Answer on the question #69582, Chemistry / Physical Chemistry

Question:

One mole of an ideal gas with Cp = (7/2) R and Cv = (5/2) R expands from P1= 8 bar & T1= 600K to P2 = 1bar by each of the following paths?

(1) Constant volume. (2) Constant temperature. (3) Adiabatically. Assuming mechanical reversibility calculate W, Q, Δ U and Δ H for each process

Solution:

1) Constant volume process :

$$W = -\int_{V_1}^{V_2} pdV = 0$$

$$Q = \int_{T_1}^{T_2} C_V dT = C_V(T_2 - T_1)$$

Let's find the final temperature :

$$\frac{p_1}{T_1} = \frac{p_2}{T_2}$$

$$T_2 = \frac{p_2 \cdot T_1}{p_1} = \frac{1\ bar \cdot 600K}{8\ bar} = 75\ K$$

Thus, heat is :

$$Q = \frac{5}{2} \cdot 8.314 \cdot (75 - 600) = -10.91\ kJ$$

Change in internal energy is :

$$\Delta U = Q + W = -10.91\ kJ$$

Change in enthalpy of ideal gas at constant volume is:

$$\Delta H = Q + V\Delta P = -10.91kJ + \frac{RT_1}{P_1}(P_2 - P_1)$$

$$= -10.91\ kJ + \frac{8.314J/K \cdot 600K}{8\ bar}(1bar\ - 8bar)$$

$$= -10.91\ kJ - 4.36kJ = -15.27\ kJ$$

2) Constant temperature process :

Work done in the process :

$$W = -\int_{V_1}^{V_2} pdV = nRTln\frac{p_2}{p_1} = 8.314\frac{J}{K} \cdot 600K \cdot \ln\left(\frac{1}{8}\right) = -10.37\ kJ$$

As for ideal gas, it’s internal energy change and enthalpy chage are zero as the temperature is constant :

$$\Delta U = \Delta H = 0$$

Then, heat change is :

$$Q = \Delta U - W = 10.37\ kJ$$

3) Adiabatic process :

Change in heat is zero :

$$Q = 0$$

Thus, internal energy is equal to work :

$$\Delta U = W = \int_{V_1}^{V_2} PdV = \frac{nR}{\gamma - 1}(T_2 - T_1)$$

where $\gamma = \frac{C_p}{C_V} = \frac{7}{5} = 1.4$.

Let’s find the final temperature :

$$T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = 331.2\ K$$

$$\Delta U = W = \frac{8.314\ J/K}{1.4 - 1}(331.2\ K - 600\ K) = -5.59\ kJ$$

Enthalpy of the process is :

$$\Delta H = nC_P\Delta T = \frac{7}{2} \cdot \frac{8.314J}{K} \cdot (331.2\ K - 600\ K) = -7.82\ kJ$$

Answer :

(1) 0 ; -10 .91 kJ ; -10.91 kJ ; -15.27 kJ
(2) -10.37 kJ ; 10.37 kJ ; 0 ; 0
(3) -5.59 kJ ; 0 ; -5.59 kJ ; -7.82 kJ