

3)

$$S_A = N_A k \ln(V_A - b N_A) + f(V_A, N_A)$$

$$S_B = N_B k \ln(V_B) + f(V_B, N_B)$$

$$N_A = 1 \text{ mol}$$

$$N_B = 2 \text{ mol}$$

$$V = 1 \text{ m}^3$$

$$b = 4 \times 10^{-4} \text{ mol/m}^3$$

$$PV = NkT$$

$$P = \frac{NkT}{V}$$

$$P_A = P_B$$

$$\frac{N_A k T}{V_A} = \frac{N_B k T}{V_B}$$

$$N_A k (1 - V_A) = V_A N_B k$$

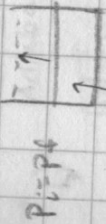
$$N_A - N_A V_A = V_A N_B$$

$$\frac{N_A}{N_B + N_A} = \frac{V_A}{V}$$

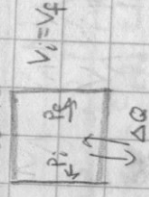
$$V_A \approx 0.333 \text{ m}^3$$

Lecture 6: Thermodynamic Processes

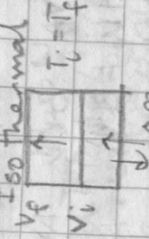
Isochoric



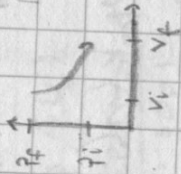
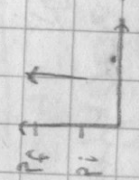
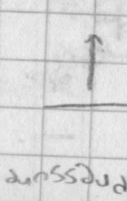
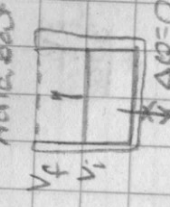
Isochoric



Isothermal



Adiabatic



Conservation:

$$\sum E_{i, \text{initial}} = \sum E_{i, \text{final}}$$

Important Eq:

2nd law:

$$\sum S_{i, \text{initial}} \leq \sum S_{i, \text{final}}$$

Quasi-static Processes:

$$U = \frac{N D F}{2} N k T + \text{const}$$

If ideal gas:

$$PV = NkT$$

A process is a line on this graph.

Consider macrostate vars P, V, U, T, N

1. Assume N is constant

2. Eq of state ($PV = NkT$ for gas)

3.

Common

Isothermal

Constant T

reversible

Constant V

irreversible

Isochoric

Constant P

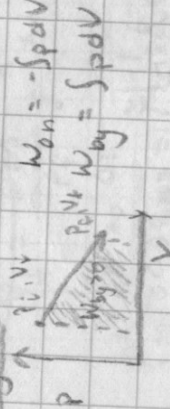
irreversible

Iso baric

Adiabatic

reversible

P-V Diagrams:



Isothermal

$$\Delta S_{\text{sys}} = -\frac{Q}{T}$$

$$\Delta S_{\text{res}} = \frac{Q}{T}$$

$$\Delta S_{\text{tot}} = 0$$

Pay attention to arrows!



$$P = \frac{NkT}{V}$$

Quasi-static processes (equilibrium)

$$ds = \frac{dq}{T}$$

If equipartition:

$$U = \frac{N D F}{2} N k T + \text{const}$$

If ideal gas:

$$PV = NkT$$

Reversible Processes

Say we have entropy of environment and system. For a new process:

$$\Delta S_{\text{sys}} + \Delta S_{\text{env}} = 0$$

No net entropy produced

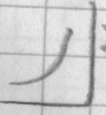
Adiabatic: $\Delta S = 0$

$$\Delta S = \int \frac{dq}{T} = 0$$

For an ideal gas?

$$P = \text{const} / V^\gamma$$

$$\gamma = \left(\frac{f}{2} + 1 \right)$$



Lecture 5: Ideal Gas Law

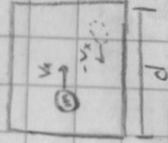
$$PV = NkT$$

$$PV = nRT$$

Applies to an ideal gas in internal equilibrium.
 "Internal equilibrium" means all internal variables have "settled down".

Equipartition: $U = \frac{3}{2} NkT + \text{const}$

Kinetic theory of ideal gas:



Temp Velocity:

$$U = \frac{3}{2} NkT + \text{const} (=0)$$

for monatomic ideal gas.

$$\langle K \rangle_{\text{trans}} = \frac{3}{2} kT$$

Pressure due to one particle on one side: $F_x = \frac{2mv_x^2}{L}$
 Pressure due to N particles, averaged over all directions: $P = \frac{N m \langle v^2 \rangle}{3V}$
 $\frac{1}{2} m \langle v^2 \rangle = \frac{3}{2} kT$
 $v_{\text{rms}} = \sqrt{\langle v^2 \rangle} = \sqrt{\frac{3kT}{m}}$

Easy Ideal gas law derivation: $\left(\frac{\partial S}{\partial V}\right)_{U,N} = \frac{P}{T}$
 $S = Nk \ln V + \text{function}(U, N)$ This works for any entropy function.

$$\left(\frac{\partial S}{\partial V}\right)_{U,N} = \frac{Nk}{V} = \frac{P}{T}$$

Homework 5: Kinetic Theory

- 1) He $T_0 = 21^\circ\text{C}$
 $V_0 = 0.0047 \text{ m}^3$
 $\Delta V = 6\%$ $T_f = ?$

$$r = 10 \text{ cm}$$

$$P = 101.3 \text{ kPa}$$

$$U = \frac{PV}{kT} \approx 1.04 \times 10^{23}$$

- 2) $w_{\text{by}} = ?$

$$w_{\text{by}} = \int P dV = 101.3 \times 10^3 \cdot (0.06 - 0.0047) \approx \boxed{25.5 \text{ J}}$$

- 2) N $m_N = 289 \text{ g/mol}$ $P = 2 \text{ atm}$ $d = 1.89 \text{ g/Liter}$ $v_{\text{rms}} = ?$

$$U = Kf = \frac{3}{2} kT = \frac{1}{2} m v^2$$

$$T = \frac{PV}{Nk} = \frac{202600 \frac{\text{J}}{\text{m}^3}}{138 \times 10^{23} \frac{1}{\text{m}^3}} = 1.47 \times 10^{-2} \text{ K}$$

$$\frac{3}{2} kT = \frac{1}{2} m v^2$$

$$\frac{3kT}{m} = v^2$$

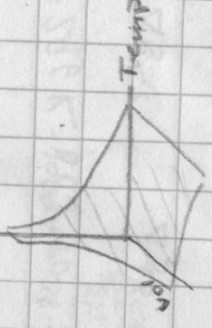
$$m = \frac{m_N}{N_A} = 4.65 \times 10^{-26} \text{ kg}$$

$$\frac{V}{N} = \frac{0.0047 \text{ m}^3}{1.38 \times 10^{23}} = 3.4 \times 10^{-27} \text{ m}^3$$

$$v = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3 \cdot 1.38 \times 10^{-23} \cdot 1.47 \times 10^{-2}}{4.65 \times 10^{-26}}} \approx \boxed{581 \text{ m/s}}$$

10/23/23

Pressure



Temp

