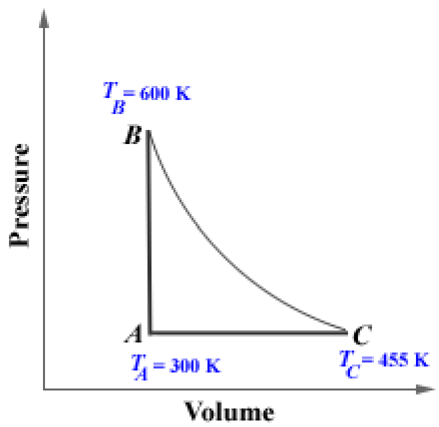
235.

<u>Problem 25.43 (RHK)</u>

An engine carries 1.00 mol *of an ideal monatomic gas around the cycle shown in the figure. Process AB takes place at constant volume, process BC is adiabatic, and process CA takes place at constant pressure.* (a) *We have to compute the heat Q, the change in internal energy* ΔE_{int}, *and the work W for each of the three processes and for the cycle as a whole.* (b) *If the initial pressure at point A is* 1.00 atm, *we have to find the pressure and the volume at points B and C. We will use* $1\ \text{atm} = 1.013\times10^{5}\ \text{Pa}$ and $R = 8.314\ \text{J mol}^{-1}\ \text{K}^{-1}$.



Solution:

Data of the problem are

$T_A = 300$ K, $T_B = 455$ K, $T_C = 600$ K, and

$p_A = 1.013 \times 10^5$ Pa.

Amount of ideal monatomic gas is $n = 1.00$ mol.

We use the ideal gas equation for determining the values of the thermodynamic state variables at points *A*, *B*, and *C*.

$$V_A = \frac{nRT_A}{p_A} = \frac{8.314 \times 300}{1.013 \times 10^5} \text{ m}^3 = 2.462 \times 10^{-2} \text{ m}^3.$$

$V_B = 2.462 \times 10^{-2}$ m^3.

$$p_B = \frac{nRT_B}{V_B} = \frac{8.314 \times 600}{2.462 \times 10^{-2}} \text{ Pa} = 2.026 \times 10^5 \text{ Pa} = 2.00 \text{ atm}.$$

$$V_C = \frac{nRT_C}{p_C} = \frac{8.314 \times 455}{1.013 \times 10^5} \text{ m}^3 = 3.734 \times 10^{-2} \text{ m}^3.$$

And

$p_C = 1.013 \times 10^5$ Pa.

(a)

Process *AB*

During the process AB the work done on the gas will be zero, as the change occurs at constant volume. Change in the internal energy of the gas during *AB* is determined by the change in temperature, that is

$$\Delta E_{\text{int}}\left(AB\right)=\frac{3}{2}R\left(T_B-T_A\right)=\frac{3\times 8.314\times 300}{2}\ \text{J}=3741.3\ \text{J}.$$

From the first law we get

$$Q\left(AB\right)=3741.3\ \text{J}.$$

Process *BC*

As the change from B to C is adiabatic, the work done on the gas, $W\left(BC\right)$, can be obtained from the relation

$$W=\frac{p_f V_f-p_i V_i}{\gamma-1}.$$

As the gas is monatomic $\gamma=5/3$.

Therefore,

$$W\left(BC\right)=\frac{p_C V_C-p_B V_B}{\frac{5}{3}-1}=\frac{3}{2}\times R\left(T_C-T_B\right)=\frac{3\times 8.314\times\left(-145\right)}{2}\ \text{J}$$

$$=-1808.3\ \text{J}.$$

And as the process is adiabatic

$$Q\left(BC\right)=0.$$

Process *CA*

The process CA takes place at constant pressure. The work done on the gas will be

$$W(CA) = -(p_A V_A - p_C V_C) = -R(T_A - T_C) = -8.314 \times (-155) \text{ J}$$
$$= 1288.7 \text{ J.}$$

Change in internal energy of the gas will be

$$\Delta E_{\text{int}}(CA) = \frac{3}{2} R \times (T_A - T_C) = \frac{3 \times 8.314 \times (-155)}{2} \text{ J}$$
$$= -1933 \text{ J.}$$

From the first law we calculate the heat absorbed by the gas during this process. We find

$$Q(CA) = \Delta E_{\text{int}}(CA) - W(CA) = (-1933 - 1288.7) \text{ J}$$
$$= -3221.7 \text{ J.}$$

We now have the data for calculating the work done and the heat absorbed during the cycle as a whole.

$$W_{cycle} = W(AB) + W(BC) + W(CA) = (0 - 1808.3 + 1288.7) \text{ J}$$
$$= -519.6 \text{ J.}$$

Total heat absorbed by the gas during the whole cycle will be

$$Q_{cycle} = Q(AB) + Q(BC) + Q(CA) = (3741.3 - 3221.7) \text{ J}$$
$$= 519.6 \text{ J.}$$