Lecture 15, Oct 13, 2022

Phase Change in Constant Pressure Systems

- Consider a system with a liquid with temperature T and volume V; heat the system under constant pressure
  - Eventually we will reach T_{sat}, and the system has a combination of a vapour and liquid
  - Eventually all the liquid changes into vapour, and the vapour expands as an ideal gas
  - A plot of T against v will show an increasing line up to T_{sat}, then the temperature stays constant, but volume increases substantially, until all the liquid changes into vapour and the temperature increases again
- v_f is the specific volume of the saturated liquid, v at T_{sat}; v_g is the specific volume of the saturated vapour, v when all the liquid changes into vapour
  - A higher pressure increases v_f but decreases v_g
  - If we keep increasing pressure, these will eventually meet; this is known as the *critical pressure*
  - At the critical pressure we no longer have a horizontal line in the middle but just an inflection point
- If we draw a line through all the v_f, v_g for various pressures, we get the *vapour dome*

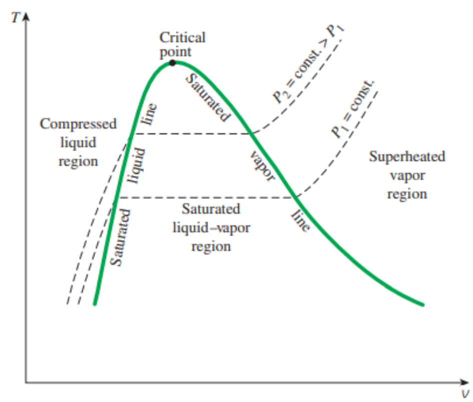

Figure 1: Vapour dome on a T-v diagram

- Where $T < T_{sat}$ we have a *subcooled liquid*; where $T > T_{sat}$ we have a *superheated vapour*
  - In the middle, the horizontal line where $T = T_{sat}$, we have the *saturated mixture*
- Since $v_f = v_g$ at the critical point, we can regard it as one phase, as a *supercritical fluid*
  - Visually we no longer see any boundaries

Phase Change in Constant Temperature Systems

- Consider a system with only vapour at constant temperature; if we compress this system, we will get some liquid forming, and then eventually only liquid
- On a P-v diagram:
- We need two independent intensive properties to define the state of a system
  - If we have a mixture, the temperature and pressure are not independent, they are related by the Clausius-Clapeyron Equation (e.g. if we have boiling water at 1atm, we immediately know the pressure)
  - Therefore we need one additional property to fix the state for mixtures
- Define a new property, the *quality* $x = \dfrac{m_g}{m}$ where m_g is the mass of the vapour and m is the mass of the mixture
  - $x = 0 \implies$ saturated liquid, $x = 1 \implies$ saturated vapour, $0 < x < 1$ is a saturated mixture

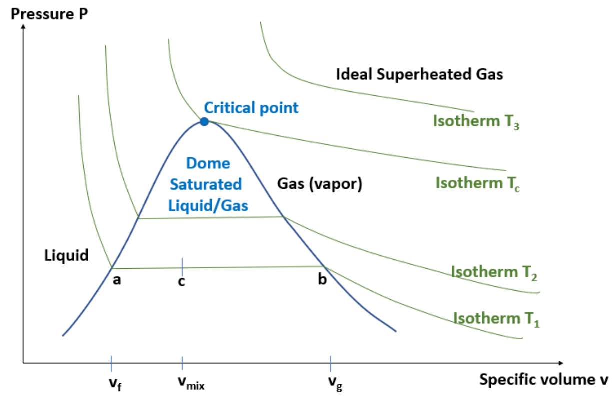

Figure 2: Phase change in a constant temperature system

- The quality can be used to determine the volume
- Suppose the volume of a mixture is $V = mv = m_g v_g + m_f v_f \implies v = \frac{m_g}{m} v_g + \frac{m_f}{m} v_f$
  - $v = xv_g + (1-x)v_f$
  - This works for any other property – $h = xh_g + (1-x)h_f = h_f + x(h_g - h_f) = h_f + xh_{fg}$ where h_{fg} is the latent heat of vaporization