Epsilite Team
The 2nd Problem Set

Exercise 1: Tire Pressure and Temperature

A tire is filled with air until it reaches a pressure of P_1 = 3atm at a temperature of T_1 = 25°C. After being exposed to the sun, the temperature of the air inside the tire rises to T_2 = 50°C.

1. Assuming the volume of the tire remains constant, calculate the new pressure P_2 of the air inside.
2. If the tire can withstand a maximum pressure of 6atm, is there a risk that it will burst at this new temperature?

Exercise 2: Ideal Gas Cycle Analysis ($P-T$ Diagram)

Consider one mole of an ideal gas in an initial state **A**, undergoing the reversible transformations represented in the following figure:

1. Give the nature of each transformation ($C \rightarrow A$, $A \rightarrow B$, and $B \rightarrow C$).

2. Calculate the state variables (P,V,T) defining each thermodynamic state **A**, **B**, and **C**.

3. Calculate, for this gas during each transformation and for the whole cycle: W, Q, ΔU, ΔH, and ΔS.

4. State, with justification, if the First Law of Thermodynamics is verified for the cycle and identify the nature of the cycle.

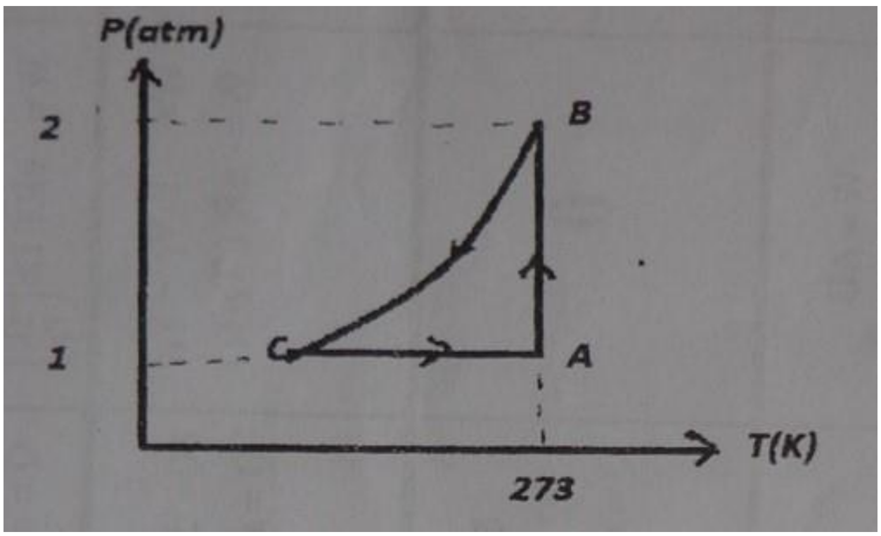


Figure 1: Ideal Gas Cycle Diagram

Data: $\gamma = 1.4$; $R = 8.314 \mathrm{J} \cdot \mathrm{K}^{-1} \cdot \mathrm{mol}^{-1} = 0.082 \mathrm{L} \cdot \mathrm{atm} \cdot \mathrm{K}^{-1} \cdot \mathrm{mol}^{-1}$.

Exercise 3: Heat Engine Cycle

A machine uses one mole of an ideal gas with $C_v = 2.9 \mathrm{cal} \cdot \mathrm{mol}^{-1} \cdot \mathrm{K}^{-1}$, describing the following cycle:

- **A to B:** Adiabatic heating from $T_A = 350\mathrm{K}$ to $T_B = 470\mathrm{K}$.

- **B to C:** Isobaric heating from $V_B = 4.5\mathrm{L}$ to $V_C = 5.0\mathrm{L}$.

- **C to D:** Adiabatic cooling.
- **D to A:** Isochoric cooling.

1.Calculate the ratio $\gamma = C_p/C_v$.

R = 2 cal/mol.k

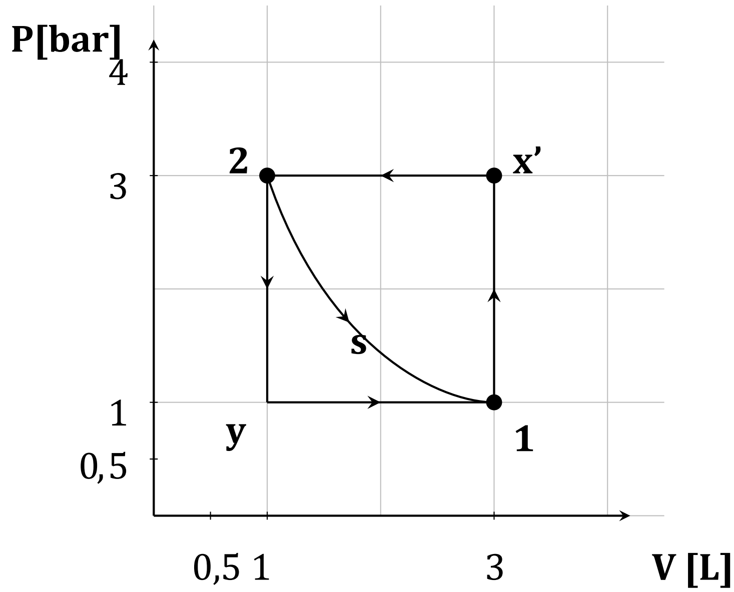
2.Calculate Q, W, and ΔU for each step and for the cycle.

3.Prove that the thermal efficiency R_t is:

$$R_t = \left|1 - \frac{T_D - T_A}{\gamma(T_C - T_B)}\right|$$

Exercise 4: Nitrogen Compression (P–V Diagram)

Nitrogen gas (N_2) is compressed from state (1) to (2) via different paths. Path **s** is isothermal (constant temperature). The transformations are represented in the diagram below:



1. Determine the number of moles of N_2 if $T_1 = 298$K.
2. Calculate the work received by the gas for each represented path ($1 \rightarrow x' \rightarrow 2$, $1 \rightarrow y \rightarrow 2$, and path **s**).
3. For path **s**, deduce ΔU, Q, and ΔH.

Exercise 5: Calorimetry

A calorimeter (C = 209J/K) contains m_1 = 350g of water at T_1 = 16°C. Lead (m_2 = 280g at T_2 = 98°C) is added. Equilibrium temperature is T_{eq} = 17.7°C.

- Calculate the specific heat capacity of lead ($C_{p,\text{lead}}$).

Data: $C_{\text{water}} = 4.185 \text{J}/(\text{g} \cdot \text{K})$.