ESO 201A: Thermodynamics

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Introduction-part 2

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Learning objectives

1. Review of metric SI
2. Explain basic concept of :
   - *system, state, state postulate, equilibrium, and process*
3. Define intensive and extensive properties of system
4. Define density, specific gravity, and specific weight
5. Discuss temperature scale
6. Understanding pressure, barometer, manometer

Properties of a system

A thermodynamic systems may consist of many species.

- A mixture of N_2, H_2, and NH_3, in a reactor, at a given T and P

Predicting the state of a gas mixture (system) when the conditions of reaction are altered- we must have the knowledge of properties of the materials!

Essential features of a property are:

a) A property should have a definite value when the system is in a particular state, and
b) The value of the property should be determinable irrespective of how the system is brought to that particular state.

$$\int_i^f dZ = Z_f - Z_i$$

Thermodynamic property

if $Z = Z(x, y)$ then

$$dZ = \left(\frac{\partial Z}{\partial x}\right)_y dx + \left(\frac{\partial Z}{\partial y}\right)_x dy = Mdx + Ndy$$

if $\left(\frac{\partial M}{\partial y}\right)_x = \left(\frac{\partial N}{\partial x}\right)_y$, then dZ is said to be an exact differential.

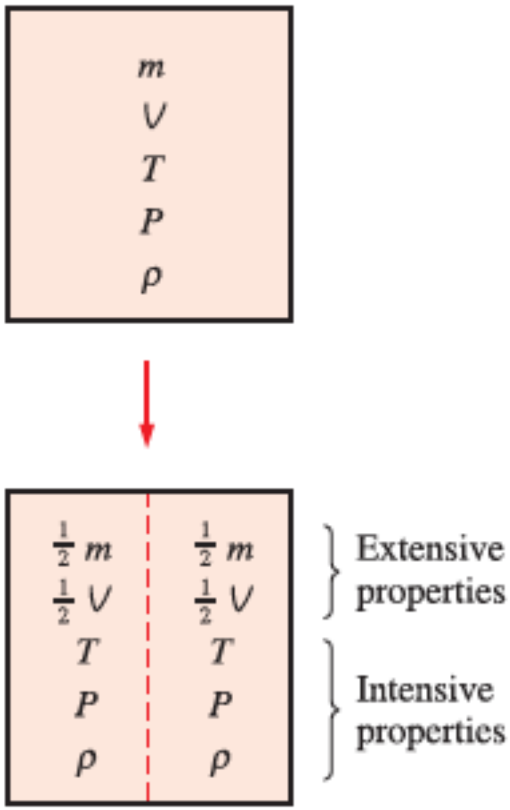
$$\Delta Z = \int_i^f dZ = Z_f - Z_i$$

Thermodynamics property (Z) is independent of the path, and is a point function

Properties of a system

- Examples:
  - Pressure, P
  - Temperature, T
  - Volume V,
  - Mass, m

  Properties are considered to be either *intensive* or *extensive*



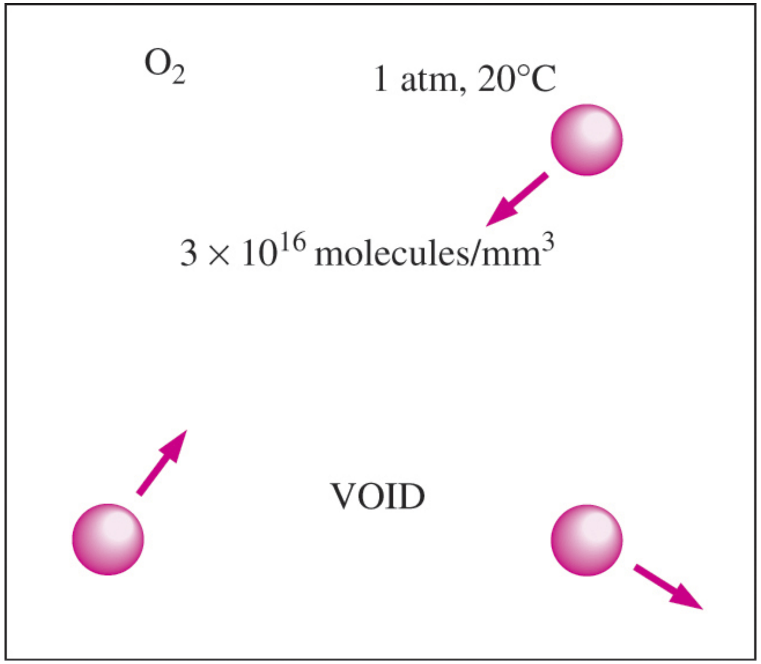
- **Intensive**
  - Independent of mass, T, P, ρ
- **Extensive**
  - Depend on the size, or extent of the system, *m*, *V*, total momentum

Specific properties: extensive properties per unit mass

e.g. : specific volume

Continuum Idealization

- Matter is made up of atoms
  - view it as a continuous, homogeneous matter with no holes, that is, a **continuum**.
- The continuum idealization
  - allows us to treat properties as point functions
  - to assume the properties vary continually in space with no jump discontinuities.
- This idealization is valid as long as the size of the system we deal with is large relative to the space between the molecules.
  - *This is the case in practically all problems.*
- In this course, we will limit our consideration to substances that can be modeled as a continuum.



Despite the large gaps between molecules, a substance can be treated as a continuum because of the very large number of molecules even in an extremely small volume.

Density and specific gravity

Density $\rho = \dfrac{m}{V} \quad (\text{kg/m}^3)$

Specific volume $v = \dfrac{V}{m} = \dfrac{1}{\rho}$

Sometime density is given in terms of Specific gravity:

$$\text{SG} = \frac{\rho}{\rho_{\text{H}_2\text{O}}}$$

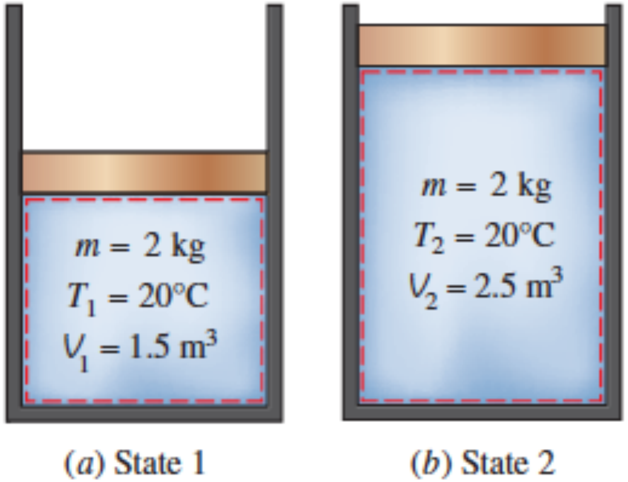
$$V = 12 \text{ m}^3$$
$$m = 3 \text{ kg}$$
$$\Downarrow$$
$$\rho = 0.25 \text{ kg/m}^3$$
$$v = \frac{1}{\rho} = 4 \text{ m}^3/\text{kg}$$

Density of liquids are essentially constants – approximated as incompressible substance during most processes

Specific gravities of some substances at 0°C

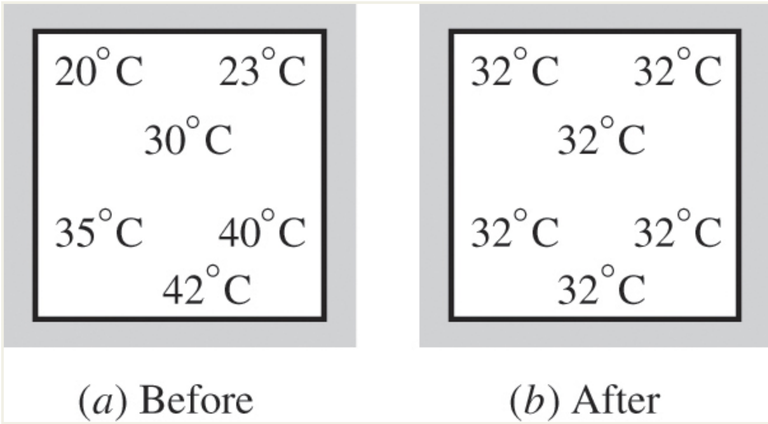
Substance	SG
Water	1.0
Blood	1.05
Seawater	1.025
Gasoline	0.7
Ethyl alcohol	0.79
Mercury	13.6
Wood	0.3–0.9
Gold	19.2
Bones	1.7–2.0
Ice	0.92
Air (at 1 atm)	0.0013

State and equilibrium



State

- System is not undergoing change
- One can measure all the properties describing the condition



A closed system reaching thermal equilibrium.

Equilibrium

- State of balance, no driving force or no unbalanced potentials within the system
- An isolated system at equilibrium undergoes no change.

State and equilibrium

A system at equilibrium should have

Thermal equilibrium

- No temperature gradient i.e., no driving force for heat flow

Mechanical equilibrium

- No change in pressure at any point in the system with time(pressure can change within the system with elevation)

Chemical equilibrium: If the chemical composition of a system does not change with time, that is, no chemical reactions occur.

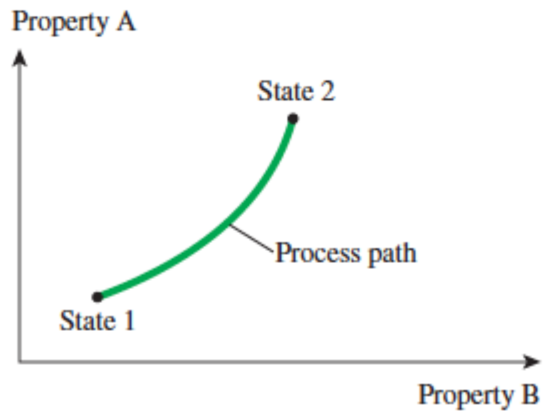
Phase equilibrium: If a system involves two phases and when the mass of each phase reaches an equilibrium level and stays there.

The state postulate

- The number of properties required to fix the state of a system is given by the **state postulate**:
  - *The state of a simple compressible system is completely specified by two independent, intensive properties.*
- **Simple compressible system:** If a system involves no electrical, magnetic, gravitational, motion, and surface tension effects.

The state of nitrogen is fixed by two independent, intensive properties.

Processes and cycle



Process

Any change from one equilibrium state to another

Path

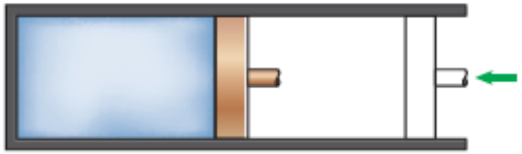
Series of change states through which system passes through

Quasi-static or quasi-equilibrium process

Process where system remains infinitesimally close to an equilibrium state at all time

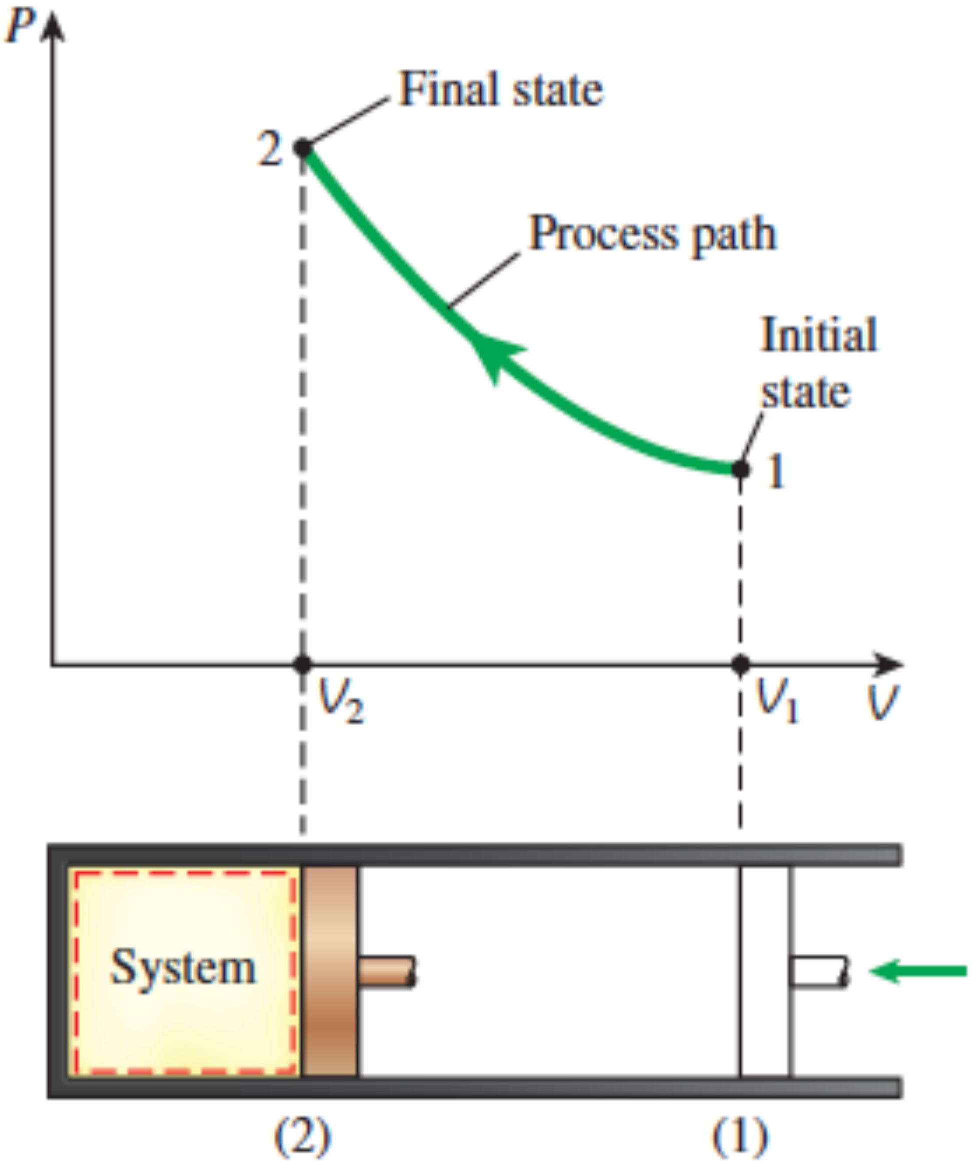
- Idealised process
- easy to analyse
- work producing device deliver the max work when operate on quasi-equilibrium

(*a*) Slow compression (quasi-equilibrium)



(*b*) Very fast compression (nonquasi-equilibrium)

Process diagram



The *P*-*V* diagram of a compression process.

Processes and cycle

Process diagram useful in visualizing the process

- common properties: T, V, P

Process path- only for quasi-equilibrium/equilibrium

- Not useful for non-equilibrium

Isothermal process: A process during which the temperature *T* remains constant

Isobaric process: A process during which the pressure *P* remains constant.

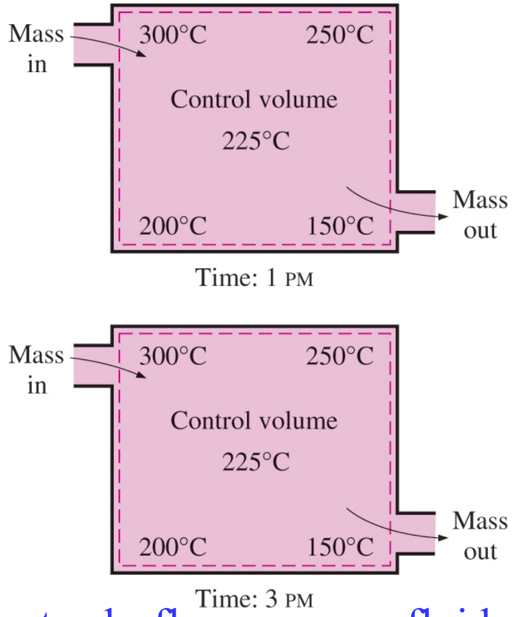
Isochoric process : A process during which the specific volume *v* remains constant.

Cycle: A process during which the initial and final states are identical.

Steady flow process

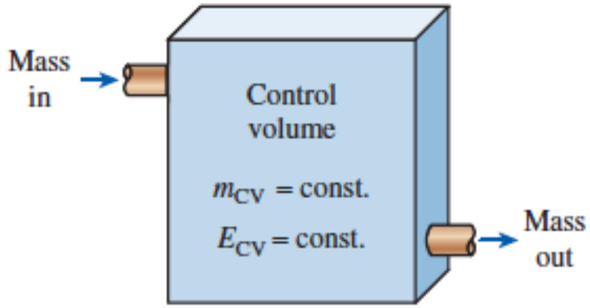
Steady- No change in time
Uniform- no change with location

Steady-flow process- process during which a fluid flows through a control volume steadily.



During a steady-flow process, fluid properties within the control volume may change with position but not with time.

Closely approximated for continuous operated devices such as turbines, pumps, boilers, condensers, and heat exchangers or power plants or refrigeration systems



Under steady-flow conditions, the mass and energy contents of a control volume remain constant.

Next lecture

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