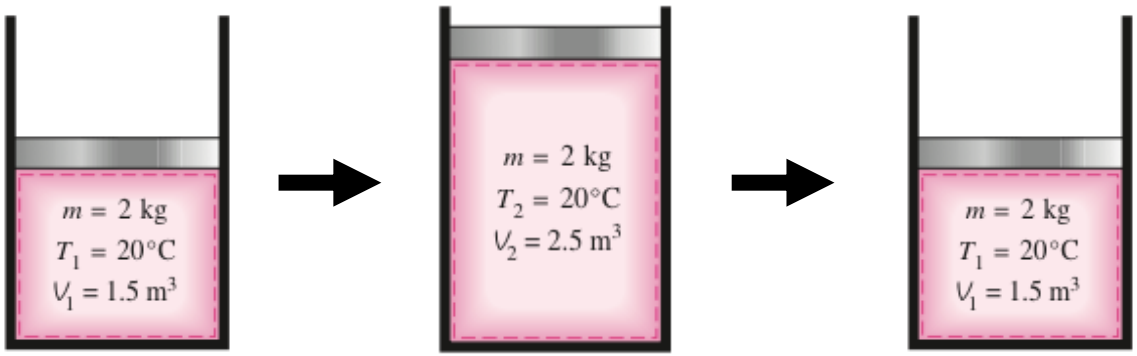
Chapter 1

Introduction (conti.)

Properties and State of a Substance

- **Phase**: a quantity of matter that is homogeneous throughout. (uniform properties)
  - cf. state of matter: liquid, solid, gas
- **State**
  - In each phase, the substance may exist in various states.
  - A state can be completely described (or identified) by a set of properties.
  - state1: (T_1, P_1, V_1, …), state2: (T_2, P_2, V_2, …), …
  - Independent of the path of property change.

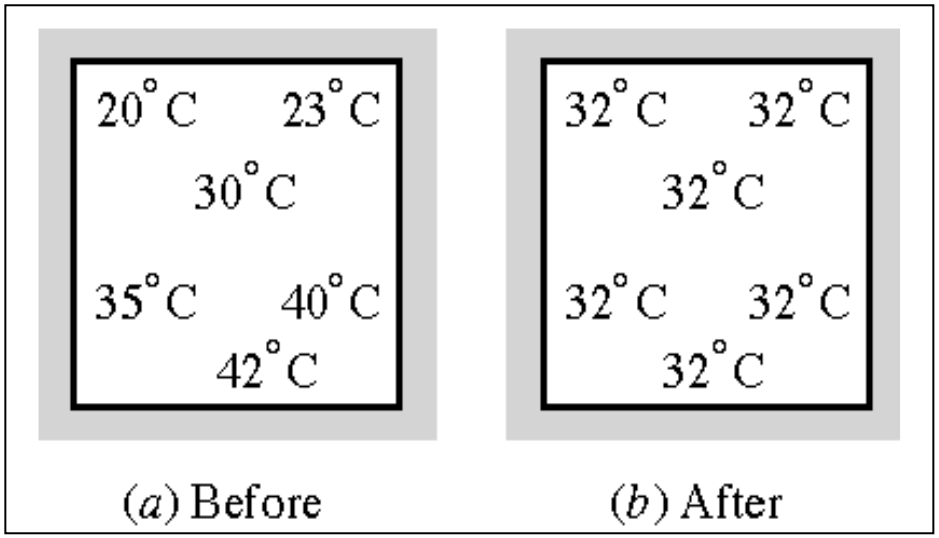


State1 State2 State1 (?)

Thermodynamic Equilibrium

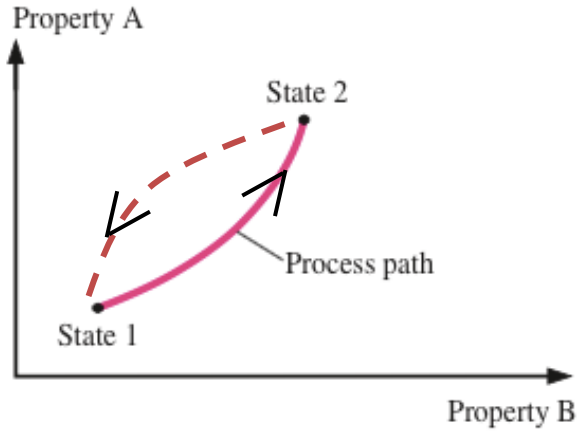
- When it comes to a system, equilibrium should be achieved to describe the state of the system with its properties .
- When a system is in equilibrium regarding all possible changes of state, we say that the system is in **thermodynamic equilibrium**.

✓ Thermal equilibrium (T)
✓ Mechanical equilibrium (P)
✓ Chemical equilibrium (n_i)

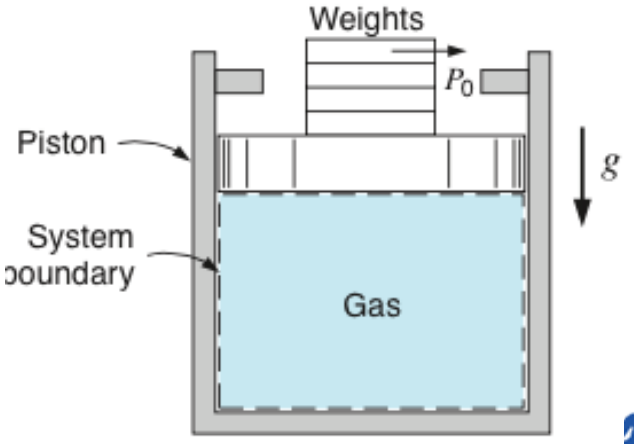


Processes and Cycles

- **Process**
  - The path of the succession of states through which the system passes



- **Quasi-equilibrium process**
  - The deviation from thermodynamic equilibrium is so small that all the states the system passes during the quasi-equilibrium process may be considered equilibrium states.
- Non-equilibrium process
- Isothermal process → constant *T*
- Isobaric process → constant *P*
- Isochoric process → constant *V*



Units

- SI units vs Imperial units (UK)

- Force
  - F = ma
  - 1 kg m/s^2 = 1 N
- Length
  - 1 ft = 0.3048 m = 12 inch
- Mass
  - 1 lbm (pound mass) = 0.455 kg

- We use the metric SI system in this class.

Energy

- Energy can be stored in a system or can be transferred from one system to another.
- In the case of a gas at a given state within a vessel, we can define 3 kinds of energy from the molecular viewpoint.
  - **Intermolecular potential energy** → interaction between molecules

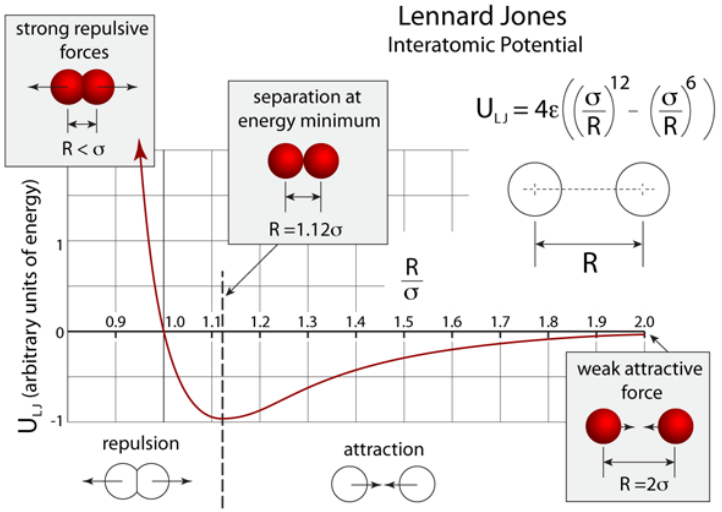
    ex> Van der Waals interaction

    What about ideal gas?

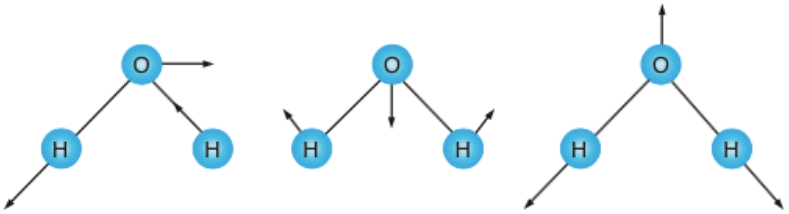
  - **Translational energy** (v_x, v_y, v_z)

  - **Intramolecular energy**

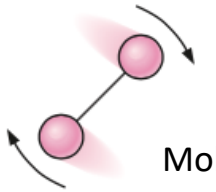
    → rotational & vibrational energy



Ref: www.atonsinmotion.com



3 principal vibrational modes for the water molecule

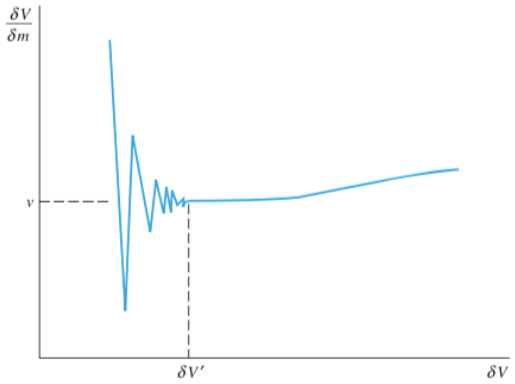


Molecular rotation

Specific volume & density

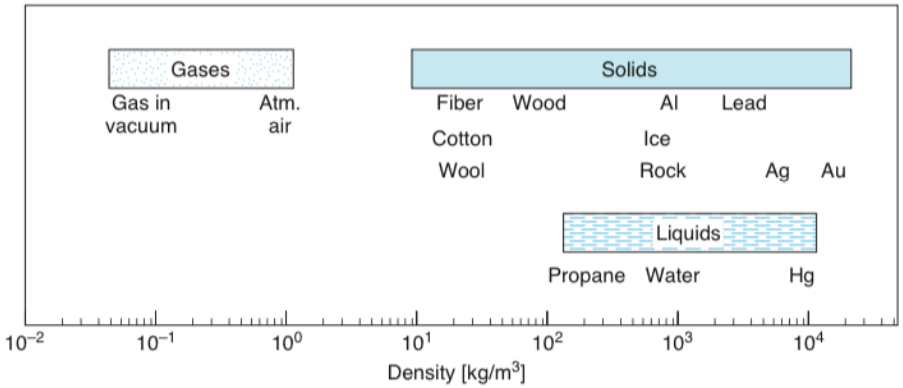
- **Specific volume (*v*)**
  - The volume per unit mass (m^3/kg)
  - At a point of a given system,

$$v = \lim_{\delta V \to \delta V'} \frac{\delta V}{\delta m}$$



($\delta V'$: the smallest volume that satisfies the continuum limit)

- **Density (*ρ*)**
  - The reciprocal of the specific volume (kg/m^3)
  - $1/v$



1 L = 10^{-3} m^3

- Molar specific volume ($\bar{v}$) (unit: m^3/mol) , molar density ($\bar{\rho}$) (unit: kg/mol)

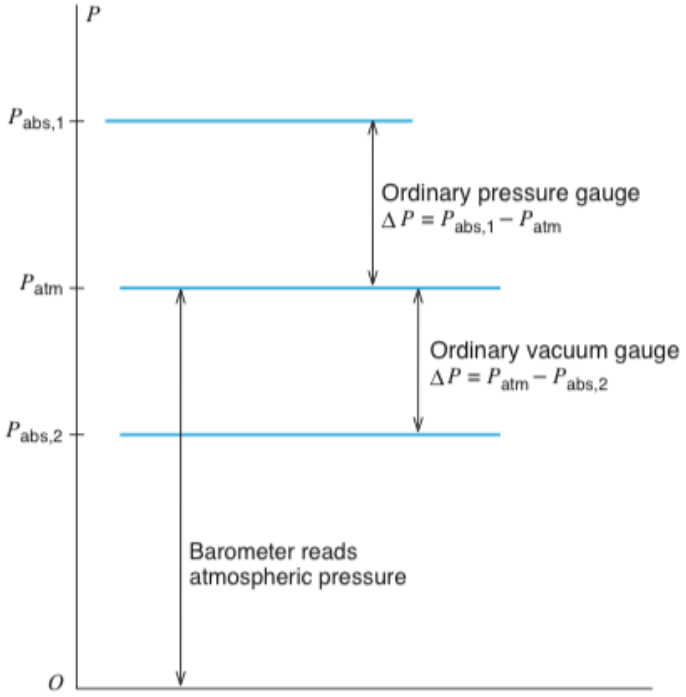
Pressure

- For a fluid system, pressure is defined as the normal force per unit area

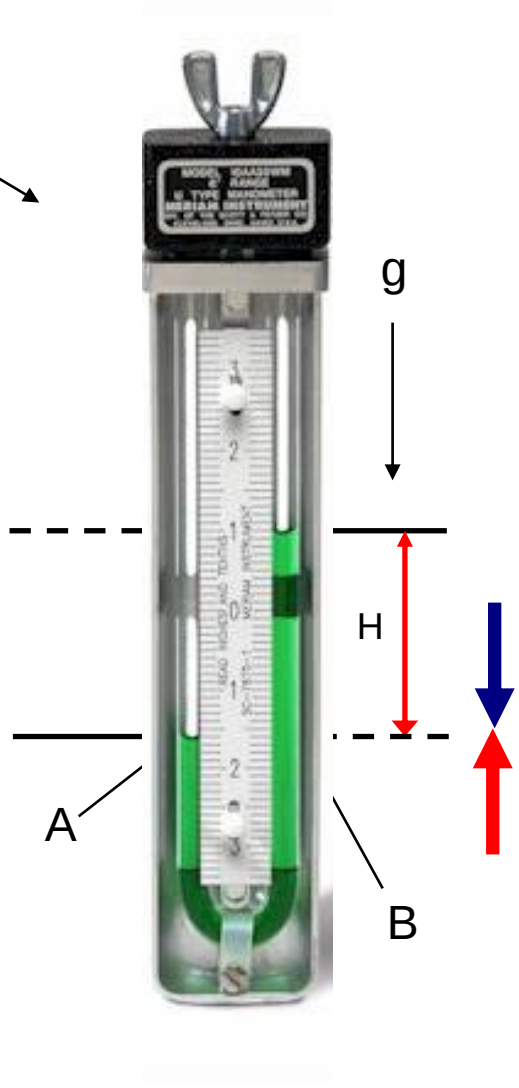
$$P = \lim_{\delta A \to \delta A'} \frac{\delta F_n}{\delta A}$$

($\delta A'$: the smallest area that satisfies the continuum limit)

- Atmospheric pressure
  - 1 atm; 101.3 kPa; 1 bar; 760 Torr (or mmHg)
- Absolute pressure
- Gage pressure
  - Ordinary pressure gauge: P_{abs} - P_{atm}
  - Ordinary vacuum gauge: P_{atm} - P_{abs}



Measurement of Pressure



$$P_B A = P_0 A + \rho A H g$$

$$\therefore \Delta P = P_B - P_0 = \rho g H$$

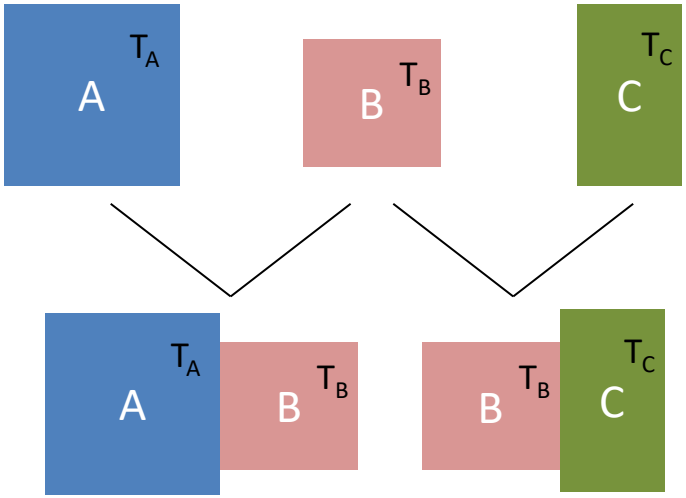
$$F_{B\uparrow} = F_{B\downarrow}$$

$$F_{B\downarrow} = P_0 A + mg = P_0 A + r\, AHg$$

$$F_{B\uparrow} = P_B A$$

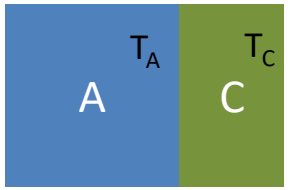
We always refer to ***absolute pressure***

The zeroth law of thermodynamics



Thermal equilibrium & no change in T

then



$T_A = T_C$

When two bodies have equality of temperature with a third body, they in turn have equality of temperature with each other.

* The colors of the boxes do not indicate temperature values.

- The basic principle that validates temperature measurement

$$K = °C + 273$$

$$(F = °C \times 9/5 + 32)$$

Summary

- Control volume/mass/surface
- Open/closed/isolated system
- Intensive/extensive properties
- State
- Process
- Cycle
- Thermodynamic equilibrium
- Quasi-equilibrium
- 0^{th} law of thermodynamics