ChE 222: Problem Set #3
Due: February 13, 2009 (2:00 pm)

(17) 1.) Koretsky, Problem 2.9

(8) 2.) Koretsky, Problem 2.11

(14) 3.) Koretsky, Problem 2.13

2.9

(a)
From Steam Tables:

$$\hat{u}_1 = 2967.8\left[\frac{\text{kJ}}{\text{kg}}\right] \qquad (100 \text{ kPa, } 400\ ^\circ\text{C}) \qquad +1$$

$$\hat{u}_2 = 2659.8\left[\frac{\text{kJ}}{\text{kg}}\right] \qquad (50 \text{ kPa, } 200\ ^\circ\text{C}) \qquad +1$$

$$\Delta\hat{u} = \hat{u}_2 - \hat{u}_1 = -308.0\left[\frac{\text{kJ}}{\text{kg}}\right] \qquad +2$$

(b)
From Equations 2.53 and 2.63

+2

$$\Delta u = u_2 - u_1 = \int_{T_1}^{T_2} c_v dT = \int_{T_1}^{T_2} (c_P - R)dT$$

+2

From Appendix A.2

$$c_P = R(A + BT + CT^2 + DT^{-2} + ET^3)$$

$$\Delta u = R\int_{T_1}^{T_2}\left[A + BT + CT^2 + DT^{-2} + ET^3 - 1\right]dT \qquad +1$$

Integrating

$$\Delta u = R\left[(A-1)(T_2 - T_1) + \frac{B}{2}(T_2^2 - T_1^2) + \frac{C}{3}(T_2^3 - T_1^3) - D\left(\frac{1}{T_2} - \frac{1}{T_1}\right) + \frac{E}{4}(T_2^4 - T_1^4)\right] \qquad +5$$

The following values were found in Table A.2.1

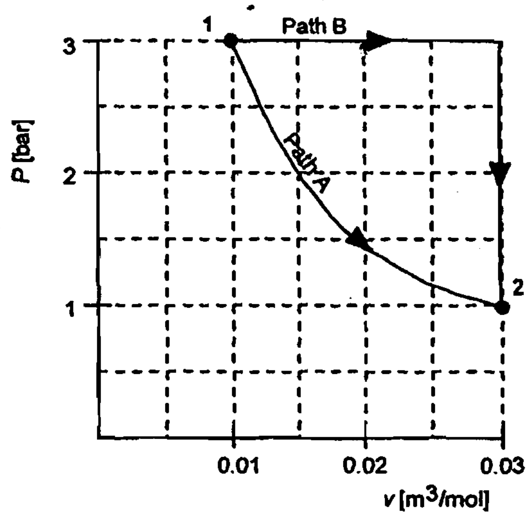
$$A = 3.470$$
$$B = 1.45\times10^{-3}$$
$$C = 0$$
$$D = 1.21\times10^{4}$$
$$E = 0$$

Substituting these values and using

2.11

(a)

(i).



+2

(ii).

Since internal energy is a function of temperature only for an ideal gas (Equation 2.4) and the process is isothermal

$$\boxed{\Delta u = 0}$$

+2

(b)

(i). See path on diagram in part (a) +2

(ii).

Since the overall process is isothermal and u and h are state functions

$$\boxed{\Delta u = 0}$$
$$\boxed{\Delta h = 0}$$

+2

2.13
First, start with the energy balance. Potential and kinetic energy effects can be neglected. Therefore, the energy balance becomes

$$\Delta U = Q + W \qquad +1$$

The value of the work will be used to obtain the final temperature. The definition of work (Equation 2.7) is

$$W = -\int_{V_1}^{V_2} P_E dV \qquad +1$$

Since the piston expands at constant pressure, the above relationship becomes

$$W = -P_E(V_2 - V_1) \qquad +2$$

From the steam tables

$$\hat{v}_1 = 0.02641\left[\frac{\text{m}^3}{\text{kg}}\right] \quad (10 \text{ MPa}, 400\ ^\circ\text{C}) \qquad +1$$

$$V_1 = m_1\hat{v}_1 = (3\text{ kg})\left(0.02641\left[\frac{\text{m}^3}{\text{kg}}\right]\right) = 0.07923\left[\text{m}^3\right] \qquad +1$$

Now V_2 and v_2 are found as follows

$$V_2 = V_1 - \frac{W}{P_E} = 0.07923\text{ m}^3 - \frac{-748740\text{ J}}{2.0\times10^6\text{ Pa}} = 0.4536\left[\text{m}^3\right] \qquad +2$$

$$\hat{v}_2 = \frac{V_2}{m_2} = \frac{0.4536\left[\text{m}^3\right]}{3\left[\text{kg}\right]} = 0.1512\left[\frac{\text{m}^3}{\text{kg}}\right] \qquad +1$$

Since $\hat{v}_2$ and P_2 are known, state 2 is constrained. From the steam tables:

$$\boxed{T_2 = 400\left[^\circ\text{C}\right]} \qquad \left(20\text{ bar}, 0.1512\left[\frac{\text{m}^3}{\text{kg}}\right]\right) \qquad +1$$

Now ΔU will be evaluated, which is necessary for calculating Q. From the steam tables:

$$\hat{u}_2 = 2945.2\left[\frac{\text{kJ}}{\text{kg}}\right] \qquad \left(20\text{ bar}, 0.1512\left[\frac{\text{m}^3}{\text{kg}}\right]\right) \qquad +1$$

$$\hat{u}_1 = 2832.4\left[\frac{\text{kJ}}{\text{kg}}\right] \qquad (100\text{ bar}, 400\,°\text{C}) \qquad +1$$

$$\Delta U = m_1(\hat{u}_2 - \hat{u}_1) = (3\,[\text{kg}])\left(2945.2\left[\frac{\text{kJ}}{\text{kg}}\right] - 2832.4\left[\frac{\text{kJ}}{\text{kg}}\right]\right) = 338.4\,[\text{kJ}] \qquad +1$$

Substituting the values of ΔU and W into the energy equation allows calculation of Q

$$Q = \Delta U - W$$
$$Q = 338400\,[\text{J}] - (-748740\,[\text{J}]) = 1.09 \times 10^6\,[\text{J}] \qquad +1$$