State vs. Path Functions

- **State**:
  - \( U, H, p, V, T \)
  - Independent of preparation

- **Path**:
  - \( \Delta U = U_f - U_i \)
  - Independent of path

- \( dq, dw \) are inexact differentials
  - \( \frac{dU}{dT} = C_p \cdot \) isothermal
  - \( \frac{dH}{dT} = C_p \cdot \) isenthalpic

Changes in Internal Energy

- \( dU = \frac{dH}{dT} \cdot dV + C_p \cdot dT \)

Internal Pressure

- \( \pi_T = \frac{dU}{dV} \cdot T \)
  - Measure of cohesive forces
  - \( \pi_T = 0 \) for perfect gas

Joule Apparatus

- Expanded gas into a vacuum

Joule-Thomson Effect

- \( \mu, \mu_T \) determine the signs of \( \mu \) and \( \mu_T \)

Apparatus #1

- \( \mu = \frac{d(TdP)}{dV} \)
  - Linde refrigerator

Apparatus #2

- \( \mu_T = \frac{d(HdP)}{dV} \)
  - Isothermal

Examples of Using \( \kappa_T \)

- JT coefficient

- \( \kappa_T = \frac{1}{\mu} \left( \frac{dV}{dP} \right)_T \)

- \( \frac{dU}{dT} = \kappa_T \cdot \) isothermal

- \( \frac{dH}{dT} = \kappa_T \cdot \) isenthalpic

Changes in \( U \), Const. \( p \)

- \( \alpha = \frac{1}{\mu} \left( \frac{dV}{dP} \right)_T \)

New: Expansion Coefficient, \( \alpha \)

- Large \( \alpha \), big responses to change in \( T \)

Perfect Gas, \( \pi_T = 0 \)

- \( C_p - C_v = \frac{dH}{dT} - \frac{dU}{dT} \)

Relation between \( C_p \) and \( C_v \)

- Prove that (know this proof):

State vs. Path

- Exact differentials: \( \Delta U = U_f - U_i \)
- Independent of path

- \( dU \) is an exact differential
- \( q, w \) inexact differentials
- Inexact differentials are dependent on path

- \( dU = \frac{dH}{dT} \cdot dV + C_p \cdot dT \)

- \( \frac{dU}{dT} = C_p \cdot \) isothermal

Apparatus #1

- \( \mu = \frac{d(TdP)}{dV} \)

Apparatus #2

- \( \mu_T = \frac{d(HdP)}{dV} \)

Examples of Using \( \kappa_T \)

- JT coefficient

- \( \frac{dU}{dT} = \kappa_T \cdot \) isothermal

- \( \frac{dH}{dT} = \kappa_T \cdot \) isenthalpic

Changes in \( H \), Const. \( V \)

- \( dH = \frac{dU}{dT} \cdot dV + C_p \cdot dT \)

Total Differential Equation (TDE):