrigerant and an absorber rather than a refrigerant/compressor in a normal refrigerator. It runs off a low-level heat source such as solar heat or a gas burner (RV refrigerators). In the ammonia (1) and water (2) refrigerator, water is the absorber, and ammonia is the refrigerant. In one iteration of such a refrigerator, ammonia vapor is absorbed into water at 40.6°C and 0.515 MPa, $x_1 = 0.5$ ammonia (*Absorber*).

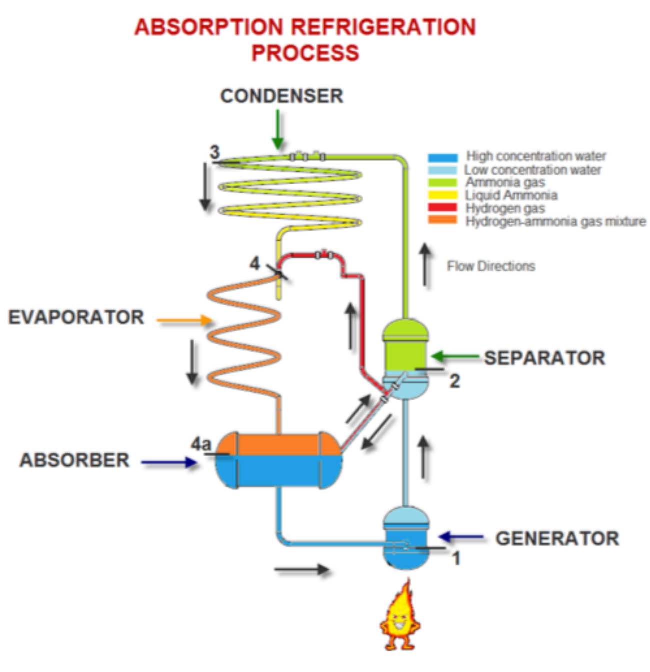
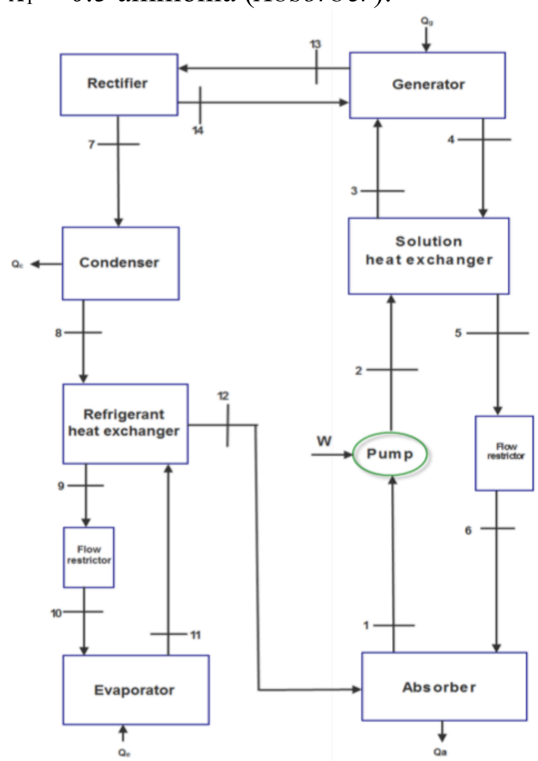


Figure 10 Diagram with state points of a basic three fluid absorption system.



USE THE ANSWER SHEET TO GIVE YOUR ANSWERS
BUT ALSO SHOW WORK (show some work if you use Excel).

a) Ganesh** reports an equilibrium point of P=3.5 MPa, T = 90°C, x_1=0.709 and y_1 = 0.871 for the ammonia/water system. Use these values to calculate the ***two***-parameter Margules coefficients, A_{12} and A_{21}.
b) Calculate the ***one***-parameter Margules coefficient "A_{12}" using "A_{12}" = $(x_1 \ln\gamma_1 + x_2 \ln\gamma_2)/(x_1 x_2)$.
c) **Compare** "A_{12}" from part "b" with the two-parameter result and comment on the advantage of the two-component model using the Redlich-Kister form, $G_E/RT = x_1 x_2 (B_{12} + C_{12} (x_1 - x_2))$ considering $B_{12} = (A_{21} + A_{12})/2$ and $C_{12} = (A_{21} - A_{12})/2$. *That is, compare B_{12} with "A_{12}" from the one-component model; and compare the value of C_{12} to B_{12} to assess the importance of asymmetry in G_E as a function of x_1.*
d) Using the one-parameter Margules coefficient from part "b" calculate the bubble pressure in the absorber at 40.6°C and 0.515 MPa, $x_1 = 0.5$.
e) Using the one-parameter Margules coefficient from part "b" calculate the dew pressure in the generator which is at 79.15°C, $y_1 = 0.987$. Proceed until reasonable convergence.

f) Extra credit: The ammonia-water refrigerator had a small impact in the 1920's before widespread electrification in the US (Crosley Icyball manufactured in Cincinnati https://en.wikipedia.org/wiki/Icyball) but it has had almost no impact in the developing world despite widespread need for refrigeration for vaccines and other uses. List some reasons that you think could explain why this absorption refrigerator hasn't found wider application in areas without electrification (Crosley delivered 10,000 Icyballs to Tanzania in the 1930's).

* https://web.wpi.edu/Pubs/E-project/Available/E-project-042612-110655/unrestricted/MQP-Design_and_Analysis_of_an_Absorption_Refrigeration_System.pdf
** http://shodhganga.inflibnet.ac.in/handle/10603/37842

R = 8.314 J/(mole °K)

$$\frac{G^E}{RT} = A_{12}x_1x_2 = x_1 \ln\gamma_1 + x_2 \ln\gamma_2$$

$$\ln\gamma_1 = A_{12}x_2^2$$

$$\ln\gamma_2 = A_{12}x_1^2$$

Antoine Constants (*T in °K P in Bar*)

	A	B	C	T_{Min}(°K)	T_{Max} (°K)
(1) Ammonia	4.87	1110	-10.4	240	372
(2) Water	3.56	644	-198	379	573
(2) Water	4.65	1440	-64.8	256	373

T is in °K and P is in Bar

$\log_{10}(P) = A - (B / (T + C))$

$$\boxed{\frac{G^E}{RT} = x_1x_2(A_{21}x_1 + A_{12}x_2)}$$

$$A_{12} = \left(2 - \frac{1}{x_2}\right)\frac{\ln\gamma_1}{x_2} + \frac{2\ln\gamma_2}{x_1}$$

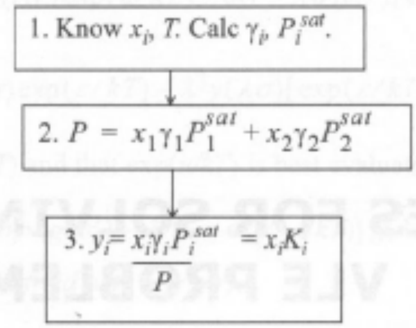
$$A_{21} = \left(2 - \frac{1}{x_1}\right)\frac{\ln\gamma_2}{x_1} + \frac{2\ln\gamma_1}{x_2}$$

Modified Raoult's law.

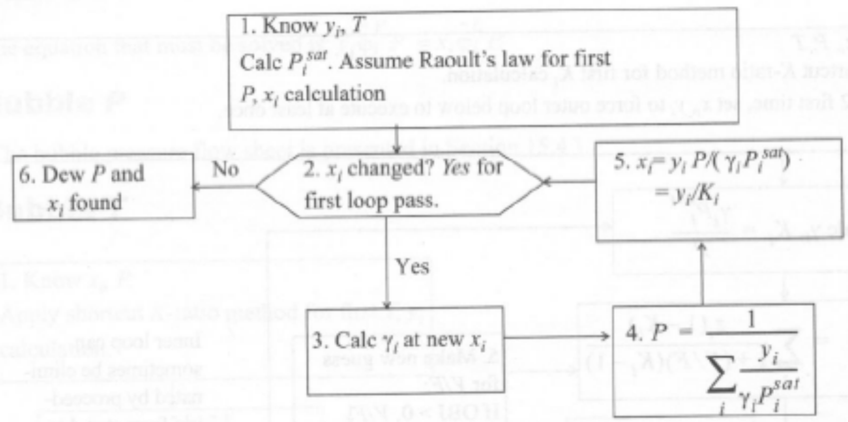
$$\boxed{y_iP = x_i\gamma_iP_i^{sat}} \quad \text{or} \quad \boxed{K_i = \frac{\gamma_i^L P_i^{sat}}{P}} \qquad 11.18$$

The equation that must be solved is: $y_iP = x_i\gamma_i P_i^{sat}$

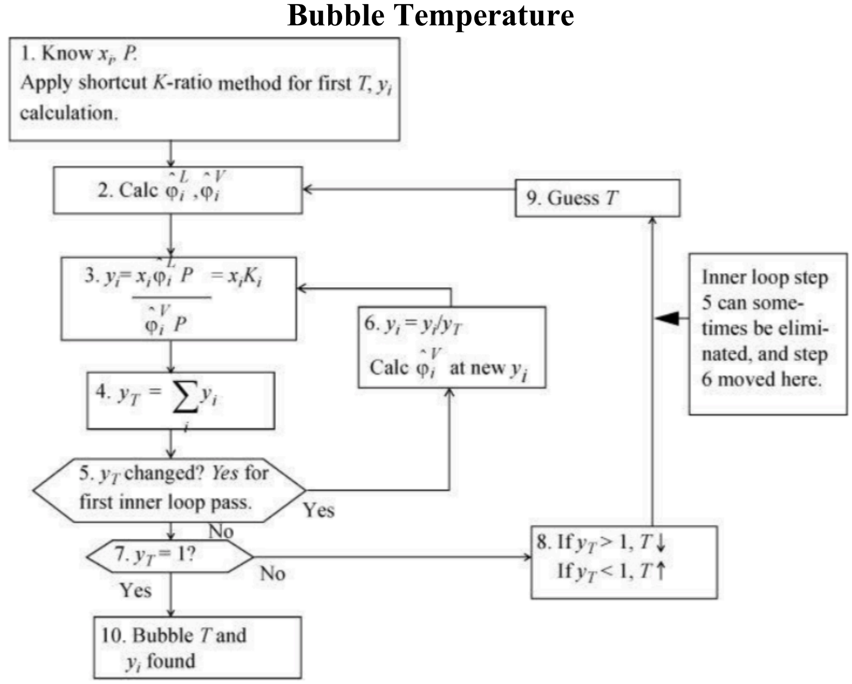
Bubble *P*



Dew *P*



Bubble Temperature



Answer Sheet

a) A_{12}:

A_{21}:

b) "A_{12}":

c) B_{12}:

C_{12}:

Compare B_{12} to "A_{12}":

Compare C_{12} to B_{12}:

d) Bubble Pressure:

e) Dew Pressure:

f) List some reasons:

Answer Sheet

a) A_{12}: 9.90

A_{21}: 1.22

b) "A_{12}": 3.75

c) B_{12}: 5.56

C_{12}: -4.34

Compare B_{12} to "A_{12}":
This comparison reflects the difference in value at x = 0.5. The value is about 33% different so this is significant. It indicates that the one parameter model is not very good for this system in terms of the general value of A_{12}.

Compare C_{12} to B_{12}:

C_{12}/B_{12} is about 32% which indicates a large degree of skewedness. The negative sign indicates that the curve is skewed to the left. This also indicates that the one parameter Margulus function is not very good for this system.

d) Bubble Pressure: 20.7 bar

e) Dew Pressure: 33.0 bar

f) List some reasons:
-Ammonia danger
-Comparison of cost with a solar panel and a conventional refrigerator. The corrosive nature of ammonia and the pressure of the system requires the use of stainless steel which is very expensive compared to a solar panel and a conventional refrigerator.
-Overall the system is "clunky".
-There is something like a street appeal to this kind of appliance and the ammonia refrigerator doesn't have street appeal. There might be a way to improve on this with careful design. Ammonia absorption refrigeration is widely used on the industrial scale, especially in the food processing industry.
-There are probably many more reasons.

		TC	TK	P bar		
		90	363	35		
		A	B	C	D	
1	Ammonia	4.87	1110	-10.4		**Part a**
2	Water	4.65	1440	-64.8		two param.
		Psat Bar	x	y	gamma	A (12;21)
1	Ammonia	52.7177531	0.709	0.871	0.815611	**9.90**
2	Water	0.66225639	0.291	0.129	23.4281831	**1.22**
Part b	A12 one parameter					
	3.75					
Part c	B12	C12	C12(x1-x2)	C12(x1-x2)/B12		
	5.56	**-4.34**	**-1.8143553**	**-0.326183**		
	Value at x=.5			Skewedness		

		TC	TK	P bar		
		40.6	313.6			
		A	B	C		
1	Ammonia	4.87	1110	-10.4		
2	Water	4.65	1440	-64.8		**Part d**
		Psat Bar	x	y	gamma	P bar
1	Ammonia	16.1826683	0.5	0.99552061	2.5523317	**20.7**
2	Water	0.07281463	0.5	0.00447939	2.5523317	

Psat1 bar	Psat2 bar
42.01813	0.437829

		g1	g2	P bar	
x1	x2	1	1	18.8	
0.44160937	0.5582088	3.21712784	2.07782285	46.3146565	
0.33816648	0.66183352	5.16853103	1.53547095	41.8722831	
0.19030051	0.80969949	11.687849	1.14545686	35.8021733	
0.07195405	0.92804595	25.2735864	1.01960489	33.2773545	
0.03092875	0.96907125	33.8392573	1.00359364	33.0253203	
0.02292486	0.97707514	35.8747741	1.00197275	33.0160801	
0.02161806	0.97838194	36.2202031	1.00175406	33.0158352	Part e
0.02141173	0.97858827	36.2750881	1.00172071	33.0158291	
0.02137933	0.97862067	36.2837155	1.0017155	33.015829	
0.02137425	0.97862575	36.2850694	1.00171469	33.015829	
0.02137345	0.97862655	36.2852818	1.00171456	33.015829	
0.02137333	0.97862667	36.2853151	1.00171454	33.015829	
0.02137331	0.97862669	36.2853203	1.00171454	33.015829	
0.0213733	0.9786267	36.2853211	1.00171454	33.015829	
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