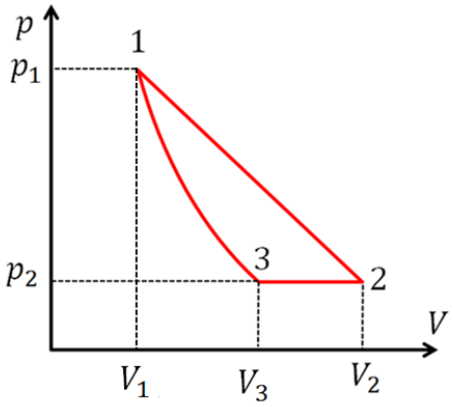
Answer on Question #78936, Physics / Molecular Physics | Thermodynamics

Question. $1\ kg$ of a fluid expands reversibly according to a linear law from $4.2\ bar$ to $1.4\ bar$; the initial and final volumes are $0.004\ m^3$ and $0.02\ m^3$. The fluid is then cooled reversibly at constant pressure, and finally compressed reversibly according to a law $pV = constant$ back to the initial conditions of $4.2\ bar$ and $0.004\ m^3$. Calculate the work done in each process and the net work of the cycle. Sketch the cycle on a $p - V$ diagram.

Given. $m = 1\ kg; p_1 = 4.2\ bar = 4.2 \cdot 10^5\ Pa; p_2 = 1.4\ bar = 1.4 \cdot 10^5\ Pa; V_1 = 0.004\ m^3; V_2 = 0.02\ m^3.$

Find. $W_{12}, W_{23}, W_{31}, W - ?$

Solution



$$W_{12}(area\ of\ the\ trapezoid) = \frac{1}{2}(p_1 + p_2)(V_2 - V_1) = \frac{1}{2}(4.2 \cdot 10^5 + 1.4 \cdot 10^5)(0.02 - 0.004) = 4480\ J$$

The work done by the fluid.

$$W_{23}(area\ of\ the\ rectangle) = p_2(V_3 - V_2)$$

$$p_3V_3 = p_1V_1\ \ and\ \ p_3 = p_2$$

$$V_3 = \frac{p_1}{p_2}V_1 = \frac{4.2 \cdot 10^5}{1.4 \cdot 10^5}0.004 = 0.012\ m^3$$

$$W_{23} = 1.4 \cdot 10^5\ (0.012 - 0.02) = -1120\ J$$

The work done on the fluid.

$$W_{31} = \int_{V_3}^{V_1} pdV = \int_{V_3}^{V_1} \frac{m}{M}\frac{RT}{V}dV = \frac{m}{M}RT\ln\frac{V_1}{V_3} = p_3V_3\ln\frac{V_1}{V_3} = p_1V_1\ln\frac{V_1}{V_3} = 4.2 \cdot 10^5\ \cdot 0.004 \cdot \ln\frac{0.004}{0.012} =$$

$$= -1845\ J$$

The work done on the fluid.

$$W = W_{12} + W_{23} + W_{31} = 4480 - 1120 - 1845 = 1515\ J$$

The work done by the fluid.

Answer. $W_{12} = 4480\ J;\ W_{23} = -1120\ J;\ W_{31} = -1845\ J;\ W = 1515\ J.$

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