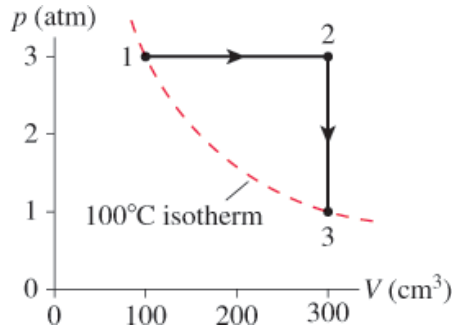
**102.** | | A monatomic gas follows the process $1 \rightarrow 2 \rightarrow 3$ shown in Figure P12.102. How much heat is needed for (a) process $1 \rightarrow 2$ and (b) process $2 \rightarrow 3$?

**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 $2 \rightarrow 3$?

$pV = nRT$

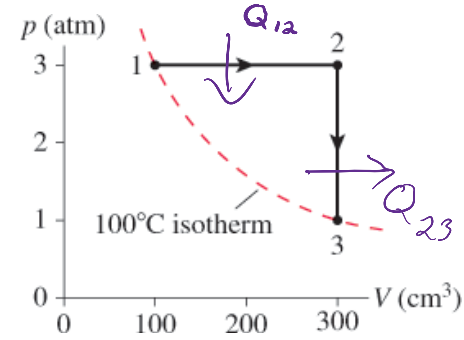
**Figure P12.102**

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

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

$T_1 = 373 \text{ K}$

$n = \dfrac{p_1 V_1}{RT_1} = 0.0098 \text{ mol}$




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

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

$T_2 = 3T_1 = 1119 \text{ K}$

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

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

OR: $\Delta E_{th_{12}} = \frac{3}{2}(nRT_2 - nRT_1) = \frac{3}{2}(p_2V_2 - p_1V_1)$
$= 91.2 \text{ J}$

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

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

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

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$2 \rightarrow 3$

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

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

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

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

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

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

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

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