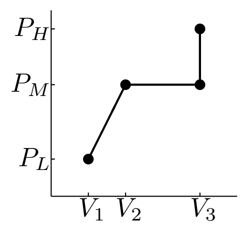
DO NOT WRITE ON THE BLUE TABLES. RETURN THE BLUE TABLES WITH YOUR EXAM. DO NOT STAPLE THE EXAM SHEETS TOGETHER. Put your answers on the same sheet as the question, Use at least 5 significant digits in your computations and answers where possible. You must give the units of your answers. You must write 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%) 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 class formula for each process type.



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

2. (5%) The ambient pressure is one atmosphere, and you need to measure a gauge pressure of 0.12 atmosphere. If you use a manometer filled with light oil, the measured oil deflection should be 136.25 cm.

3. (5%) A 5 kg piston with a diameter of 4 cm floats on a substance in a cylinder. The ambient pressure is 1 bar. The pressure in the substance is 139.02 kPa.

4. (5%) Given substance tables and the pressure and temperature, what would be enough additional information to determine the number of moles; (1) ρ, (2) v, or (3) V: 3 .

5. (5%) If you isobarically increase the temperature of saturated liquid a little bit, (1) it will be vapor only; (2) it will start to create a few vapor bubbles; (3) it will turn into compressed liquid: 1 .

6. (5%) The pressure of superheated water vapor at 200°C and 0.15 m^3/kg equals 1346.9 kPa kPa.

7. (5%) The molar specific volume of benzene at 25°C is $88.867\ 10^{-6}$ m^3/mol.

8. (33%) A rigid steel container contains 3 kg of water, initially at 300°C and 1600 kPa. Then the water is cooled to 185°C.
   (a) Construct the initial phase of the water in a very neat Pv-diagram, marking all lines and points used to do it with their values. State the phase. Do not put more info in the diagram than is needed to construct the phase.
   (b) What are the initial volume, specific volume, and quality, if defined?
   (c) After finding enough info about the final state without assuming a phase, construct and state its phase in a very neat Tv diagram, meeting the same conditions as the Pv diagram above.
   (d) What are the final pressure, volume, specific volume, and quality, if defined?
   (e) What is the work performed by the water during the cooling?

   Items are not equal credit. Remember, 5 significant digits throughout.

   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:

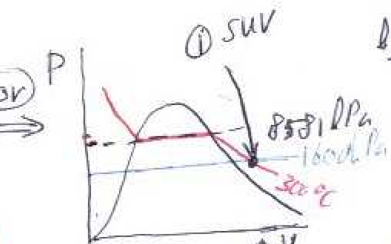
① H_2O, 300°C I, 1600 kPa I, 3 kg E —cool→ ② 185°C I, $m_2 = m_1 = 3$ kg E, $V_2 = V_1$ }, $v_2 = v_1$ I

steel container → isochoric → ${}_1W_2 = 0$

Asked $(Pv)_1$, x_1 defined, v_1, V_1, $(Tv)_2$, P_2, v_2, V_2, x_2 if defined, ${}_1W_2$ 5 digits

Solution: ${}_1W_2 = 0$

or ⟺

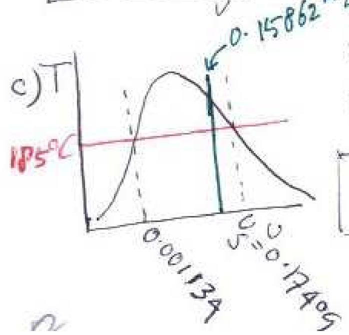


b) Table B.1.3 @ 300°C, 1600 kPa

$v = 0.15862 \ \frac{m^3}{kg}$

$V_1 = 3\,kg \ 0.15862 \ \frac{m^3}{kg} = 0.47586 \ m^3$

x_1 undefined



$v_2 = v_1 = 0.15862 \ m^3/kg$

$V_2 = V_1 = 0.47586 \ m^3$

$P_2 = 1122.7$ kPa

$v = v_f + x(v_g - v_f)$

$x = \frac{v - v_f}{v_g - v_f} = 0.91059 = x$

(.91714 → no v_f) (.90462 → no v_f (col))

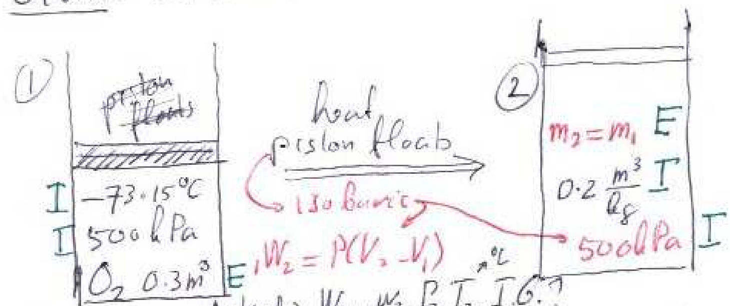
(.91114 = v/v_g)

9. (32%) A cylinder initially contains 0.3 m^3 of normal oxygen at -73.15°C and 500 kPa, secured by a heavy piston floating on the oxygen. Then the oxygen is heated until it reaches 0.2 m^3/kg.
   (a) What are the final pressure and temperature? (Same units as the initial values.)
   (b) What are the work and specific work performed by the oxygen during the heating? Show the specific work graphically in a Pv diagram with the values of the initial and final states numbered on the axes.
   (c) Is the ideal gas assumption valid according to the criteria of the book as given in your class notes? Explain every detail of the needed reasoning unambiguously.

Items are not equal credit.

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 block



Asked: $_1W_2$, $_1w_2$, P_2, T_2, I.G.?

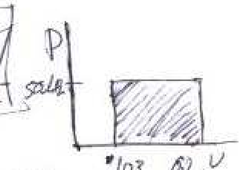
Solution:

$P_1V_1 = mRT_1$ $\quad m = \frac{P_1V_1}{RT_1} = \frac{500\,kPa\ 0.3\,m^3}{0.2598\frac{kJ}{kg\,K}(-73.15+273.15)K} = 2.88683\,kg$

$V_2 = mv_2 = 2.88683\,kg\ 0.2\,m^3/kg = 0.57736\,m^3$

$_1W_2 = P(V_2 - V_1) = 500\,kPa\,(0.57736 - 0.3)\,m^3 = \boxed{138.68\,kJ}$

$_1w_2 = {_1W_2}/m = \boxed{48.04\,kJ/kg}$ $\quad \boxed{P_2 = P_1} = \boxed{500\,kPa}$



$P_2v_2 = RT_2$ $\quad T_2 = \frac{500\,kPa\ 0.2\,m^3/kg}{0.2598\,kJ/kg\,K} = 384.91\,K = \boxed{111.76\,°C}$

$\frac{P}{P_c} = \frac{0.500}{5.04} \sim 0.1 \Rightarrow$ O.K. if superheated vapor $\quad \frac{T}{T_c} = \frac{200\,K}{154.K} > 1$

$\Rightarrow$ cannot be liquid or 2phase