3.020 Lecture 2

Prof. Rafael Jaramillo
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 not described $\Rightarrow$ no time in thermo $\Rightarrow$ Thermo describes the why, only hints at the how.

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

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.

6. Equations of state

\[ X = f(Y_1, Y_2, Y_3, \ldots) \]

\[ \text{state fn.} \quad \text{state variables} \]

\[ e.g. \quad PV = NRT \]

\[ R = \frac{PV}{NT} \propto \frac{Pa \cdot m^3}{\# \cdot K} = \frac{N \cdot m^3}{m^2 \cdot K} = \frac{N \cdot m}{K} = \frac{J}{K} \]
7. Thermodynamic properties

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

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

Simple for ideal gas

\[ V_f = V_i + \int_{P_i}^{P_f} dV = V_i + \int_{P_i}^{P_f} dP(-V\beta) = V_i - \int_{P_i}^{P_f} dP \frac{NRT}{P} \frac{1}{P} \]

\[ = V_i - \frac{NRT}{P_i} + \frac{NRT}{P_f} \]

Trivial for ideal gas

\[ (P_i, V_i) \]
\[ (P_f, V_f) \]

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
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.

\[
\text{exchanging volume, heat energy and mass across the phase boundary
}\]