Chapter 19

1 The First Law of Thermodynamics

In a thermodynamic process, Q is positive when heat flows **into** a system, and negative when heat flows **out** of the system.

Work W is **positive** when work is done by the system against its surroundings, and hence corresponds to energy leaving the system. W is negative when work is done on the system.

1.1 Work Done During Volume Changes

- Isobaric: p is constant

$$\begin{aligned} dW &= (F)dx \\ dW &= (pA)dx, \quad \text{Pressure} = \frac{\text{Force}}{\text{Area}} \\ dW &= (p)dV \\ \int_0^W (1)dW &= p\int_{V_0}^{V_1}(1)dV \\ W &= p\left[V_1 - V_0\right] \\ W &= p\left[V_1 - V_0\right] \end{aligned} \tag{1}$$

- Isochoric: V is constant, $\Delta U = Q - 0$

$$W = \int (p)dV = p(0) = 0$$

- Isothermal: T is constant, $0 = Q - nRT\ln\frac{V_1}{V_0}$

$$\begin{aligned} W &= \int (p)dV \\ W &= \int \left(\frac{nRT}{V}\right)dV \\ W &= nRT\int_{V_0}^{V_1}\left(\frac{1}{V}\right)dV \\ W &= nRT\ln\left[\frac{V_1}{V_0}\right] \end{aligned}$$

- Adiabatic: No heat enters or exits, $Q = 0$, $\Delta U = 0 - W$

1.1.1 Question

$$dW = \int \left(\frac{nRT}{P}\right) dp$$
$$\int_0^W (1) dW = nRT \int_{p_0}^{p_1} \left(\frac{1}{P}\right) dp$$

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(a)

$$W_{1,3} = p_1(V_2 - V_1)$$
$$W_{3,2} = 0$$
$$W_{2,4} = p_2(V_1 - V_2)$$
$$W_{4,1} = 0$$

$$W_{total} = p_1(V_2 - V_1) + p_2(V_1 - V_2)$$
$$W_{total} = p_1(V_2 - V_1) - p_2(-V_1 + V_2)$$
$$W_{total} = (p_1 - p_2)(V_2 - V_1)$$