3.020 Lecture 2

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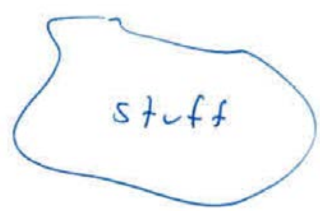
1. Scope of thermodynamics

(a) states of matter: have well-defined response to

- squeezing
- heating
- adding more stuff
- different stuff
- applying fields



(b) Transformations between states

- Starting/final states described with certainty

  e.g. phase diagrams
- Process is abstract
- Kinetics is <u>not</u> described ⇒ <u>no time</u> in thermo ⇒ Thermo describes the why, only hints at the how.

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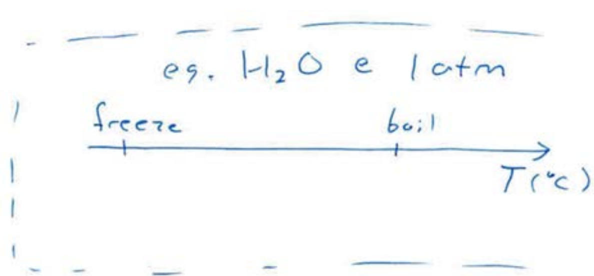
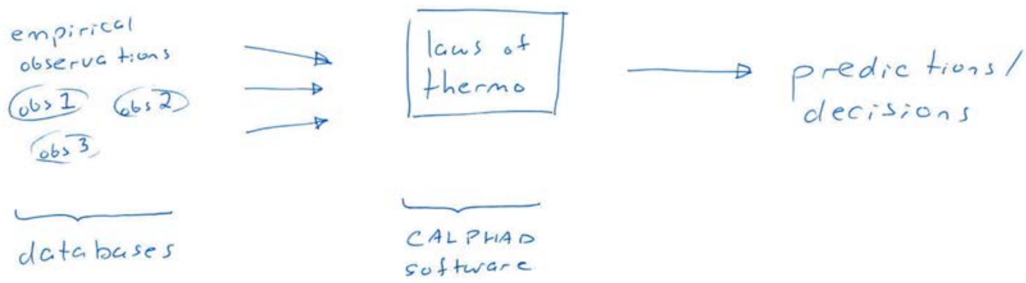
2. Use of thermodynamics

- Predict & Control matter
- Transfer Knowledge

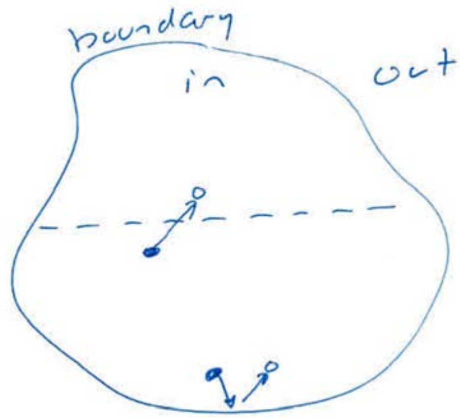
  e.g. phase diagrams



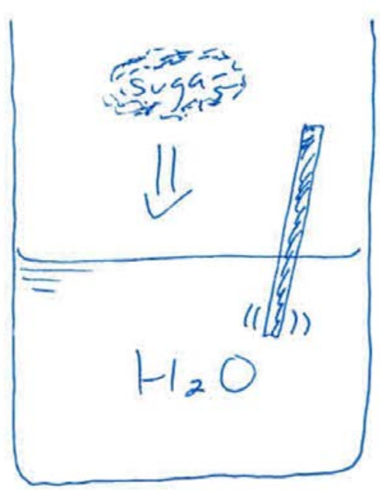


3. Systems in thermodynamics

- Characterized by :
  - Temperature
  - Pressure
  - Volume
  - Composition
- Draw boundaries out of convenience



e.g. adding sugar to a glass of water and stir



- System: H_2O Sugar Glass atmosphere stirring stick
- Boundaries:

  open/closed
  rigid/not rigid
  adiabatic/diathermal

4. Types of systems: Classifications

(I) Uniary=one component — e.g. H_2O

v.s.

MultiComponent — e.g. $H_2O + C_{12}H_{22}O_{11}$

(I) Homogeneous = one phase — e.g. sodium acetate solu.

v.s.

Heterogeneous = more than one phase — e.g. sodium acetate solu.+solid sodium acetate

(I) Closed = no mass exchange with surroundings — e.g. closed soda bottle

Open = can exchange mass — e.g. open soda bottle

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5. State functions/variables

- Characterize a system
- Independent of history

Common state functions found in 3.020:

- temperature (T)
- pressure (P)
- entropy (S)
- volume (V)
- composition (c.t.%)
- mole # (N)
- Gibbs free energy (G)
- etc.

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6. Equations of state

$$\underbrace{X}_{\text{state fn.}} = f(\underbrace{Y_1, Y_2, Y_3, \ldots}_{\text{state variables}})$$

$$e.g. \quad PV = NRT$$

$$R = \frac{PV}{NT} \propto \frac{Pa \cdot m^3}{\# \cdot K} = \frac{N \cdot m^3}{m^2 \cdot K} = \frac{N \cdot m}{K} = \frac{J}{K}$$

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7. Thermodynamic properties

- Compressibility $\beta = -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T = -\left(\frac{\partial lnV}{\partial P}\right)_T$
- Thermal expanstion $\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P = \left(\frac{\partial lnV}{\partial T}\right)_P$

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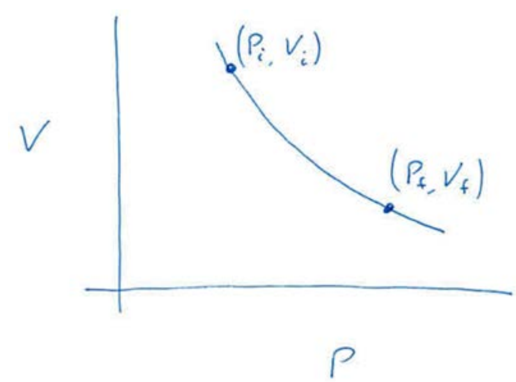
e.g. Compressing an ideal gas at fixed temperature $V_i(P_i) \rightarrow V_f(P_f)$

$$\beta = -\frac{1}{V}\left(\frac{\partial}{\partial P}\frac{NRT}{P}\right)_T = \frac{NRT}{VP^2} = \frac{NRT}{VP}\frac{1}{P} = \frac{1}{P}$$

simple for ideal gas

$$V_f = V_i + \int_{P_i}^{P_f} dV = V_i + \int_{P_i}^{P_f} dP(-V\beta) = V_i - \int_{P_i}^{P_f} dP\frac{NRT}{P}\frac{1}{P}$$
$$= V_i - \frac{NRT}{P_i} + \frac{NRT}{P_f} \quad \text{trivial for ideal gas}$$



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8. Intensive v.s. extensive properties

- Intensive: Can be defined at any point in a system
  e.g. temperature, density, composition, pressure, compressibility
- Extensive: Depends on extent of system, scales with system size
  e.g. energy, volume, moles, entropy, mass

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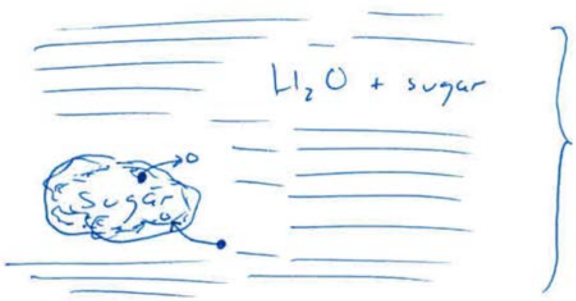
9. Phases of matter

- Phase = region of space within which all (intensive) properties are uniform
  e.g. solid sucrose, pure water, sugar, sugar water, pure copper, pure zinc, brass
- Phase boundaries classified similarly to system boundaries
  e.g. sugar + sugar water.



exchanging volume, heat energy and mass across the phase boundary