Thermodynamic System

Example:

Box of gas $N, P, V, T$

characterize the state of the system. Imagine changing. How?

$Q =$ heat put in, $> 0$

(taken out) $< 0$

Work:

$W =$ work done by system.

$W > 0$ done by system on environment

$W < 0$ environment on system

Both introduction of $Q + W$

cause change of state

so... $P, V, T$ change!
What will matter?

- Q: changes energy \( \underline{\text{AND}} \) entropy
- W: no entropy change

on PV diagram:

\[ T = \frac{pV}{Nk} = \frac{pV}{nR} \]

\[ U_i = \frac{3}{2} nRT_i \]

Internal energy if monatomic only depends on \( T \)

Now, add heat and/or let system do work. Get to \( p_2 V_2 \)

\[ \int_{V_i}^{V_2} p(V) \, dV \]

\[ W = \int_{V_i}^{V_2} p(V) \, dV \]

depends on path!
Notice what does not depend on path... Internal energy!

\[ U_1 = \frac{3}{2} n R T_1 \quad \text{(monatomic)} \]
\[ U_2 = \frac{3}{2} n R T_2 \]

\[ U_2 - U_1 = \Delta U = \frac{3}{2} n R (T_2 - T_1) \]
\[ = \frac{3}{2} (P_2 V_2 - P_1 V_1) \]

Same energy, did work... ????

Heat must have made up the difference.

\[ \Delta U = \frac{3}{2} n R (T_2 - T_1) = Q - W \]

First Law of Thermodynamics

\[ \text{path independent but difference not.} \]
Isotherm

\[ pV = nRT = \text{constant} \]  
\[ p(V) = \frac{nRT}{V} \]

"Higher \"Isotherm\""

\[ W = \int p(V) dV = \int \frac{nRT}{V} dV \]

\[ W = nRT \ln \left( \frac{V_2}{V_1} \right) = nRT \ln \left( \frac{P_1}{P_2} \right) \]

\[ \Delta U = Q - W \]

\[ Q = W = nRT \ln \left( \frac{V_2}{V_1} \right) = nRT \ln \left( \frac{P_1}{P_2} \right) \]
Constant Pressure

\[ W = p_1 (V_2 - V_1) \]
\[ = p_1 V_2 - p_1 V_1 \]
\[ = nRT_2 - nRT_1 = nR(T_2 - T_1) \]

\[ \Delta U = Q - W = nC_p(T_2 - T_1) - nR(T_2 - T_1) \]

\[ \frac{3}{2} nR(T_2 - T_1) \quad \text{(monatomic)} \]
\[ \frac{5}{2} nR(T_2 - T_1) \quad \text{(diatomic)} \quad \text{etc.} \]

\[ nC_p(T_2 - T_1) = \left( \frac{3}{2} + 1 \right) nR(T_2 - T_1) \]
\[ nC_p(T_2 - T_1) = \frac{5}{2} nR(T_2 - T_1) \]
\[ C_p = \frac{5}{2} R = C_v + R \]