**EML 3100 Exam 1** **THERMODYNAMICS** **2/4/14 11:45-1:00 pm**
Page 1/3 Solutions (dommelen@eng.fsu.edu) series a

DO NOT WRITE ON THE BLUE TABLES. RETURN THE BLUE TABLES WITH YOUR EXAM. DO NOT STAPLE THE EXAM SHEETS TOGETHER. Put your answers on the same sheet as the question, Use at least 5 digits in your computations and answers where possible. You must give the units of your answers. You must write clearly. Encircle the right answer number in multiple choice. To correct, erase the wrong circle as well as you can and encircle the corrected answer number twice. Best possible answer for multiple choice. For questions asking a number, putting the clear correct formula(s) below the question might result in partial credit even if the answer is wrong. *Not following those requirements will result in reduced or no credit.*

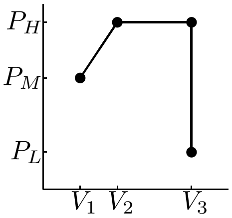
1. (5%) A rigid container contains compressed liquid.
   [✓ 1.] You must cool it to make it boil.
   2. You must heat it to make it boil.
   3. In a rigid container, it can only freeze, not boil.

2. (5%) One leg of a mercury manometer is open to the ambient pressure of 100 kPa. The other is connected to a container with a gas. The mercury stands 15 cm higher in that leg. The pressure of the gas is 80.053 kPa and the gauge pressure of the gas is -19.947 kPa.

3. (5%) Given tables for the substance, what would be enough information to determine the number of moles:
   1. $P$, $v$, and $T$
   2. $P$, $v$, and $x$.
   [✓ 3.] $P$, $V$ and $x$

4. (5%) A substance at 150 kPa is in a cylinder with a 1 cm diameter. A piston floats on it and the ambient pressure is 100 kPa. The weight of the piston is 3.9270 N.

5. (5%) Write the expression for the work done in the shown process, in terms of $V_1$, $V_2$, $V_3$, $P_L$, $P_M$, and $P_H$. Use the standard formulae for those processes.



$\frac{1}{2}(P_M + P_H)(V_2 - V_1) + P_H(V_3 - V_2)$ .

6. (5%) Without using interpolation, the most accurate value of the density of water at 100°C and 100 atm is 962.93 in units of kg/m$^3$ .

7. (5%) The volume of 2 kmol of liquid benzene at about room temperature and pressure is 0.17774 m$^3$.

8. (33%) A rigid container contains 2.5 L of water at 175°C and 0.00125 $\mathrm{m}^3/\mathrm{kg}$. Then the water is heated until the pressure becomes 10,000 kPa.

   (a) Construct the initial and final phases of the water in two *separate* very neat $Pv$-diagrams, marking all lines and points used to do it with their values. State the phases. Do not put more info in the diagrams than is needed to construct the phase.

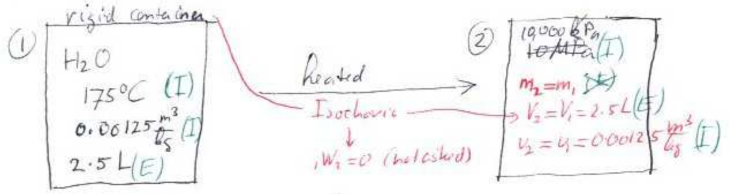
   (b) Show the process as a fat line in the diagram for the final phase.

   (c) Find the initial pressure, mass of the vapor and mass of the liquid, if any.

   (d) Find the final temperature, mass of the vapor, and mass of the liquid, if any.

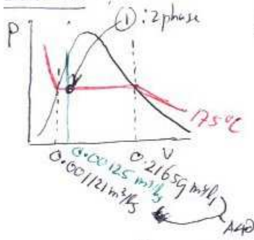
   You must show the derivations and reasoning completely and correctly for full credit. You must give simplified units for your answers. Most accurate procedure only unless stated otherwise. Use at least 5 significant digits in your computations and answers. Give the source of every number.

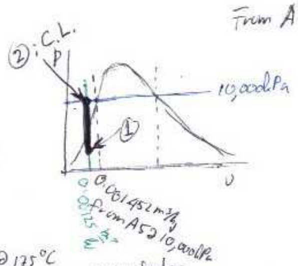
Given: In black



Asked: $P_1$, $m_{1\,vap}$, $m_{2\,vap}$, $T_2$, $m_{1\,liq}$, $m_{2\,liq}$, $(Pv)_1$, $(Pv)_2$

Solution:





From A-4: $\overset{\text{for ①}}{P_1} = 892.6$ kPa

$v_1 = v_{f_1} + x(v_{g_1} - v_{f_1})$

$0.00125 \frac{\mathrm{m}^3}{\mathrm{kg}} = 0.001121 \frac{\mathrm{m}^3}{\mathrm{kg}} + x(0.21659 - 0.001121) \frac{\mathrm{m}^3}{\mathrm{kg}}$

$$x = \frac{\overset{.000129}{0.00125 - 0.001121}}{0.21659 - 0.001121} = \frac{0.000129}{0.2154\ldots} = 0.000598694$$

$$m_1 = m = \frac{V}{v_1} = \frac{2.5\,\mathrm{L}\ \frac{1\,\mathrm{m}^3}{1000\,\mathrm{L}}}{0.00125\,\mathrm{m}^3/\mathrm{kg}} = 2\,\mathrm{kg}$$

→ conv. factor

$m_{1\,vap} = x\,m = 0.0011974$ kg

$m_{1\,liq} = m_1 - m_{1\,vap} = 1.9988$ kg

State 2, from A-7 @ 10 MPa, 0.00125 $\frac{\mathrm{m}^3}{\mathrm{kg}}$:

$g = 0.00125 \frac{\mathrm{m}^3}{\mathrm{kg}}$   $g_1 = 0.0012192 \frac{\mathrm{m}^3}{\mathrm{kg}}$   $g_2 = 0.0012653 \frac{\mathrm{m}^3}{\mathrm{kg}}$

$d_1 = 240$°C   $d_2 = 260$°C

$$T_2 = d_1 + \frac{g - g_1}{g_2 - g_1}(d_2 - d_1) = 240°\mathrm{C} + \frac{0.00125 - 0.0012192}{0.0012653 - 0.0012192}(260 - 240)°\mathrm{C}$$

$$= 240°\mathrm{C} + 0.668113\ 20°\mathrm{C} = 253.36°\mathrm{C}$$

$m_{2\,vap} = 0$   $m_{2\,liq} = 2$ kg

1 diagram
2 line 1
2 find sat
2 plot cal
~~2 line 2 based on above~~
2 I.D.
1 Proc

~~2 compute m units!~~
2 read A-4 $P_1$, [$v_{f_1}$, $v_{g_1}$]
5 2 phase formula
1 compute x
2 compute $m_{liq}$
~~compute~~ units!
(12)

1 $m_2 = m_1$
2 $v_2 = v_1$
2 Read A-7
4 Interpolate (2)
9

9. (32%) A spring-loaded piston-cylinder combination contains 5 kg of Argon at 25°C in an initial volume of 3 m$^3$. Then the Argon expands until the pressure is 50 kPa and the temperature 10°C.

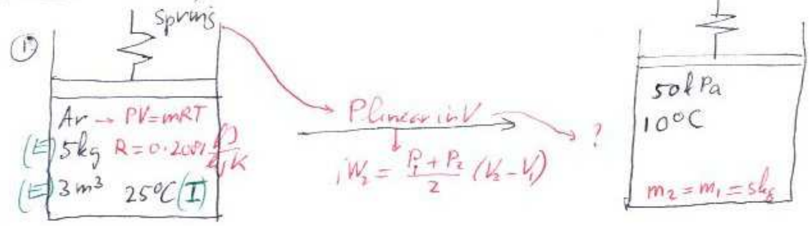
   (a) What is the work done by the argon in the process?

   (b) Do you expect the Argon to be a good ideal gas under the given conditions? Give multiple reasons.

   (c) Show the process and work graphically in a very neat $PV$ diagram.

   You must show the derivations and reasoning completely and correctly for full credit. You must give simplified units for your answers. Most accurate procedure only unless stated otherwise. Use at least 5 significant digits in your computations and answers. Give the source of every number.

Given: In black:



Asked $_1W_2$, PV, ideal gas?

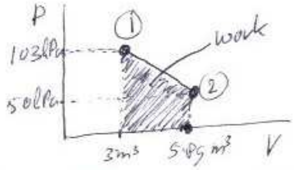
Solution: $P_1V_1 = m_1RT_1$ $\quad P_1\,3\text{m}^3 = 5\cancel{\text{kg}}\;\underbrace{0.2081\frac{\text{kJ}}{\cancel{\text{kg}}\,\cancel{\text{K}}}\;\underbrace{(273.15+25)\cancel{\text{K}}}_{298.15}}_{62.04}$

$$P_1 = \frac{310.225\ \text{kJ}}{3.\ \ \text{m}^3} = \underline{\underline{103.41\ \text{kPa}}}$$

$P_2V_2 = m_2RT_2$ $\quad 50\text{kPa}\ V_2 = 5\cancel{\text{kg}}\ 0.2081\frac{\text{kJ}}{\cancel{\text{kg}}\,\cancel{\text{K}}}(273.15+10)\cancel{\text{K}}$

$$V_2 = \frac{5\ \ 0.2081\ \ 283.15\ \text{kJ}}{50\ \text{kPa}} = \frac{294.61}{50}\frac{\text{kJ}}{\text{kPa}} = 5.8924\text{m}^3$$

$${}_1W_2 = \frac{P_1+P_2}{2}(V_2-V_1) = \frac{103.41+50}{2}\text{kPa}\,(5.8924-3)\text{m}^3 = \underline{\underline{221.86\text{kJ}}}$$



~~Good~~ Excellent ideal gas since

$\frac{T}{T_c} \approx 2 \gg 1$ and $\frac{P}{P_c} \approx \frac{100}{5000} \ll 1$

↳ cannot be liquid above $T_c$

~~PV = mRT~~
~~R from A-1 or $\bar{R}_u$~~
~~find $P_1 V_2$ units~~
~~$m_2 = m_1$~~
~~$_1W_2$ formula~~

7 PV = m RT (2)
3 R from A-1 or Ru(1)
3 Convert T to K (2)
1 Compute $P_1$, $V_1$ ~~units~~
2 $m_2 = m_1$

6 work formula
4 ~~compute $_1W_2$~~, units (2) ↓ kJ/m³
4 PV diagram
2 Good I.G.