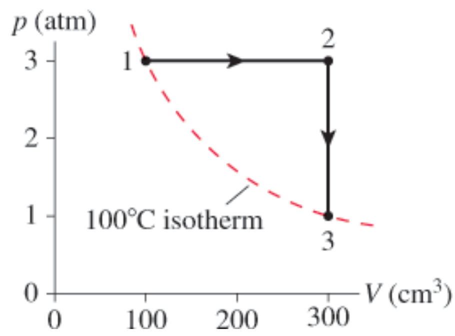
102. | | A monatomic gas follows the process $1 \rightarrow 2 \rightarrow 3$ shown in Figure P12.102. How much heat is needed for (a) process $1 \rightarrow 2$ and (b) process $2 \rightarrow 3$?

Figure P12.102



102. || A monatomic gas follows the process $1 \rightarrow 2 \rightarrow 3$ shown in Figure P12.102. How much heat is needed for (a) process $1 \rightarrow 2$ and (b) process $2 \rightarrow 3$?

$pV = nRT$

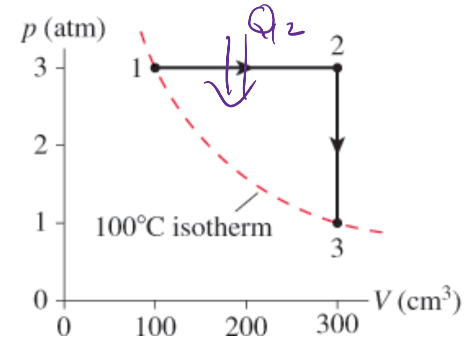
Figure P12.102

$p_1 = 304{,}000\ \text{Pa}$

$V_1 = 1.0 \times 10^{-4}\ m^3$

$T_1 = 373\ K$

$n = \frac{p_1 V_1}{R T_1} = 0.0098\ \text{mol}$



$p_2 = 304{,}000\ \text{Pa}$

$V_2 = 3V_1 = 3.0 \times 10^{-4}\ m^3$

$T_3 = 3T_1 = 1119\ K$

1st Law: $Q_{12} = \Delta E_{th\,12} + W_{12}$

$\Delta E_{th_{12}} = \frac{3}{2} N k_B \Delta T = \frac{3}{2} nR(T_2 - T_1) = 91.2\ J$

OR: $\Delta E_{th_{12}} = \frac{3}{2}(nRT_2 - nRT_1) = \frac{3}{2}(p_2V_2 - p_1V_1)$

$= 91.2\ J$

$W_{12} = p_1 \Delta V = p_1(V_2 - V_1) = 60.8\ J$

$Q_{12} = 91.2\ J + 60.8\ J = \boxed{152\ J}$

OR: $Q_{12} = n C_p \Delta T = n\left(\frac{5}{2}R\right)\Delta T = 152\ J$

$2 \rightarrow 3$

$p_3 = \frac{1}{3} p_2 = 101{,}300\ \text{Pa}$

$V_3 = V_2 = 3.0 \times 10^{-4}\ m^3$

$T_3 = \frac{1}{3} T_2 = 373\ K$

$Q_{23} = \Delta E_{th\,23} + W_{23}$ ← volume doesn't change

$Q_{23} = \frac{3}{2} nR(T_3 - T_2) + 0$

$= \frac{3}{2}(0.0098\ \text{mol})\left(8.314\ \frac{J}{\text{mol}\cdot K}\right)(373 - 1119)\ K$

$\boxed{Q_{23} = -91.2\ J}$

OR $Q_{23} = n C_v \Delta T = n\left(\frac{3}{2}R\right)\Delta T = -91.2\ J$