Department of Chemical and Process Engineering
Thermodynamics

Tutorial Sheet: First Law of Thermodynamics

1. 7 moles of methane contained in a closed vertical piston/cylinder arrangement undergo a heating process at the same time as a mass of 10 kg is placed on the piston. The heat transferred to the gas is 40 J and the mass causes the piston to be displaced downward by 30 cm. Calculate the molar change in internal energy of the gas. You can consider that the acceleration of gravity is equal to 9.82 m/s^2.

2. For product quality reasons, in a heat exchanger it is required to cool 120 kg per hour of an oil with a specific heat capacity (c_P) of 3.5 kJ/kgK. The oil enters at a temperature of 90°C and it is required to reduce this temperature to 30°C otherwise it will degrade and be unable to act as a lubricant. This is achieved with a cooling water flow. You can assume that the pressure of the system remains constant.

Write down the First Law and calculate the heat rate that is required to carry out this process. What have you had to assume regarding the value of c_P?

3. A <u>closed</u> system consists of a fixed amount of gas. The system undergoes a reversible process, expanding from an initial state of 20 bar to a final state of 8 bar. The path for the process is described by:

$$P = \frac{0.036}{V} - 4$$

with P (bar) and V (m^3).

The change in internal energy (ΔU) for this process is –1400 J.

(a) What are the units for the two constants (0.036 and 4)?

(b) Write down the expression for the work term in a closed system in terms of pressure and volume and calculate the work term (W)

(c) Use the First Law to determine the exchange of heat (Q).

(d) Use the definition relating enthalpy and internal energy to determine the value of ΔH.

Make sure that you take care with the units: [1 J = 1 Pa m^3]

CP203 -Thermodynamics Tutorial Solutions Week 3
Group 17

1.

$$\Delta U = Q + W$$
$$\Delta U = 40 + (10 \cdot 9.82 \cdot 0.3)$$
$$\Delta U = 69.5\, J$$
$$\Delta u = 69.5 \div 7 = 9.93\, Jmol^{-1}$$

2.

$$U = Q + \cancel{W}$$
$$Q = C_p \Delta T$$
$$Q = 3.5(30 - 90) = -210\, kJ$$
$$\dot{Q} = -210 \cdot 120 = -25,200\, kJh^{-1}$$
$$\dot{Q} = -7\, kJs^{-1} = -7\, kW$$

In this question we must assume that the heat capacity remains constant and does not change as the temperature changes.

3.

a)

$$P = 0.036V^{-1} - 4$$
$$Bar = x \cdot m^{-}3 - y$$
$$y = Bar$$
$$x = m^3 Bar$$

b)

$$W = -\int_{V_1}^{V_2} P dV$$
$$W = -\int_{V_1}^{V_2} 0.036V^{-1} - 4dV$$
$$W = -\int_{V_1}^{V_2} 0.036V^{-1}dV - \int_{V_1}^{V_2} 4dV$$
$$W = -[0.036 \ln V]_{V_1}^{V_2} - [4V]_{V_1}^{V_2}$$
$$V_1 = 0.036 \div (20 + 4) = 0.0015$$
$$V_2 = 0.036 \div (8 + 4) = 0.003$$
$$W = -[0.036 \ln V]_{0.0015}^{0.003} - [4V]_{0.0015}^{0.003}$$
$$W = -0.0189\, m^3 Bar$$
$$W \approx -2000\, J$$

c)

$$\Delta U = Q + W$$
$$-1400 = Q - 2000$$
$$Q = 600\, J$$

d)

$$H = U + PV$$
$$\partial H = \partial U + \partial(PV)$$
$$\partial H = -1400 + [(8 \cdot 0.003) - (20 \cdot 0.0015)]$$
$$\partial H = -1400 - 600$$
$$\partial H = -2000\, J$$