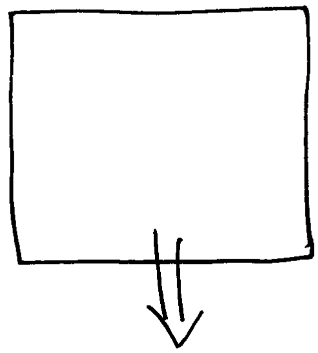
# Problem 5.36

What is the final temp. ($T_2$), Work ($_1W_2$) and heat transfer ($_1W_2$) ?



$P_1 = 1200$ kPa
$T_1 = 300^\circ$C

Container
$m = 0.75$ kg
(water)

Cooling
(Final ~~temp~~ pressure $P_2 = 300$ kPa)

**Solution:**

**Fix State 1**

1. Sat. Table (B.1.2 ; Page 680)
   For $P_1 = 1200$ kPa $\Rightarrow T_{sat} = 187.99^\circ$C

2. Since $T_1 > T_{sat} \Rightarrow$ State is superheated.

At 1200 kPa, 300°C (Table B.1.3 ; page 684)

$v_1 = 0.21382$ m³/kg

$u_1 = 2789.22$ kJ/kg

Process is constant volume ($v = c$) : $v_2 = v_1$
(Since $V_2 = V_1$ ; and $m_2 = m_1$).

In final state 2, $v_2 = 0.21382$ m³/kg
$P_2 = 300$ kPa.

**Fix state 2** : Sat. Table (B.1.2 ; Page 678)

at $P_2 = 300$ kPa $\Rightarrow v_f = 0.001073$ m³/kg
$v_g = 0.60582$ m³/kg

Since $v_f \leq v_2 \leq v_g \Rightarrow$ state 2 is saturated.

- Calculate quality $x_2$

$$v_2 = v_f + x_2 v_{fg} \Rightarrow x_2 = (v_2 - v_f)/v_{fg}$$

$$x_2 = (0.21382 - 0.001073)/0.60475$$

$$x_2 = 0.351$$

- $$U_2 = u_f + x_2 u_{fg} = 561.13 + 0.351 * 1982.43$$

$$U_2 = 1258.5355$$

$$m_2 = m_1 = \quad m = 0.75 \text{ kg.}$$

- Work $_1W_2 = 0$ since constant volume process is carried out.

$$_1W_2 = \int_{V_1}^{V_2} P\,dV = 0 \Rightarrow V_1 = V_2 \quad (\text{or } v_1 = v_2).$$

- First Law: System

$$_1Q_2 = U_2 - U_1 + {_1W_2}^{\nearrow 0} = m(u_2 - u_1)$$

$$_1Q_2 = 0.75(1258.5355 - 2789.22)$$

$$= -1148.0 \text{ KJ}$$

(Negative sign indicates heat transfer from the system to surroundings) ⇒ Cooling process.

**5.87**

For an application the change in enthalpy of carbon dioxide from 30 to 1500°C at 100 kPa is needed. Consider the following methods and indicate the most accurate one.

a. Constant specific heat, value from Table A.5.

b. Constant specific heat, value at average temperature from the equation in Table A.6.

c. Variable specific heat, integrating the equation in Table A.6.

d. Enthalpy from ideal gas tables in Table A.8.

Solution:

a) $\Delta h = C_{po}\Delta T = 0.842\ (1500 - 30) = \mathbf{1237.7\ kJ/kg}$

b) $T_{ave} = \frac{1}{2}(30 + 1500) + 273.15 = 1038.15\ K; \quad \theta = T/1000 = 1.0382$

Table A.6 $\Rightarrow$ $C_{po} = 1.2513$

$\Delta h = C_{po,ave}\ \Delta T = 1.2513 \times 1470 = \mathbf{1839\ kJ/kg}$

c) For the entry to Table A.6: $\theta_2 = 1.77315\ ; \ \theta_1 = 0.30315$

$$\Delta h = h_2 - h_1 = \int C_{po}\ dT$$

$$= [0.45\ (\theta_2 - \theta_1) + 1.67 \times \frac{1}{2}(\theta_2^2 - \theta_1^2)$$

$$-1.27 \times \frac{1}{3}(\theta_2^3 - \theta_1^3) + 0.39 \times \frac{1}{4}(\theta_2^4 - \theta_1^4)] = \mathbf{1762.76\ kJ/kg}$$

d) $\Delta h = 1981.35 - 217.12 = \mathbf{1764.2\ kJ/kg}$

The result in d) is best, very similar to c). For large $\Delta T$ or small $\Delta T$ at high $T_{avg}$, a) is very poor.

**5.105**

A piston/cylinder contains 0.001 $m^3$ air at 300 K, 150 kPa. The air is now compressed in a process in which $P\,V^{1.25} = C$ to a final pressure of 600 kPa. Find the work performed by the air and the heat transfer.

Solution:

C.V. Air. This is a control mass, values from Table A.5 are used.

Continuty: $m_2 = m_1$

Energy Eq.5.11: $m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$

Process : $PV^{1.25} = \text{const.}$

State 2: $V_2 = V_1\,(P_1/P_2)^{1.25} = 0.00033\ m^3$

$$T_2 = T_1\,P_2V_2/(P_1V_1) = 300\,\frac{600 \times 0.00033}{150 \times 0.001} = 395.85\ K$$

$${}_1W_2 = \frac{1}{n-1}(P_2\,V_2 - P_1V_1) = \frac{1}{n-1}(600 \times 0.00033 - 150 \times 0.001) = -\,0.192\ kJ$$

$${}_1Q_2 = m(u_2 - u_1) + {}_1W_2 = \frac{P_1V_1}{RT_1}\,C_v\,(T_2 - T_1) + {}_1W_2$$

$$= 0.001742 \times 0.717 \times 95.85 - 0.192 = \mathbf{-\,0.072\ kJ}$$