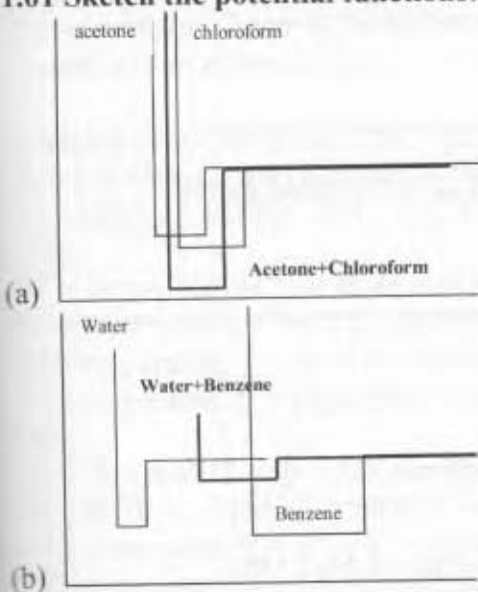


Introductory Chemical Engineering Thermodynamics

Homework Solutions

CHAPTER 1

1.01 Sketch the potential functions:



(1.02) For each of the states below, calculate....

- a) $n = PV/RT = 2 \text{ MPa}(3\text{E}3\text{cm}^3)/8.314/673 = \underline{1.07 \text{ mol}}$
 b) $n = PV/RT = 0.7 \text{ MPa}(3\text{E}3\text{cm}^3)/8.314/500 = \underline{0.505 \text{ mol}}$
 c) $n = PV/RT = 1.5 \text{ MPa}(3\text{E}3\text{cm}^3)/8.314/450 = \underline{1.20 \text{ mol}}$

(1.03) A 5 m³ tank form gas storage...

initial state $n^i = P^iV/RT = 0.1 \text{ MPa}(5\text{E}6 \text{ cm}^3)/8.314/291.15 = 206.6 \text{ moles}$

a) $n_{\text{removed}} = 0.1013(1\text{E}6 \text{ cm}^3)/8.314/273.15 = 44.6 \text{ mols}$

$P = (206.6 - 44.6)RT/V = 162(8.314)291.15/5\text{E}6 = 0.078 \text{ MPa} = \underline{0.78 \text{ bar}}, T = 291 \text{ K}$

b) $P = P^i(T^f/T^i) = 0.78(313.15/291.15) = \underline{0.839 \text{ bar}}, T = 313\text{K}$

c) $n_{\text{added}} = 0.1013(1.2\text{E}6)/8.314/273.15 = 53.53 \text{ mols}$

$P = (162 + 53.5)8.314(308.15)/5\text{E}6 = 0.11 \text{ MPa} = \underline{1.1 \text{ bar}}, T = 308.15\text{K}$

d) $P_f = P_i(T_f/T_i) = 0.11(291.15/308.15) = \underline{0.104 \text{ MPa}} = \underline{1.04 \text{ bar}}, T = 291\text{K}$

(1.04) An automobile tire has a pressure of 255 kPa (gauge)...

$P_1 V_1 / T_1 = P_2 V_2 / T_2 = R = \text{const.}$, $P_2 = P_1 T_2 / T_1$ since volume the same,
 $P_2 = (0.255 + 0.1013)(273.15)/(323.15) = 0.3012 \text{ MPa} = 0.2 \text{ kPa gauge}$

(1.05) A 5 m³ outdoor gas storage tank warms..

$n = PV/RT = 0.12 \text{ MPa}(5\text{E}6\text{cm}^3)/8.314/283.15 = 255 \text{ mol}$
 $P^f = P^i(T^f/T^i) = 0.12*(313.15/283.15) = 0.133 \text{ MPa}$

(1.06) Calculate the mass density of the following...

For all gases, $V = RT/P = 8.3143*298/0.1 = 24777 \text{ cm}^3/\text{mol}$
a) nitrogen, MW = 28, $\rho = \text{MW}/V = 28/24777 = 1.13\text{E-}3 \text{ g/cm}^3$
b) oxygen, MW = 32, $\rho = \text{MW}/V = 32/24777 = 1.29\text{E-}3 \text{ g/cm}^3$
c) air, ave molecular weight = $0.79*28 + 0.21*32 = 28.84$
 $\text{MW} = 28.84$, $\rho = \text{MW}/V = 28.84/24777 = 1.16\text{E-}3 \text{ g/cm}^3$
d) CO₂, MW = 44, $\rho = \text{MW}/V = 44/24777 = 1.78\text{E-}3 \text{ g/cm}^3$
e) argon, MW = 40, $\rho = \text{MW}/V = 40/24777 = 1.61\text{E-}3 \text{ g/cm}^3$

(1.07) Calculate the mass of air (in kg) that is contained...

$V = 12*7*3 = 252 \text{ m}^3$, $n = PV/RT = 0.1\text{MPa}(252\text{E}6\text{cm}^3)/8.314/293 = 10345 \text{ moles}$
air, ave molecular weight = $0.79*28 + 0.21*32 = 28.84$
 $m = n*\text{MW} = 10345 * 28.84 = 298345 = 298 \text{ kg}$

(1.08) Five grams of the specified pure solvent...

Use densities at 20°C from CRC handbook

a) hexane ($\rho = 0.66 \text{ g/cm}^3$, MW = 86.18)
moles of hexane, $n = (5 \text{ g})/\text{MW} = 5/86.18 = 5.80\text{E-}2 \text{ moles}$
 $V^L = \text{MW}/\rho = 86.18/0.66 = 130.6 \text{ cm}^3/\text{mol}$

30°C

$P^{\text{sat}} = 10^{(A-B/(T+C))} = 187 \text{ mm Hg} * (0.1013 \text{ MPa}/760 \text{ mm Hg}) = 2.5\text{E-}2 \text{ MPa}$

$V^V = RT/P = 8.314*303.15/2.5\text{E-}2 = 100965 \text{ cm}^3/\text{mol}$

50% evaporated, $\underline{V} = \underline{V}^L + \underline{V}^V = n^L V^L + n^V V^V = 3.8 + 2929 = 2933 \text{ cm}^3$

75% evaporated, $\underline{V} = 1.9 + 4393 = 4395 \text{ cm}^3$

50°C

$P^{\text{sat}} = 10^{(A-B/(T+C))} = 406 \text{ mm Hg} * (0.1013 \text{ MPa}/760 \text{ mm Hg}) = 0.0541 \text{ MPa}$

$V^V = RT/P = 8.314*323.15/0.0541 = 49705 \text{ cm}^3/\text{mol}$

50% evaporated, $\underline{V} = \underline{V}^L + \underline{V}^V = n^L V^L + n^V V^V = 3.79 + 1442 = 1446 \text{ cm}^3$

75% evaporated, $\underline{V} = 1.9 + 2163 = 2165 \text{ cm}^3$

At both temperatures the volume occupied by liquid is less than 1%.

The volumes are lower at the higher temperature because the pressure increases faster than the expansion due to temperature.

b) benzene ($\rho = 0.87865 \text{ g/cm}^3$, $\text{MW} = 78.12$)

moles of benzene, $n = (5 \text{ g})/\text{MW} = 5/78.12 = \underline{6.4E-2 \text{ moles}}$

$$V^L = \text{MW}/\rho = 78.12/0.87865 = 88.94 \text{ cm}^3/\text{mol}$$

30°C

$$P^{\text{sat}} = 10^{(A-B/(T+C))} = 119.3 \text{ mm Hg} * (0.1013 \text{ MPa}/760 \text{ mm Hg}) = 1.59E-2 \text{ MPa}$$

$$V^V = RT/P = 8.314 * 303.15 / 1.59E-2 = 158475 \text{ cm}^3/\text{mol}$$

$$50\% \text{ evaporated, } \underline{V = V^L + V^V = n^L V^L + n^V V^V = 2.85 + 5070 = 5073 \text{ cm}^3}$$

$$75\% \text{ evaporated, } \underline{V = 1.42 + 7604 = 7606 \text{ cm}^3}$$

50°C

$$P^{\text{sat}} = 10^{(A-B/(T+C))} = 271 \text{ mm Hg} * (0.1013 \text{ MPa}/760 \text{ mm Hg}) = 0.0362 \text{ MPa}$$

$$V^V = RT/P = 8.314 * 323.15 / 0.0362 = 74269 \text{ cm}^3/\text{mol}$$

$$50\% \text{ evaporated, } \underline{V = V^L + V^V = n^L V^L + n^V V^V = 2.8 + 2376 = 2378 \text{ cm}^3}$$

$$75\% \text{ evaporated, } \underline{V = 1.4 + 3564 = 2565 \text{ cm}^3}$$

At both temperatures the volume occupied by liquid is less than 1%,

The volumes are lower at the higher temperature because the pressure increases faster than then expansion due to temperature.

ethanol ($\rho = 0.7893 \text{ g/cm}^3$, $\text{MW} = 46.07$)

moles of ethanol, $n = (5 \text{ g})/\text{MW} = 5/46.07 = \underline{0.1085 \text{ moles}}$

$$V^L = \text{MW}/\rho = 46.07/0.7893 = 58.37 \text{ cm}^3/\text{mol}$$

30°C

$$P^{\text{sat}} = 10^{(A-B/(T+C))} = 78.44 \text{ mm Hg} * (0.1013 \text{ MPa}/760 \text{ mm Hg}) = 1.05E-2 \text{ MPa}$$

$$V^V = RT/P = 8.314 * 303.15 / 1.05E-2 = 241062 \text{ cm}^3/\text{mol}$$

$$50\% \text{ evaporated, } \underline{V = V^L + V^V = n^L V^L + n^V V^V = 3.2 + 13081 = 13084 \text{ cm}^3}$$

$$75\% \text{ evaporated, } \underline{V = 1.6 + 19622 = 19623 \text{ cm}^3}$$

50°C

$$P^{\text{sat}} = 10^{(A-B/(T+C))} = 221 \text{ mm Hg} * (0.1013 \text{ MPa}/760 \text{ mm Hg}) = 0.0295 \text{ MPa}$$

$$V^V = RT/P = 8.314 * 323.15 / 0.0295 = 91121 \text{ cm}^3/\text{mol}$$

$$50\% \text{ evaporated, } \underline{V = V^L + V^V = n^L V^L + n^V V^V = 3.2 + 4945 = 4948 \text{ cm}^3}$$

$$75\% \text{ evaporated, } \underline{V = 1.6 + 7417 = 7419 \text{ cm}^3}$$

At both temperatures the volume occupied by liquid is less than 1%,

The volumes are lower at the higher temperature because the pressure increases faster than then expansion due to temperature.

c) water ($\rho = 1 \text{ g/cm}^3$, $\text{MW} = 18.02$)

moles of water, $n = (5 \text{ g})/\text{MW} = 5/18.02 = \underline{0.2775 \text{ moles}}$

$$V^L = \text{MW}/\rho = 18.02/1 = 18 \text{ cm}^3/\text{mol}$$

30°C

$$P^{\text{sat}} = 10^{(A-B/(T+C))} = 31.7 \text{ mm Hg} * (0.1013 \text{ MPa}/760 \text{ mm Hg}) = 4.23E-3 \text{ MPa}$$

$$V^V = RT/P = 8.314 * 303.15 / 4.23E-3 = 595750 \text{ cm}^3/\text{mol}$$

$$50\% \text{ evaporated, } \underline{V = V^L + V^V = n^L V^L + n^V V^V = 2.5 + 82650 = 85653 \text{ cm}^3}$$

$$75\% \text{ evaporated, } \underline{V = 1.25 + 123976 = 123977 \text{ cm}^3}$$

50°C

$$P^{\text{sat}} = 10^{(A-B/(T+C))} = 92.3 \text{ mm Hg} * (0.1013 \text{ MPa}/760 \text{ mm Hg}) = 1.23E-2 \text{ MPa}$$

$$V^V = RT/P = 8.314 * 303.15 / 1.23E-2 = 218382 \text{ cm}^3/\text{mol}$$

$$50\% \text{ evaporated, } \underline{V = V^L + V^V = n^L V^L + n^V V^V = 2.5 + 30297 = 30300 \text{ cm}^3}$$

75% evaporated, $\underline{V} = 1.25 + 45446 = 45447 \text{ cm}^3$

At both temperatures the volume occupied by liquid is less than 1%,

The volumes are lower at the higher temperature because the pressure increases faster than the expansion due to temperature.

d) water using steam tables ($\rho = 1 \text{ g/cm}^3$, $\text{MW} = 18.02$)

moles of water, $n = (5 \text{ g})/\text{MW} = 5/18.02 = 0.2775 \text{ moles}$

$V^L = \text{MW}/\rho = 18.02/1 = 18 \text{ cm}^3/\text{mol}$

30°C

$P^{\text{sat}} = 4.247\text{E-}3 \text{ MPa}$ from steam tables

From steam tables: $V^V = RT/P = 8.314 \cdot 303.15 / 4.247\text{E-}3 = 593451.6 \text{ cm}^3/\text{mol}$

or from Steam Tables, $V^V = 32878.3 \text{ cm}^3/\text{g} \cdot 18.02 \text{ g/mol} = 592447 \text{ cm}^3/\text{mol}$

using steam table volumes

50% evaporated, $\underline{V} = \underline{V}^L + \underline{V}^V = n^L V^L + n^V V^V = 2.5 + 82202.0 = 82205 \text{ cm}^3$

75% evaporated, $\underline{V} = 1.25 + 123303 = 123304 \text{ cm}^3$

50°C

$P^{\text{sat}} = 1.24\text{E-}2 \text{ MPa}$ from steam tables

$V^V = RT/P = 8.314 \cdot 303.15 / 1.24\text{E-}2 = 216667 \text{ cm}^3/\text{mol}$

or from Steam Tables, $V^V = 12026.9 \text{ cm}^3/\text{g} \cdot 18.02 \text{ g/mol} = 216725 \text{ cm}^3/\text{mol}$

using steam table volumes

50% evaporated, $\underline{V} = \underline{V}^L + \underline{V}^V = n^L V^L + n^V V^V = 2.5 + 30070 = 30073 \text{ cm}^3$

75% evaporated, $\underline{V} = 1.25 + 45105 = 45106 \text{ cm}^3$

At both temperatures the volume occupied by liquid is less than 1%,

The volumes are lower at the higher temperature because the pressure increases faster than the expansion due to temperature.

(1.09) A gasoline spill is about 4L of liquid....

$\text{MW} = 114$

$$\frac{4000 \text{ cm}^3}{\text{cm}^3} \cdot \frac{0.692 \text{ g}}{114 \text{ g}} = 24.28 \text{ mol}$$

$V = RT/P = 8.314 \cdot 293 / 0.1 = 24.36 \text{ L/mol}$

$\underline{V} = nV = 24.28 \cdot 24.36 = 591 \text{ L}$

(1.10) The gross lifting force of a balloon...

At 100°C and 0.1013 MPa, $V = RT/P = 8.314 \cdot 373.15 / 0.1013 = 30626 \text{ cm}^3/\text{mol}$

$\rho_{\text{gas}} = \text{MW}/V = 32/30626 = 1.045\text{E-}3$

At 25°C and 0.1013 MPa, $V = RT/P = 8.314 \cdot 298.15 / 0.1013 = 24470 \text{ cm}^3/\text{mol}$

$\rho_{\text{air}} = \text{MW}/V = 29/24470 = 1.185\text{E-}3$

lifting force = $(1.185\text{E-}3 - 1.045\text{E-}3 \text{ g/cm}^3)(1\text{kg}/1000\text{g})1.5\text{E}9\text{cm}^3 = 210 \text{ kg}$

To obtain lifting force in Newtons, multiply by g/g.

(1.11) LPG is a useful fuel in rural locations...

MW = 44

$$\frac{40000 \text{ cm}^3}{\text{cm}^3} \times \frac{0.24 \text{ g}}{44 \text{ g/mol}} = 218 \text{ mol}$$

$$V = RT/P = 8.314 \times 293 / 0.1 = 24.36 \text{ L/mol}$$

$$\underline{V} = nV = 218 \times 24.36 = \underline{5315 \text{ L}}$$

mass density,

$$\frac{218 \text{ mol}}{5315 \text{ L}} \times \frac{44 \text{ g}}{\text{mol}} = 1.805 \text{ g/L}$$

air density (molar density given above)

$$\frac{\text{mol}}{24.36 \text{ L}} \times \frac{28.8 \text{ g}}{\text{mol}} = 1.18 \text{ g/L}$$

LPG is more dense and will stay near the ground unless mixed with air.

(1.12) The gas-phase reaction $A \Rightarrow 2R$ is conducted...

$$T^i = 400 \text{ K}, P^i = 0.05 \text{ MPa},$$

$$\text{Let } \xi \text{ be mols of A reacted, } n_A^f = n_A^i - \xi = n_A^i/2 \rightarrow \xi = n_A^i/2$$

$$n_R^f = 2\xi = n_A^i; n^f = n_A^f + n_R^f = 1.5 n_A^i$$

$$\underline{V} = nRT/P = n_A^i RT^i/P^i = n^f RT^f/P^f$$

$$\text{Rearranging: } P^f = 1.5 \frac{n_A^i}{n^f} \left(\frac{T^f}{T^i} \right) P^i = 1.5 (350/400) 0.05 = \underline{0.065 \text{ MPa}}$$

(1.13) A gas stream entering an absorber....

a) inlet flow

$$\dot{n}^i = P \underline{V}^i / RT = 0.1 \text{ MPa} \times (1 \text{E6 cm}^3/\text{min}) / 8.314 / 360 \text{ K} = 33.41 \text{ mol/min}$$

$$\begin{aligned} \text{ave mol wt.} &= 0.2 \times 44 \text{ g/mol} + 0.8 \times (0.79 \times 28 \text{ g/mol} + 0.21 \times 36 \text{ g/mol}) = \\ &= 0.2 \times 44 \text{ g/mol} + 0.8 \times 29.68 \text{ g/mol} = 32.54 \text{ g/mol} \end{aligned}$$

$$\text{Flow in} = \dot{m} = \dot{n}(MW) = 33.41 \times 32.54 = \underline{1087 \text{ g/min}}$$

outlet flow

$$\dot{m}_{\text{air}} = \dot{n}_{\text{air}}(MW) = 0.8 \times 33.41 \times 29.68 = 793.3 \text{ g/min}$$

$$\dot{m}_{\text{CO}_2} = \dot{n}_{\text{CO}_2}(MW) = 0.004 \times 33.41 \times 44 = 5.88 \text{ g/min}$$

$$\text{total mass flow out} = 793.3 + 5.9 = \underline{799.2 \text{ g/min}}$$

$$\begin{aligned} \text{b) volumetric flowrate, } \underline{V} &= \dot{n}RT/P = (0.804 \times 33.41) 8.314 \times 320 \text{ K} / 0.1 \text{ MPa} = \\ &= \underline{714 \text{ L/min} = 0.714 \text{ m}^3/\text{min}} \end{aligned}$$

(1.14) A permeation membrane separates an inlet air stream...

overall balance, $F = M + J$

nitrogen balance, $0.79 F = 0.5 M + 0.87 J$

$F = 2$, $M = 0.432$, $J = 1.568$ mol/min

at outlet conditions $V = RT/P = 8.314 \cdot 293 / 0.1 = 24360 \text{ cm}^3/\text{mol} = 24.36 \text{ L/mol}$

$\dot{V}_J = V \dot{n}_J = 24.36 \cdot 1.568 = 38.2 \text{ L/min}$, $\dot{V}_M = V \dot{n}_M = 24.36 \cdot 0.432 = 10.52 \text{ L/min}$

(1.15) (a) What size vessel holds 2 kg water...

a) from saturation temperature table at 80°C , $P = 0.0474 \text{ MPa}$

70 % vapor, $\underline{V} = 1.4 \text{ kg } V^V + 0.6 \text{ kg } V^L = 1.4 \cdot 3.405 + 0.6 \cdot 0.00103 = 4.77 \text{ m}^3$

$\underline{U} = 1.4 \cdot 2481.56 + 0.6 \cdot 334.96 = 3675.2 \text{ kJ}$

b) from the saturation pressure table at 0.2 MPa , $T = 120.2^\circ\text{C}$

$V = 1.6 \text{ m}^3 / 2 \text{ kg} = V^L + q \Delta V^{\text{vap}} = 0.001061 + q (0.8857 - 0.001061)$, $q = 0.903$

$\underline{U} = 2(504.49 + 0.903 \cdot 2024.6) = 4666 \text{ kJ}$

(1.16) For water at each of the following states, determine...

(a) superheated table, $U(\text{kJ/kg}) = 2515.5$, $H(\text{kJ/kg}) = 2687.5$

(b) single interpolation, $U(\text{kJ/kg}) = 3175.2 + 0.25(3167.9 - 3175.2) = 3173.4 \text{ kJ/kg}$

$H = 3541.3 + 0.25(3531.6 - 3541.3) = 3538.9 \text{ kJ/kg}$

(c) double interpolation, interpolate pressure first for higher accuracy.

T(C)\P(MPa)	7	7.5	8
450	U = 2979.0 H = 3288.3	2973.4 3280.8	2967.8 3273.3
475		U = 3021.7 kJ/kg H = 3343.2 kJ/kg	
500	U = 3074.3 H = 3411.4	3069.9 3405.5	3065.4 3399.5

(d) double interpolation, interpolate between saturation table and superheated table

T(C)\P(MPa)	0.6	0.7	0.8
164.95 (from sat table)		U = 2571.81 H = 2762.75	
180		U = 2599.0 kJ/kg H = 2798.1 kJ/kg	
200 (from superheated table)	U = 2639.3 H = 2850.6	2635.15 2845.15	2631.0 2839.7

(1.17) Determine the temperature, volume, and quality under the following conditions:

a) $U=3000$, $P=0.3 \Rightarrow$ superheated $q = 1$, $T = 400 + (3000 - 2966) / (3047.5 - 2966.0) \cdot 50 = 421^\circ\text{C}$

$V = 1.0315 + 21/50 \cdot (1.1092 - 1.0315) = 1.064 \text{ m}^3/\text{kg}$

b) $U=2900$, $P=1.7 \Rightarrow q = 1$

	U kJ/kg
350	2865.1 by single interpolation
$T = 370.7$ by interpolation between 350 and 400	2900
400	2949.5 by single interpolation

$V = 0.1646$ at 350 by interpolation, $V = 0.1793$ at 400 by interpolation,
 $V = 0.1646 + 20.7/50 * (0.1793 - 0.1646) = 0.1707 \text{ m}^3/\text{kg}$

c) $U=2500, P=0.3 \Rightarrow$ two-phase, $T = 133.58^\circ\text{C}$
 $U = 2500 = 561. + q*1982.0, q = 0.978$
 $V = 0.001073 + 0.978 * (0.6058 - 0.001073) = 0.593 \text{ m}^3/\text{kg}$

d) $U=350, P=0.03 \Rightarrow$ two-phase, $T = 69.1^\circ\text{C}$
 $U = 350 = 289.24 + q*2178.46, q = 0.028$
 $V = 0.001022 + 0.028 * (5.2284 - 0.001022) = 0.147 \text{ m}^3/\text{kg}$

(1.18) Two kg of water exist initially as V&L at 90°C with $V=2.42\text{m}^3$.

a) What is P ? at 90°C $L+V$ mix $\rightarrow$ therefore at saturation $\Rightarrow P^{\text{sat}} = 70.2 \text{ kPa}$

b) What is q ? $V = 2.42 \text{ m}^3 \Rightarrow V = 2.42 / 2 = 1.21 \text{ m}^3/\text{kg}$
 Use the equation: $M = M^L + q(M^V - M^L)$ call it Eqn "(A)"
 where M could be V, H or U ,

at 90°C (sat'n) $V^L = 0.001036 \text{ m}^3/\text{kg}$
 $V^V = 2.3591 \text{ m}^3/\text{kg}$

$1.21 = (0.001036) + q(2.3591 - 0.001036)$
 $q = 0.513$ (51.3 % vapor by mass)

c) If $T \rightarrow 100^\circ\text{C}$, get $q, \Delta U, \Delta H$. $V = 2.42/2 = 1.21 \text{ m}^3/\text{kg}$ (const. for system)
 $P = 0.1014 \text{ MPa}$

In sat'n temperature table, system is sat'd at 100°C

Quality

by eq. A, $1.21 = 0.01043 + q [1.6718 - 0.001043] \Rightarrow q = 0.723$

ΔH (for process)

by eq. A, $H^i = 377.04 + (0.513 \times 2282.5)$
 $= 1548.0 \text{ kJ/kg}$ at 90°C

and $H^f = 419.17 + (0.723 \times 2256.4)$
 $= 2050.5 \text{ kJ/kg}$ at 100°C

$\Delta H = 2(H^f - H^i) = 1005 \text{ kJ}$

ΔU (for process)

by eq. A, $U^i = 376.97 + (0.513 \times 2117.0)$
 $= 1463.0 \text{ kJ/kg}$

and $U^f = 419.06 + (0.723 \times 2086.96)$
 $= 1927.9 \text{ kJ/kg}$

$\Delta U = 2[U^f - U^i] = 929.9 \text{ kJ}$

Only sat'd vapor

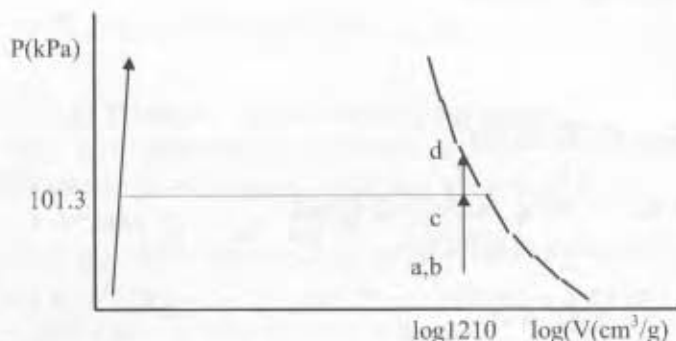
From sat'n table corresponding to $V^V = 1.21 \text{ m}^3/\text{kg}$

$T = 110^\circ\text{C}$, $P = 0.1434 \text{ MPa}$

$\Delta H = 2(H^f - H^i)$ (for process)	$\Delta U = 2(U^f - U^i)$ (for process)
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sat'd vap, H^f at $110^\circ\text{C} = 2691.1 \text{ kJ/kg}$
 (from part c)
 sat'd (L+V), H^i at $90^\circ\text{C} = 1548.0 \text{ kJ/kg}$
 $\Delta H = 2(2691.1 - 1548.0) = 2286.2 \text{ kJ}$

$U^f = 2517.7 \text{ kJ/kg}$;
 $U^i = 1463.0 \text{ kJ/kg}$
 $\Delta U = 2109.4 \text{ kJ}$



e.

(1.19) Three kg of saturated liquid water are to be evap'd at 60°C

a) **What pressure?** $P = 19.90 \text{ kPa}$ (corresponding to 60°C in sat'd steam tables)

b) **What is V_L (m³)?** $V_L = 3 \times V^L = 3 \times 0.001017 = 3.051 \times 10^{-3} \text{ m}^3$

$V^L = 0.001017 \text{ m}^3/\text{kg}$ (sat'd steam tables at 60°C (as sat'd liq volume))

c) **What V , ΔU when 2 kg evaporated?**

$V = m^L V^L + m^V V^V$
 $= 1(0.001017) + 2(7.6672) = 15.335 \text{ m}^3$
 overall specific volume $= 15.335 \text{ m}^3/3 \text{ kg}$
 $= 5.11 \text{ m}^3/\text{kg}$

$\Delta U = U^f - U^i$ (for process)
 $= [2(2455.9) + 1(251.16)] - 3(251.16)$
 $= 4409.5 \text{ kJ}$

alternatively,

$\Delta U = 2(\Delta U^{vap}) = 2(2204.74) = 4409.5 \text{ kJ}$

d) **What ΔH , ΔU when all 3 kg evap'd?**

$\Delta H = 3(\Delta H^{vap}) = 3(2357.65) = 7073 \text{ kJ}$

$\Delta U = 3(\Delta U^{vap}) = 3(2204.74) = 6614 \text{ kJ}$

e) **Make a P - V sketch of b-d.**

