The Gay-Lussac-Joule Experiments

• Measuring the dependence of the internal energy of a gas on its volume.

• Results show that the internal energy is a function of $T$ only.

• The internal energy does not depend on the volume $V$. 
The GLJ experiment is designed based on the following relationship:
\[
\left( \frac{\partial u}{\partial v} \right)_T \left( \frac{\partial v}{\partial T} \right)_u \left( \frac{\partial T}{\partial u} \right)_v = -1. 
\]
\[
\left( \frac{\partial u}{\partial v} \right)_T = -c_v \left( \frac{\partial T}{\partial v} \right)_u,
\]
which indicates that the variation of internal energy could be obtained via measuring the change of temperature with respect to volume under constant internal energy.

The key is: how to keep the internal energy constant during expansion.

Considering \( du = dq - dw \), where \( dq = 0 \) during adiabatic changes.
5.2 The Joule-Thomson Experiment
Theory of the Joule-Thomson Experiment

• In an insulated cylinder: \( dq = 0 \)
• The work done by forcing the gas through the throat (or porous plug) is \( -P_1V_1 \)
• The work done by the system in expansion is \( P_2V_2 \)
• The total work is therefore: \( P_2V_2 - P_1V_1 \)
• The variation in internal energy is
  \[
  u_2 - u_1 = P_2V_2 - P_1V_1
  \]
• Both the P and T of the gas before passing through the throat are kept constant
• The Temperature at the exit is measured at different exiting P values

• The slope of the above curve at any point is called the Joule-Thomson coefficient $\mu$, where $\mu = 0$ is called the inversion point
The Joule-Thomson experiment illustrates that the enthalpy of a gas is independent of pressure.

Theoretical analysis will be shown on chalk board
5.3 Heat Engines and the Carnot Cycle

- A system that receives an input of heat at a high temperature, does mechanical work, and gives off heat at a lower temperature.
• The efficiency of the engine \( \eta \) is equal to the work done by the system divided by the heat absorbed \( Q_2 \).

• According to the first law, \( \Delta u = Q_1 + Q_2 - W \)

• When the engine returns to the initial state after each cycle, \( \Delta u = 0 \), therefore \( Q_1 + Q_2 = W \)

• \( \eta = 1 - \frac{T_1}{T_2} \)

• The efficiency would be 100% if \( T_1 \) could be at absolute zero.
- A Carnor refrigerator is a Carnor engine in reverse
- The relationship $\frac{Q_1}{Q_2} = -\frac{T_1}{T_2}$ still holds.
- The coefficient $c$ is defined as $-\frac{Q_1}{W} = \frac{T_1}{(T_2 - T_1)}$
- $c$ can be much larger than 1.