Lecture 13

- Temperature scales, absolute zero
- Phase changes, equilibrium, diagram
- Ideal gas model

Temperature

- temperature is related to system's thermal energy (kinetic and potential energy of atoms)
- measured by thermometer: small system undergoes a change upon exchagning thermal energy, e.g., length of mercury/alcohol in glass tube or
ideal gas' pressure

Temperature Scales

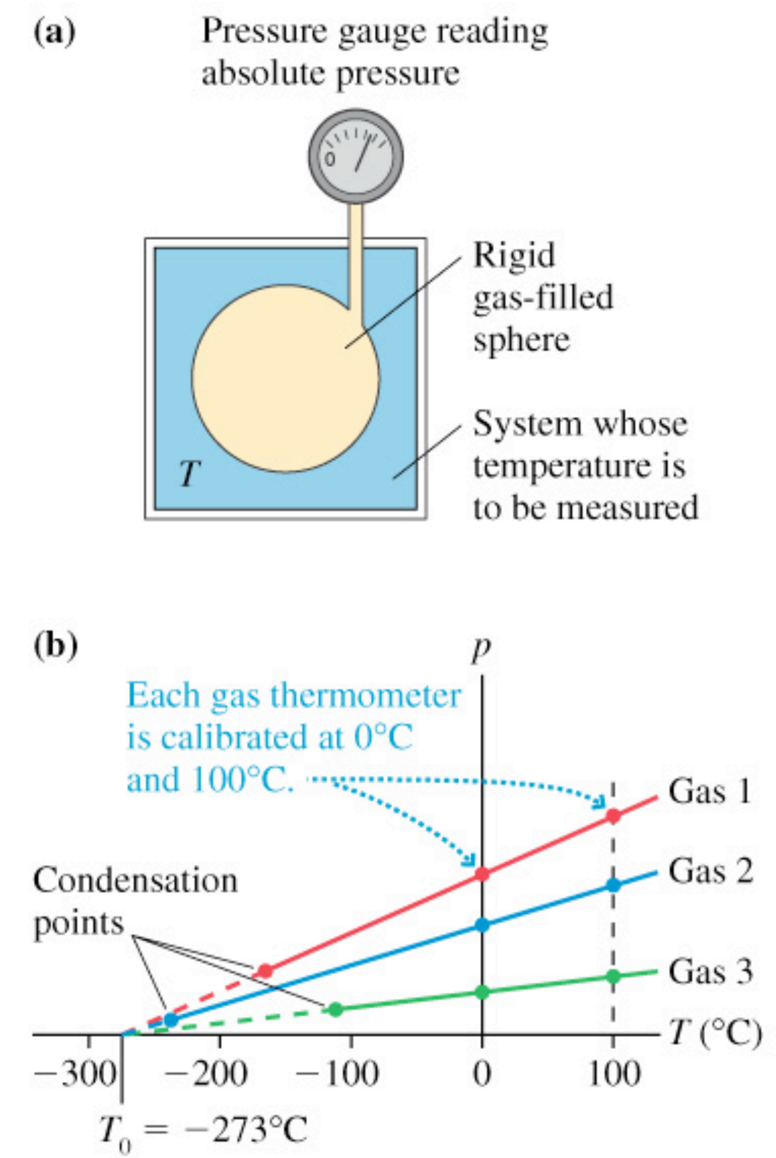
- Celcius/centigrade scale:
boiling point ($100^{\circ}C$) freezing point ($0^{\circ}C$)
- Fahrenheit scale: $T_F = \frac{9}{5}T_C + 32^{\circ}$
($212^{\circ}F$ and $32^{\circ}F$)

Absolute Zero and Absolute Temperature

- property changes linearly with temperature: e.g., pressure of constant-volume gas

- p = 0 for all gases at $T_0 = -273\,^{\circ}C$
  p due to collisions $\longrightarrow$ all motion stopped, zero thermal energy: absolute zero (lowest temperature)

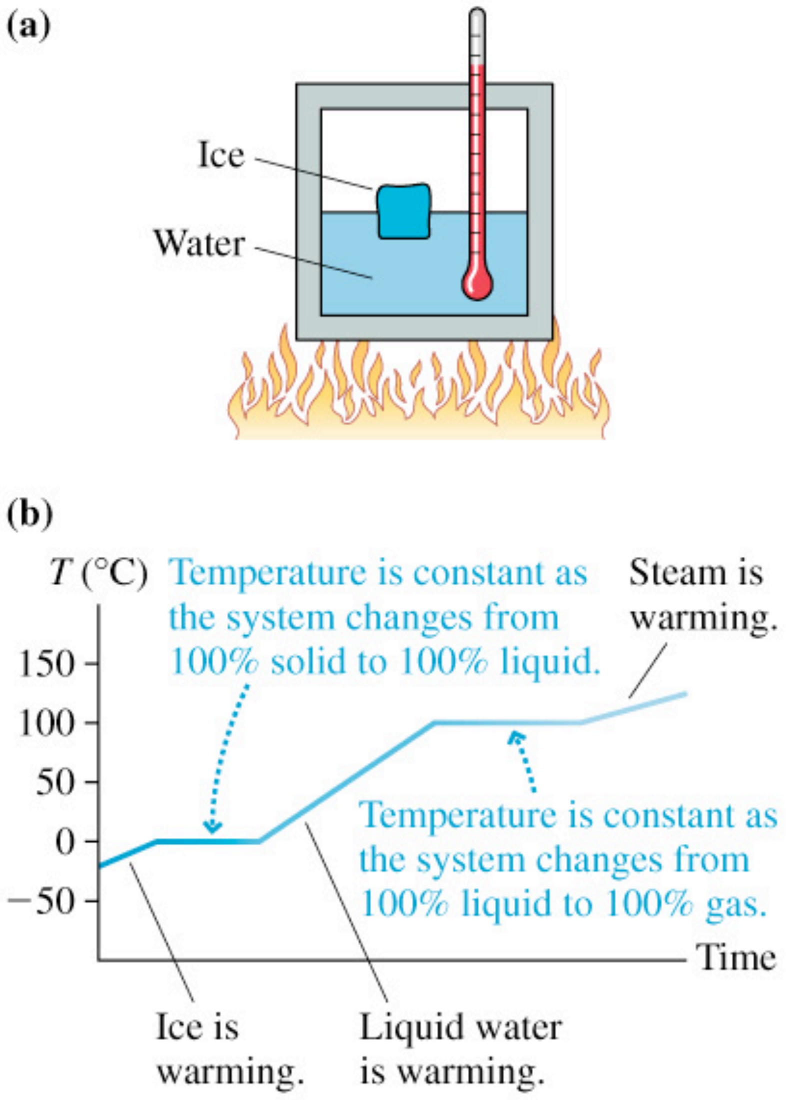
- absolute temperature scale:
  zero point at absolute zero
  Kelvin scale if same unit size as Celcius scale:



$$T_K = T_C + 273 \text{ (no degrees for Kelvin)}$$

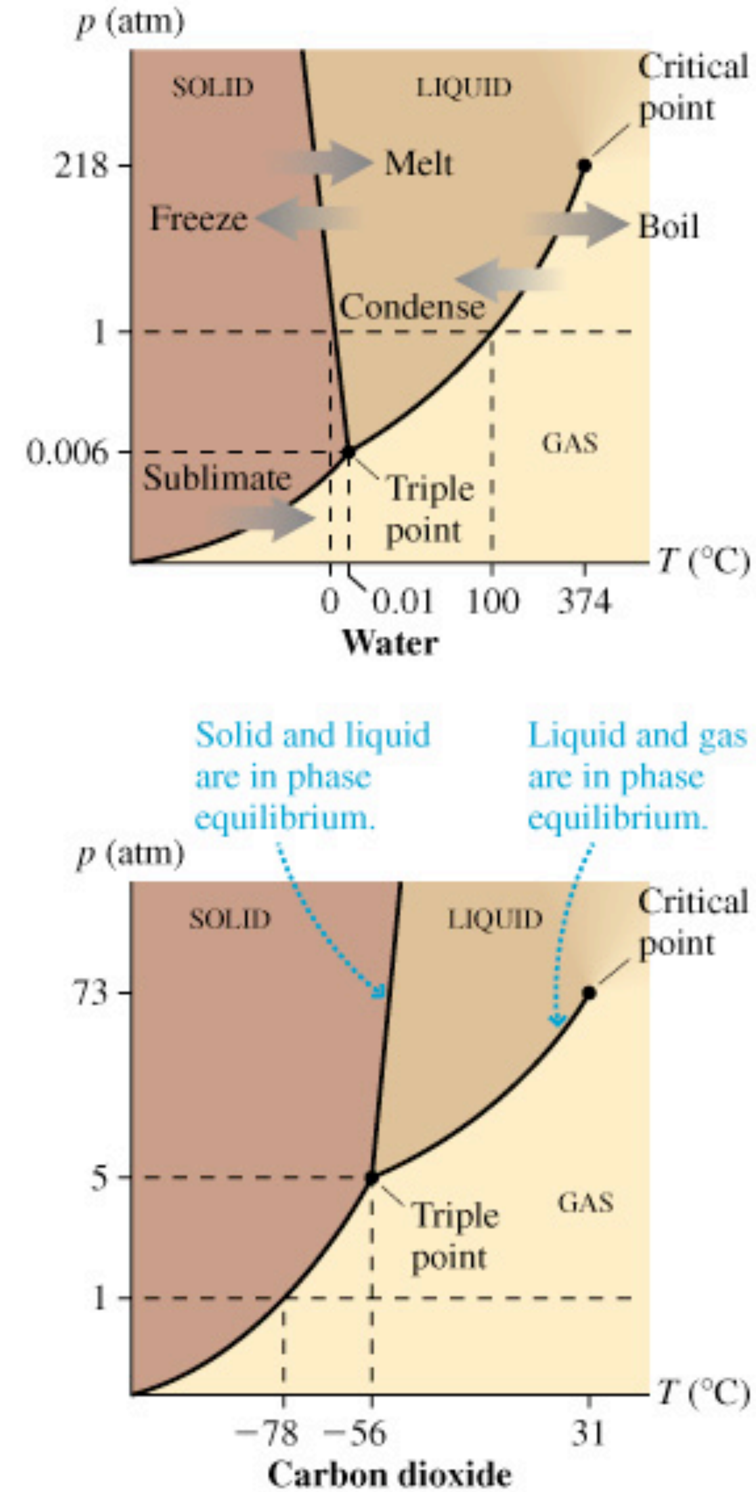
Phase Changes

- melting/freezing point: temperature at which solid becomes liquid...thermal energy large enough to allow molecules to move around
- phase equilibrium: 2 phases co-exist
- condensation/boiling point: phase equilibrium between liquid and gas thermal energy too large for bonding
- phase change temperatures are pressure-dependent: freezing (boiling) point higher (lower) at lower pressure



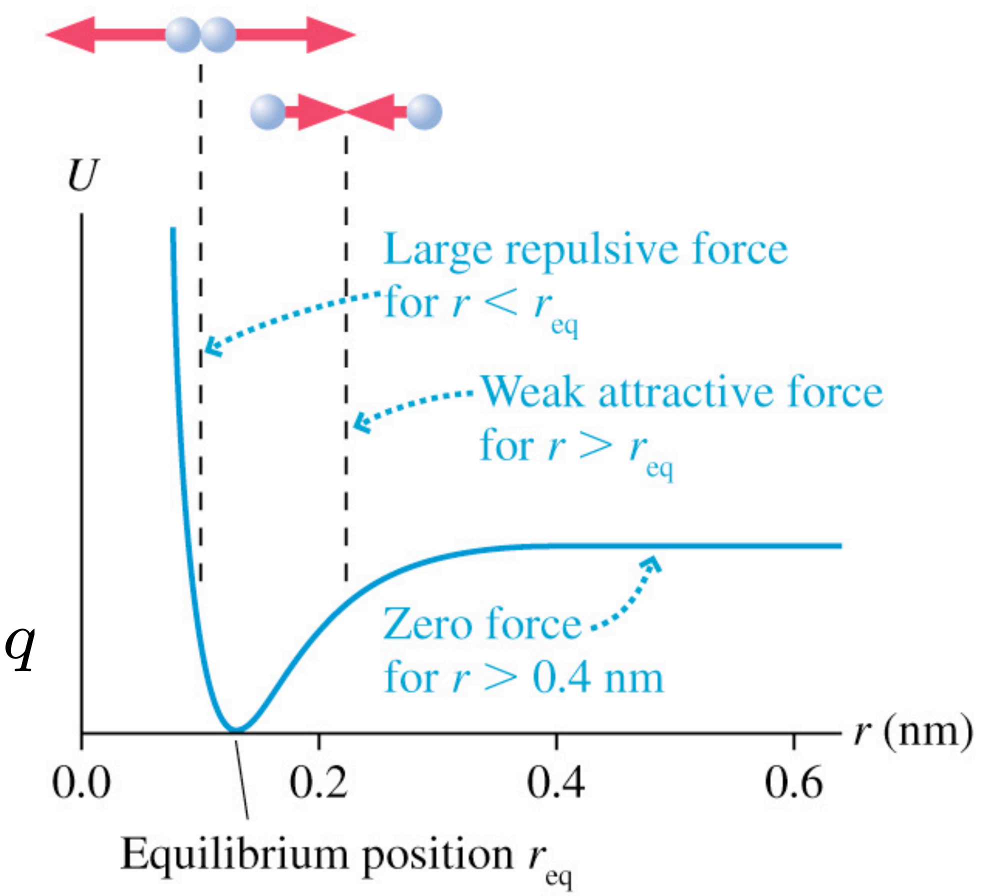
Phase diagram

- how phases and phase changes vary with T, p
- 3 regions with phase transitions at boundaries...gas-solid (sublimation)
- critical point: liquid-gas boundary ends
- triple point: all 3 phases co-exist
- triple point of water ($T_3 = 0.01^{\circ}C$) used as reference point (reproduced with no variation) for Kelvin scale: 273.16 K
  0 K fixed by gas properties
- cf. Celcius scale requires 2 reference points: boiling and melting points (p-dependent)



Ideal Gases

- (strong) repulsive forces between atoms (incompressibility of solids/liquids + (weak) attractive forces (tensile strength of solids; cohesion of liquid droplets)
- solids and liquids: atomic separation $\sim r_{eq}$



- gases: $\text{average } r \gg r_{eq} \longrightarrow$ freely moving till collide (steep wall for $r < r_{eq}$. important)
- Ideal gas model: hard non-interacting spheres, bounce on contact
- good for low density and $T \gg$ condensation point

(both mono and d-atomic gases)