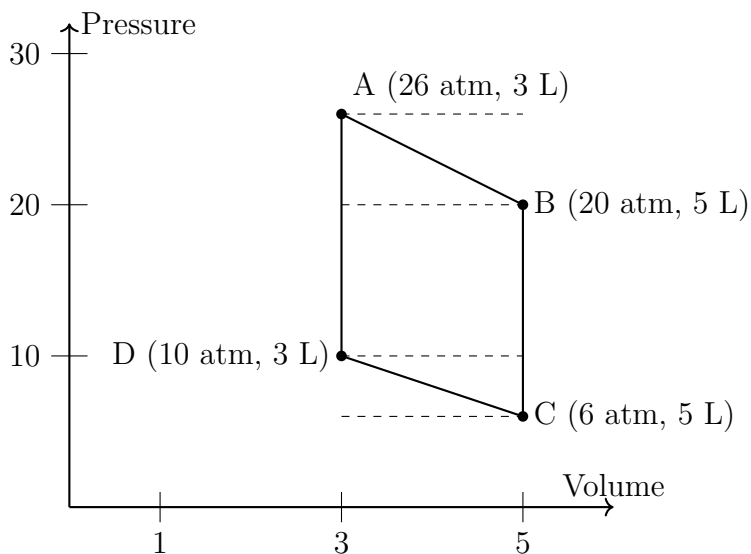


1. Find the work and heat associated with the closed cycle $D \rightarrow C \rightarrow B \rightarrow A \rightarrow D$.

Hint: Use the dashed lines to help think about this problem.



$D \rightarrow C$

$$\begin{aligned}
 w_{rect} &= -P\Delta V \\
 &= -10 \text{ atm}(3 - 1 \text{ L}) = -20 \text{ L} \cdot \text{atm} \\
 w_{triangle} &= \frac{1}{2}(2 \text{ L})(4 \text{ atm}) \\
 w_{total} &= w_{rect} - w_{triangle} = -16 \text{ L} \cdot \text{atm}
 \end{aligned}$$

$C \rightarrow B$ Isochoric, $w = 0$

$B \rightarrow A$

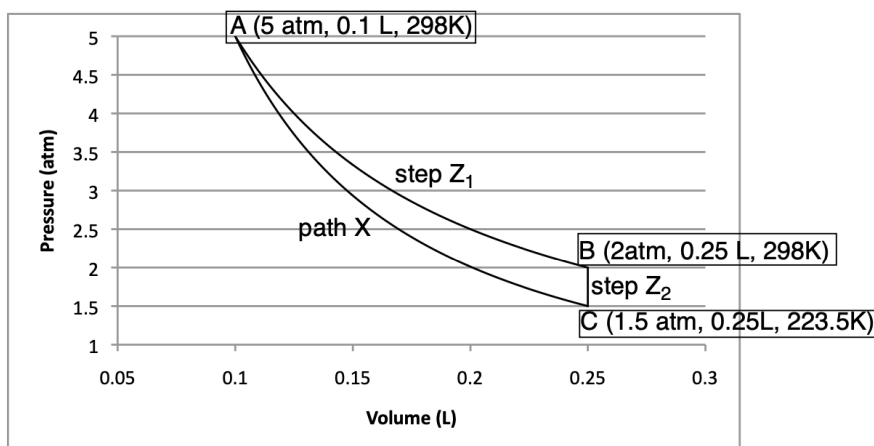
$$\begin{aligned}
 w_{rect} &= -P\Delta V \\
 &= -26 \text{ atm}(1 - 3 \text{ L}) = -52 \text{ L} \cdot \text{atm} \\
 w_{triangle} &= \frac{1}{2}(2 \text{ L})(6 \text{ atm}) \\
 w_{total} &= w_{rect} - w_{triangle} = -46 \text{ L} \cdot \text{atm}
 \end{aligned}$$

$A \rightarrow D$ Isochoric, $w = 0$

$$w_{cycle} = 46 \text{ L} \cdot \text{atm} + (-16 \text{ L} \cdot \text{atm}) = \boxed{30 \text{ L} \cdot \text{atm}}$$

$$\text{For a closed cycle, } \Delta U = q + w = 0 \implies q = -w = \boxed{-30 \text{ L} \cdot \text{atm}}$$

2. The graph below shows 0.02 moles of a linear diatomic gas undergoing expansion from point A(5 atm, 0.1 L, 298 K) to point C(1.5 atm, 0.25 L, 223.5 K) via two different pathways.



- (a) The first pathway consists of two steps: Step 1 (Z_1) is a reversible isothermal expansion from A to B, followed by Step 2 (Z_2), in which the gas is cooled from B to C.
- (b) The second pathway (X) is a direct adiabatic expansion from A to C.

What are the values of ΔU , w , q for Step Z_1 , Step Z_2 , and Path X? Express your answer in Joules.

Z_1 : Isothermal expansion, $\Delta U = 0 \implies q = -w$

$$\begin{aligned}
 w &= -nRT \ln \left(\frac{V_2}{V_1} \right) \\
 &= -(0.02 \text{ mol})(8.314 \frac{\text{J}}{\text{mol}\cdot\text{K}})(298 \text{ K}) \ln \left(\frac{0.25 \text{ L}}{0.1 \text{ L}} \right) \\
 \boxed{w = -45.4 \text{ J}} &\implies \boxed{q = 45.4 \text{ J}}
 \end{aligned}$$

Z_2 : Isochoric process, so $w = 0$

$$\begin{aligned}
 q &= \int n\bar{C}_V dT \\
 &= \int_{298}^{223.5} n \frac{7}{2} R dT = n \frac{7}{2} RT \Big|_{298}^{223.5} \\
 &= (0.02 \text{ mol}) \left(\frac{7}{2} \times 8.314 \frac{\text{J}}{\text{mol}\cdot\text{K}} \right) (223.5 \text{ K} - 298 \text{ K}) \\
 \boxed{q = -43.4 \text{ J} = \Delta U}
 \end{aligned}$$

X: Adiabatic, so $q = 0$

$$\begin{aligned}
 w &= \int n\bar{C}_V dT \\
 &= \int_{223.5}^{298} n \frac{7}{2} R dT = n \frac{7}{2} RT \Big|_{223.5}^{298} \\
 &= (0.02 \text{ mol}) \left(\frac{7}{2} \times 8.314 \frac{\text{J}}{\text{mol}\cdot\text{K}} \right) (298 \text{ K} - 223.5 \text{ K}) \\
 \boxed{w = 43.4 \text{ J} = \Delta U}
 \end{aligned}$$

Homework Problem 13

1. One mole of a monoatomic ideal gas is stored in a 5 L container at $P = 10$ bar and $T = 601$ K. Find $\Delta U, q, w$ for each of the following steps. Express your answer in Joules.

(a) Reversible Isothermal Expansion to 25 L

(b) Reversible Adiabatic Compression to 5 L, 29.2 bar

(c) Reversible Isochoric Cooling to initial conditions