ECHE363 Homework 1 - Due 1/24/15 Trevor Swan (tcs94)

1. $df = (A + Bx + Cx^2)\,dx + \frac{D}{y}\,dy$

a) $\left(\frac{\partial f}{\partial x}\right)_y = A + Bx + Cx^2$

b) $\left(\frac{\partial f}{\partial y}\right)_x = \frac{D}{y}$

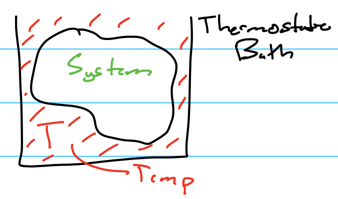
c) $\Delta f = \int_{x_1}^{x_2} \left(\frac{\partial f}{\partial x}\right)_y \Big|_{y=y_1} dx + \int_{y_1}^{y_2} \left(\frac{\partial f}{\partial y}\right)_x \Big|_{x=x_2} dy$

$= \int_{x_1}^{x_2} A + Bx + Cx^2 \, dx + \int_{y_1}^{y_2} \frac{D}{y}\, dy$

$= Ax + \frac{Bx^2}{2} + \frac{Cx^3}{3} \Big|_{x_1}^{x_2} + D\ln y \Big|_{y_1}^{y_2}$

$\Delta f = A(x_2 - x_1) + \frac{B}{2}(x_2^2 - x_1^2) + \frac{C}{3}(x_2^3 - x_1^3) + D(\ln y_2 - \ln y_1)$

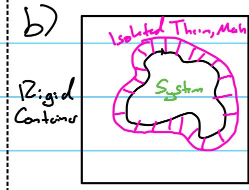
2. a)



Constraints: System remains at Bath temp T. Free Heat exchange until thermal eq. is reached.

Eq. Properties: Eventual Thermal Eq. @ Temp T. Assumed Force Eq, Phase Eq, and chemical Eq. No work is done by or on system, and properties depend on T.

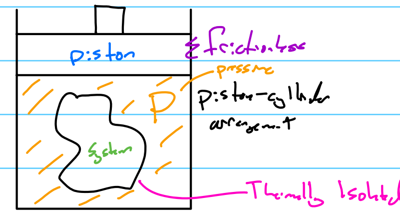
b)



Constraints: Rigid → Constant volume. No work, no heat transfer.

Eq. Properties: Internal Energy is constant. Uniform temp/pressure due to restrictions. Will tend to highest entropy over time. Phase & chem Eq assumed.

c)



Constraints: Isobaric, but influenced by pressure. Thermally isolated system, so $Q = 0$.

Equilibrium: Thermal eq and chemical eq. Could be phase eq depending on system properties. Work is done on or by the system is piston moves. Internal energy is affected by work done. $P_{sys} = P_{surroundings}$.

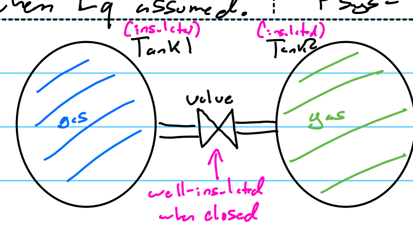
d)

Constraints: Constant temperature T and pressure P.

Equiv to bath

Eq. Properties: Temperature constant (thermal eq.), Work can be done, so no force eq. → influences volume. Internal volume depends on both volume and temp T.

e)



Short Opening:

→ Constraints: Little to no mass transfer, pressure/temp. don't change much

→ Eq. Properties: Tanks maintain original temps and pressures. Can assume Phase & chemical Equilibrium

Long Opening:

→ Constraints: Temperature and pressure can equilibrize, gradients may exist.

→ Eq. Properties: Final Pressures will equilize, and entropy will be maximized. Assume chemical & phase equilibrium.

3.

a) $V_{m,a} = \frac{V_a}{n_a}$ and $V_{m,b} = \frac{V_b}{n_b}$

$\Rightarrow V_1 = V_a + V_b$

$= V_{m,a} n_a + V_{m,b} n_b$

$V_1 = V_{m,a} n_a + V_{m,b} n_b$

b) $V_{m,1} = \frac{V_1}{n_a + n_b}$

$\Rightarrow V_{m,1} = \frac{V_{m,a} n_a + V_{m,b} n_b}{n_a + n_b}$

c) $K_1 = K_a + K_b$ or

$K_1 = K_{m,a} n_a + K_{m,b} n_b$

d) $K_{m,1} = \frac{K_{m,a} n_a + K_{m,b} n_b}{n_a + n_b}$

4. 2 kg water @ 1 bar, 45% vapor

Saturated water @ given pressure

$\begin{cases} 0.90 \text{ kg gas} = 900 \text{ g} \\ 1.10 \text{ kg liquid} = 1100 \text{ g} \end{cases}$

$1 \text{ bar} \times \frac{100 \text{ kPa}}{1 \text{ bar}} = 100 \text{ kPa}$

☆ steam tables ☆

From ECHE225 Textbook

$T_{sat} = 99.61°C$

$\hat{V}_f = 0.001043 \text{ m}^3/\text{kg}$

$\hat{V}_g = 1.6941 \text{ m}^3/\text{kg}$

Quality = 0.45

$\hat{S}_f = 1.3028 \frac{\text{kJ}}{\text{kg K}}$

$\hat{S}_g = 7.3589 \frac{\text{kJ}}{\text{kg K}}$

$\hat{V} = (1-0.45)0.001043 + 0.45(1.6941) = 0.7629 \frac{\text{m}^3}{\text{kg}}$

$\hat{S} = (1-0.45)1.3028 + 0.45(7.3589) = 4.028 \frac{\text{kJ}}{\text{kg K}}$

$\text{volume} = 2 \text{ kg} \cdot \hat{V} = 2 \text{ kg}(0.7629 \text{ m}^3/\text{kg}) = 1.5258 \text{ m}^3$

$$\boxed{\begin{array}{l} P = 1 \text{ bar or } 100 \text{ kPa}, \quad T_{sat} = 99.61°C \\ \hat{V} = 0.7629 \frac{\text{m}^3}{\text{kg}}, \quad \hat{S} = 4.028 \frac{\text{kJ}}{\text{kg K}} \\ \text{Volume of Vessel} = 1.5258 \text{ m}^3 = 1525.8 \text{ L} \end{array}}$$

5. 4 kg of water, rigid container 1 m^3

$\begin{cases} 1.6 \text{ bar} \times \frac{100 \text{ kPa}}{1 \text{ bar}} = 160 \text{ kPa} \\ \hat{V} = \frac{1 \text{ m}^3}{4 \text{ kg}} = 0.25 \text{ m}^3/\text{kg} \end{cases}$

☆ steam tables ☆ & NIST chemical webbook

$T_{sat} = 113.30°C$

$\hat{V}_L = 0.0010544 \text{ m}^3/\text{kg}$ $\quad \hat{u}_L = 8.5610 \frac{\text{kJ}}{\text{mol}}$

$\hat{V}_v = 1.0914 \text{ m}^3/\text{kg}$ $\quad \hat{u}_v = 45.424 \frac{\text{kJ}}{\text{mol}}$

$0.25 \text{ m}^3/\text{kg} = (1-x)(.0010544) + x(1.0914)$

$0.25 = 0.0010544 - 0.0010544x + 1.0914x$

$0.2489456 = 1.0903456x$

$x = 0.228$

$\hat{u} = (1-.228)(8.5610) + 0.228(45.424)$

$= 16.9775 \frac{\text{kJ}}{\text{mol}}$

$16.9775 \frac{\text{kJ}}{\text{mol}} \cdot \frac{1 \text{ mol}}{18.02 \text{ g}} \cdot \frac{1000 \text{ g}}{1 \text{ kg}} = 942.147 \frac{\text{kJ}}{\text{kg}}$

$942.147 \frac{\text{kJ}}{\text{kg}} \cdot 4 \text{ kg} = 3769.57 \text{ kJ}$

$$\boxed{\begin{array}{l} x = 0.228 \\ T_{sat} = 113.30°C \\ U_m = 16.9775 \frac{\text{kJ}}{\text{mol}} \\ \hat{U} = 942.147 \frac{\text{kJ}}{\text{kg}} \\ U = 3769.57 \text{ kJ} \end{array}}$$

From ECHE225 Textbook

6. 3 kg saturated liquid water evap. @ 60°C

☆ steam tables ☆

$P_{sat} = 19.947\ kPa$

$V_f = 0.001017\ \frac{m^3}{kg}$

$V_g = 7.6670\ \frac{m^3}{kg}$

$u_f = 251.16\ \frac{kJ}{kg}$

$u_g = 2455.9\ \frac{kJ}{kg}$

$h_f = 251.18\ \frac{kJ}{kg}$

$h_g = 2608.8\ \frac{kJ}{kg}$

a) $19.947\ kPa$

b) $3\,kg \cdot \frac{0.001017\ m^3}{1\ kg} = 0.003051\ m^3 = 3.051\ L$

c) $1\,kg \cdot 0.001017\ \frac{m^3}{kg} + 2\,kg \cdot 7.6670\ \frac{m^3}{kg} = 15.335\ m^3 = 15335\ L$

$\Delta U = \underbrace{(m_f u_f + m_g u_g)}_{\text{final}} - \underbrace{m_i u_i}_{\text{initial}}$ where $u_i = u_f$

$= (1\,kg \cdot 251.16\ \frac{kJ}{kg} + 2\,kg \cdot 2455.9\ \frac{kJ}{kg}) - 3\,kg \cdot 251.16\ \frac{kJ}{kg}$

$\Delta U = 4409.48\ kJ$

d) $\Delta U = m_g u_g - m_i u_i$

$= m(u_g - u_f)$

$= 3\,kg(2455.9\ \frac{kJ}{kg} - 251.16\ \frac{kJ}{kg})$

$\Delta U = 6614.22\ kJ$

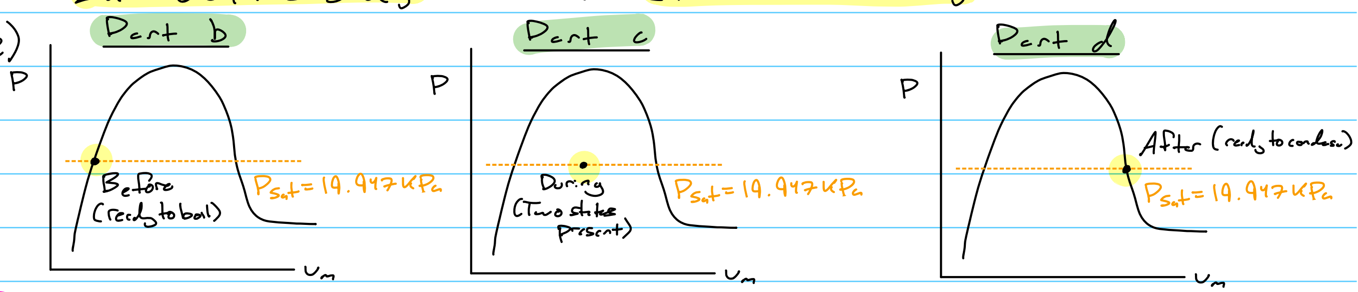
$\Delta H = m_g h_g - m_i h_i$

$= m(h_g - h_f)$

$= 3\,kg(2608.8\ \frac{kJ}{kg} - 251.18\ \frac{kJ}{kg})$

$\Delta H = 7072.86\ kJ$

e)



From ECHE225 Textbook

7. 2 kg water V/L mixture @ 90°C, rigid volume of 2.42 m³ $\hat{V} = \frac{2.42\ m^3}{2\ kg} = 1.21\ \frac{m^3}{kg}$

☆ steam tables ☆

90°C

$P_{sat} = 70.183\ kPa$

$V_f = 0.001036\ \frac{m^3}{kg}$

$V_g = 2.3593\ \frac{m^3}{kg}$

$u_f = 376.97\ \frac{kJ}{kg}$

$u_g = 2494.0\ \frac{kJ}{kg}$

$h_f = 377.04\ \frac{kJ}{kg}$

$h_g = 2659.6\ \frac{kJ}{kg}$

100°C

$P_{sat} = 101.42\ kPa$

$V_f = 0.001043\ \frac{m^3}{kg}$

$V_g = 1.6720\ \frac{m^3}{kg}$

$u_f = 419.06\ \frac{kJ}{kg}$

$u_g = 2506.0\ \frac{kJ}{kg}$

$h_f = 419.17\ \frac{kJ}{kg}$

$h_g = 2675.6\ \frac{kJ}{kg}$

a) P_{sat} @ 90°C = 70.183 kPa

b) $1.21 = (1-x)\,0.001036 + x\,2.3593$

$1.21 = 0.001036 - 0.001036x + 2.3593x$

$1.208964 = 2.358264x \Rightarrow x = 0.5126$

c) (i) $1.21 = (1-x)\,0.001043 + x\,1.6720$

$1.21 = 0.001043 - 0.001043x + 1.6720x$

$1.208957 = 1.670957x$

$x = 0.7235$

(ii) P_{sat} @ 100°C = 101.42 kPa

(iii) ΔU: $u_i = (1-.5126)(376.97) + .5126 \cdot 2494.0 = 1462.1596\ \frac{kJ}{kg}$

$u_f = (1-.5126)(419.06) + .5126 \cdot 2506.0 = 1486.8254\ \frac{kJ}{kg}$

ΔH: $h_i = (1-.7235)(377.04) + .7235 \cdot 2659.6 = 2028.4722\ \frac{kJ}{kg}$

$h_f = (1-.7235)(419.17) + .7235 \cdot 2675.6 = 2051.6971\ \frac{kJ}{kg}$

$\Delta U = 2(u_f - u_i) = 2(1486.8254 - 1462.1596) = 53.33\ kJ$

$\Delta H = 2(h_f - h_i) = 2(2051.6971 - 2028.4722) = 46.45\ kJ$

8. Answer the following reflection questions (5 points):

   a. What about the way this class is taught is helping your learning?

   b. What about the way this class is taught is inhibiting your learning?

   c. So far, we've had a brief math/calculus review, discussed different types and sources of thermodynamic properties, and solved problems involving steam quality. Is there anything you still find confusing about these or related concepts?

A. I think the pacing of this class is good for my learning. It doesn't feel like it will be moving that fast, nor does it feel like it will move to slow. There's enough time given to enforce a topic, but not so much as to make it feel overdone. Also, using written notes instead of slides helps my learning a ton, as slides always feel very surface level compared to the actual content. I also appreciate the use of examples and brief discussions in class, promoting engaging conversation.

B. There is nothing that is inhibiting my learning at this point in the semester. Once we start tackling more difficult concepts, I will have to reevaluate and see if theres anything that is preventing me from grasping the content fully, but there is nothing right now doing that.

C. I am still confused about what is meant by equilibrium properties/state. I understand the concept of equilibrium, but I was confused on homework question 2. Specifically, I was confused what was being asked for as we didn't discuss much about this in class.