Carnot Cycle Exercise

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$T_H = 490$ K
$V_c = 1.90 \times 10^{-3}$ m^3

1. Purpose

The goal of the exercise is to perform various calculations related to the Carnot cycle.

2. Given

- $T_H = 490$ K
- $T_C = 300$ K
- $P_c = 1.01 \times 10^5$ Pa
- $V_c = 1.90 \times 10^{-3}$ m^3
- $Q_{a\to b} = 300$ J
- $\gamma = 1.40$

3. Derivations

3.1. Temperature–Volume Relationship for Adiabatic Process

Given:

- $PV = nRT$
- $P_i V_i^\gamma = P_f V_f^\gamma$

$$\begin{aligned} P_i V_i^\gamma &= P_f V_f^\gamma \\ P_i V_i V_i^{\gamma-1} &= P_f V_f V_f^{\gamma-1} \\ nRT_i V_i^{\gamma-1} &= nRT_f V_f^{\gamma-1} \\ T_i V_i^{\gamma-1} &= T_f V_f^{\gamma-1} \end{aligned}$$

3.2. Work by Gas for Isothermal Process

Given:

- $PV = nRT$
- $W = \int P dV$

$$\begin{aligned} W &= \int_{V=V_i}^{V=V_f} P dV \\ W &= \int_{V_i}^{V_f} \frac{nRT}{V} dV \\ W &= nRT \ln(V)\Big|_{V_i}^{V_f} \end{aligned}$$

$$W = nRT(\ln(V_f) - \ln(V_i))$$
$$W = nRT \ln\left(\frac{V_f}{V_i}\right)$$

4. Results

4.1. Moles of Gas (n)

$$P_c V_c = nRT_c$$
$$P_c V_c = nRT_C$$
$$n = \frac{P_c V_c}{RT_C}$$
$$n = 0.0770 \text{ mol}$$

4.2. Pressure (P_b) and Volume (V_b) at b

$$T_b V_b^{\gamma-1} = T_c V_c^{\gamma-1}$$
$$V_b = V_c \left(\frac{T_c}{T_b}\right)^{\frac{1}{\gamma-1}}$$
$$V_b = V_c \left(\frac{T_C}{T_H}\right)^{\frac{1}{\gamma-1}}$$
$$V_b = 5.57 \times 10^{-4} \text{ m}^3$$

$$P_b V_b = nRT_b$$
$$P_b V_b = nRT_H$$
$$P_b = \frac{nRT_H}{V_b}$$
$$P_b = 5.63 \times 10^5 \text{ Pa}$$

Table 1. Pressure, Volume, and Temperature for Key Points

Point	P (Pa)	V (m^3)	T (K)
a			490
b	5.63×10^5	5.57×10^{-4}	490
c	1.01×10^5	1.90×10^{-3}	300
d			300

5. Conclusion

6. Citations

[1] Karen Schnurbusch, *Physics 4B Lab Book*, Mt. San Antonio College, 2023, pp. 35-38.
[2] Karen Schnurbusch, *Physics 4B Equations*, Mt. San Antonio College, 2023, pp. 1-3.