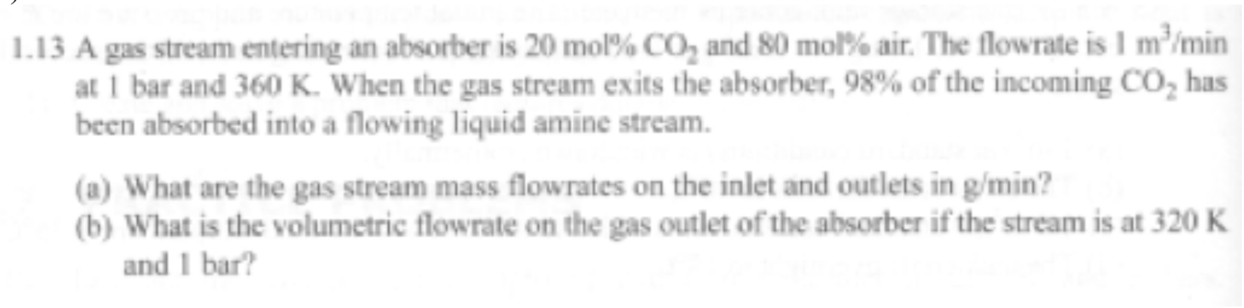
Quiz 1
Chemical Engineering Thermodynamics
January 16, 2015

1)

9. Can an ideal gas condense? Can real fluids that follow the ideal gas law condense?

2)



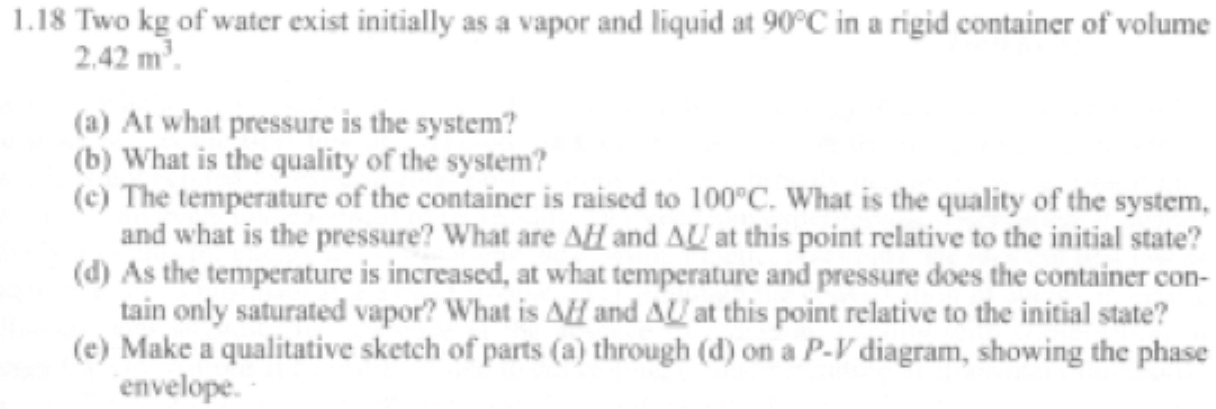
1.13 A gas stream entering an absorber is 20 mol% CO_2 and 80 mol% air. The flowrate is 1 m^3/min at 1 bar and 360 K. When the gas stream exits the absorber, 98% of the incoming CO_2 has been absorbed into a flowing liquid amine stream.

(a) What are the gas stream mass flowrates on the inlet and outlets in g/min?

(b) What is the volumetric flowrate on the gas outlet of the absorber if the stream is at 320 K and 1 bar?

Molar mass: CO2 = 44.0 g/mole, Air = 28.8 g/mole, R = 8.31e-5 bar m^3/(K mole)

3)



1.18 Two kg of water exist initially as a vapor and liquid at 90°C in a rigid container of volume 2.42 m^3.

(a) At what pressure is the system?

(b) What is the quality of the system?

(c) The temperature of the container is raised to 100°C. What is the quality of the system, and what is the pressure? What are $\Delta \underline{H}$ and $\Delta \underline{U}$ at this point relative to the initial state?

(d) As the temperature is increased, at what temperature and pressure does the container contain only saturated vapor? What is $\Delta \underline{H}$ and $\Delta \underline{U}$ at this point relative to the initial state?

(e) Make a qualitative sketch of parts (a) through (d) on a *P*-*V* diagram, showing the phase envelope.

E.9 PROPERTIES OF WATER[1]

I. Saturation Temperature

T (°C)	*P* (MPa)	V^L m^3/kg	V^V m^3/kg	U^L kJ/kg	ΔU^{vap} kJ/kg	U^V kJ/kg	H^L kJ/kg	ΔH^{vap} kJ/kg	H^V kJ/kg	S^L kJ/kg-K	ΔS^{vap} kJ/kg-K	S^V kJ/kg-K
0.01	0.000612	0.001000	205.9912	0.00	2374.92	2374.92	0.00	2500.92	2500.92	0.0000	9.1555	9.1555
5	0.000873	0.001000	147.0113	21.02	2360.76	2381.78	21.02	2489.04	2510.06	0.0763	8.9485	9.0248
10	0.001228	0.001000	106.3032	42.02	2346.63	2388.65	42.02	2477.19	2519.21	0.1511	8.7487	8.8998
15	0.001706	0.001001	77.8755	62.98	2332.51	2395.49	62.98	2465.35	2528.33	0.2245	8.5558	8.7803
20	0.002339	0.001002	57.7567	83.91	2318.41	2402.32	83.91	2453.52	2537.43	0.2965	8.3695	8.6660
25	0.003170	0.001003	43.3373	104.83	2304.30	2409.13	104.83	2441.68	2546.51	0.3672	8.1894	8.5566
30	0.004247	0.001004	32.8783	125.73	2290.18	2415.91	125.73	2429.82	2555.55	0.4368	8.0152	8.4520
35	0.005629	0.001006	25.2053	146.63	2276.04	2422.67	146.63	2417.92	2564.55	0.5051	7.8466	8.3517
40	0.007385	0.001008	19.5151	167.53	2261.86	2429.39	167.53	2405.98	2573.51	0.5724	7.6831	8.2555
45	0.009595	0.001010	15.2521	188.43	2247.65	2436.08	188.43	2394.00	2582.43	0.6386	7.5247	8.1633
50	0.012400	0.001012	12.0269	209.33	2233.40	2442.73	209.34	2381.95	2591.29	0.7038	7.3710	8.0748
55	0.015800	0.001015	9.5643	230.24	2219.10	2449.34	230.26	2369.83	2600.09	0.7680	7.2218	7.9898
60	0.019900	0.001017	7.6672	251.16	2204.74	2455.90	251.18	2357.65	2608.83	0.8313	7.0768	7.9081
65	0.025000	0.001020	6.1935	272.09	2190.32	2462.41	272.12	2345.38	2617.50	0.8937	6.9359	7.8296
70	0.031200	0.001023	5.0395	293.03	2175.83	2468.86	293.07	2333.03	2626.10	0.9551	6.7989	7.7540
75	0.038600	0.001026	4.1289	313.99	2161.25	2475.24	314.03	2320.57	2634.60	1.0158	6.6654	7.6812
80	0.047400	0.001029	3.4052	334.96	2146.60	2481.56	335.01	2308.01	2643.02	1.0756	6.5355	7.6111
85	0.057900	0.001032	2.8258	355.95	2131.86	2487.81	356.01	2295.32	2651.33	1.1346	6.4088	7.5434
90	0.070200	0.001036	2.3591	376.97	2117.00	2493.97	377.04	2282.49	2659.53	1.1929	6.2852	7.4781
95	0.084600	0.001040	1.9806	398.00	2102.04	2500.04	398.09	2269.52	2667.61	1.2504	6.1647	7.4151
100	0.101400	0.001043	1.6718	419.06	2086.96	2506.02	419.17	2256.40	2675.57	1.3072	6.0469	7.3541
105	0.120900	0.001047	1.4184	440.15	2071.75	2511.90	440.27	2243.12	2683.39	1.3633	5.9319	7.2952
110	0.143400	0.001052	1.2093	461.26	2056.41	2517.67	461.42	2229.64	2691.06	1.4188	5.8193	7.2381
115	0.169200	0.001056	1.0358	482.41	2040.92	2523.33	482.59	2215.99	2698.58	1.4737	5.7091	7.1828
120	0.198700	0.001060	0.8912	503.60	2025.26	2528.86	503.81	2202.12	2705.93	1.5279	5.6012	7.1291
125	0.232200	0.001065	0.7700	524.83	2009.44	2534.27	525.07	2188.03	2713.10	1.5816	5.4954	7.0770
130	0.270300	0.001070	0.6680	546.09	1993.44	2539.53	546.38	2173.70	2720.08	1.6346	5.3918	7.0264
135	0.313200	0.001075	0.5817	567.41	1977.24	2544.65	567.74	2159.13	2726.87	1.6872	5.2900	6.9772
140	0.361500	0.001080	0.5085	588.77	1960.85	2549.62	589.16	2144.28	2733.44	1.7392	5.1901	6.9293
145	0.415700	0.001085	0.4460	610.19	1944.23	2554.42	610.64	2129.16	2739.80	1.7907	5.0919	6.8826
150	0.476200	0.001091	0.3925	631.66	1927.39	2559.05	632.18	2113.75	2745.93	1.8418	4.9953	6.8371
155	0.543500	0.001096	0.3465	653.19	1910.32	2563.51	653.79	2098.02	2751.81	1.8924	4.9002	6.7926
160	0.618200	0.001102	0.3068	674.79	1892.99	2567.78	675.47	2081.97	2757.44	1.9426	4.8065	6.7491
165	0.700900	0.001108	0.2724	696.46	1875.39	2571.85	697.24	2065.57	2762.81	1.9923	4.7143	6.7066
170	0.792200	0.001114	0.2426	718.20	1857.53	2575.73	719.08	2048.82	2767.90	2.0417	4.6233	6.6650
175	0.892600	0.001121	0.2166	740.02	1839.37	2579.39	741.02	2031.69	2772.71	2.0906	4.5335	6.6241
180	1.002800	0.001127	0.1938	761.92	1820.91	2582.83	763.05	2014.16	2777.21	2.1392	4.4448	6.5840
185	1.123500	0.001134	0.1739	783.91	1802.13	2586.04	785.19	1996.22	2781.41	2.1875	4.3572	6.5447

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[1] Harvey, A. P. Peskin, A. P., Klein, S. A., December 1997. NIST/ASME Steam Properties, Version 2.1, NIST Standard Reference Data Program.

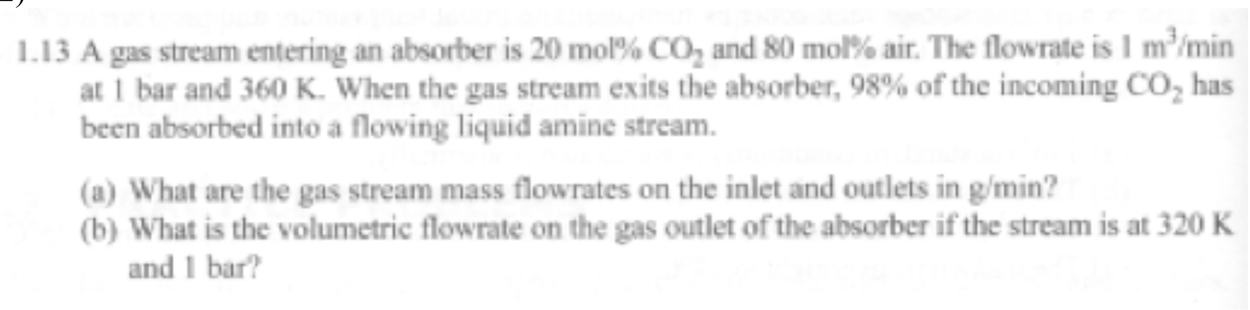
Answers Quiz 1
Chemical Engineering Thermodynamics
January 16, 2015

1)

9. Can an ideal gas condense? Can real fluids that follow the ideal gas law condense?

An ideal gas cannot condense since there are no attractive forces between the gas molecules or atoms. A real gas that follows the ideal gas law can condense since it only has ideal behavior over a limited range of temperature and pressure. At some low temperature or high pressure the attractive potential between molecules will be stronger than 3kT/2 and the molecules will condense.

2)



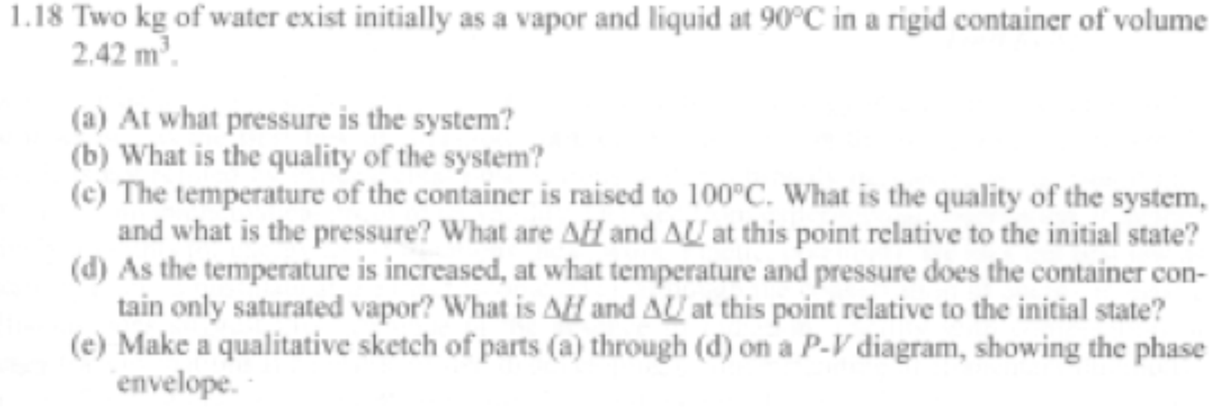
1.13 A gas stream entering an absorber is 20 mol% CO_2 and 80 mol% air. The flowrate is 1 m^3/min at 1 bar and 360 K. When the gas stream exits the absorber, 98% of the incoming CO_2 has been absorbed into a flowing liquid amine stream.

(a) What are the gas stream mass flowrates on the inlet and outlets in g/min?

(b) What is the volumetric flowrate on the gas outlet of the absorber if the stream is at 320 K and 1 bar?

a) n = PV/RT = 1 bar * 1 m^3/min/(8.31e-5 bar m^3/(K mole) 360K) = 33.4 mole/min with 20% $C0_2$ = 6.7 mole/min and 26.7 mole/min air.
In exit stream you have 0.02*6.7 mole/min CO_2 = 0.1 mole/min and 26.7 mole/min air. CO_2 molecular weight is 44.0 g/mole and air has an average molecular weight of 28.8 g/mole. So mass rate of the incoming stream is 6.7 mole/min * 44.0 g/mole + 26.7 mole/min * 28.8 g/mole = 1.06 kg/min.
Exit stream has 0.1 mole/min * 44.0 g/mole + 26.7 mole/min * 28.8 g/mole = 0.77 kg/min.
b) dV/dt = 26.8 moles/min 8.31e-5 bar m^3/(K mole) 320K/1 bar = 0.713 m^3/min

3)



1.18 Two kg of water exist initially as a vapor and liquid at 90°C in a rigid container of volume 2.42 m^3.

(a) At what pressure is the system?

(b) What is the quality of the system?

(c) The temperature of the container is raised to 100°C. What is the quality of the system, and what is the pressure? What are $\Delta \underline{H}$ and $\Delta \underline{U}$ at this point relative to the initial state?

(d) As the temperature is increased, at what temperature and pressure does the container contain only saturated vapor? What is $\Delta \underline{H}$ and $\Delta \underline{U}$ at this point relative to the initial state?

(e) Make a qualitative sketch of parts (a) through (d) on a P-V diagram, showing the phase envelope.

a) 0.070 MPa from the Saturation Temperature table.

b) $V = 2.42/2 = 1.21$ m^3/kg. $V_L = .0010$ m^3/kg $V_V = 2.36$ m^3/kg $q = (V-V_L)/(V_V-V_L)=1.21/2.36 = 0.51$

c) At 100°C the pressure is 0.101 MPa from Saturation Temperature table. $V_L = .001$ m^3/kg $V_V = 1.67$ m^3/kg $q = (V-V_L)/(V_V-V_L)=1.21/1.67 = 0.72$

At 100°C $H_L = 419$, $\Delta H = 2260$kJ/kg so $H = 419 + 0.72 * 2260$ kJ/kg = 2050 kJ/kg
At 80°C $H_L = 335$, $\Delta H = 2310$kJ/kg so $H = 335 + 0.51 * 2310$ kJ/kg = 1510 kJ/kg
So, $\Delta H = 1510$ kJ/kg - 2050 kJ/kg = -540kJ/kg

At 100°C $U_L = 419$, $\Delta U = 2087$kJ/kg so $U = 419 + 0.72 * 2087$ kJ/kg = 1920 kJ/kg
At 80°C $U_L = 335$, $\Delta U = 2147$kJ/kg so $U = 335 + 0.51 * 2147$ kJ/kg = 1430 kJ/kg
So, $\Delta U = 1430$ kJ/kg - 1920 kJ/kg = -490kJ/kg

d) From the saturated table the temperature where the specific volume for the vapor phase is 1.21 m^3/kg is 110°C.
At that point the liquid enthalpy is 461kJ/kg and the liquid internal energy is also 461 kJ/kg. so $\Delta H = 461-1510$kJ/kg = -1049 kJ/kg and $\Delta U = 461 - 1430$ kJ/kg = -969 kJ/kg.

e)