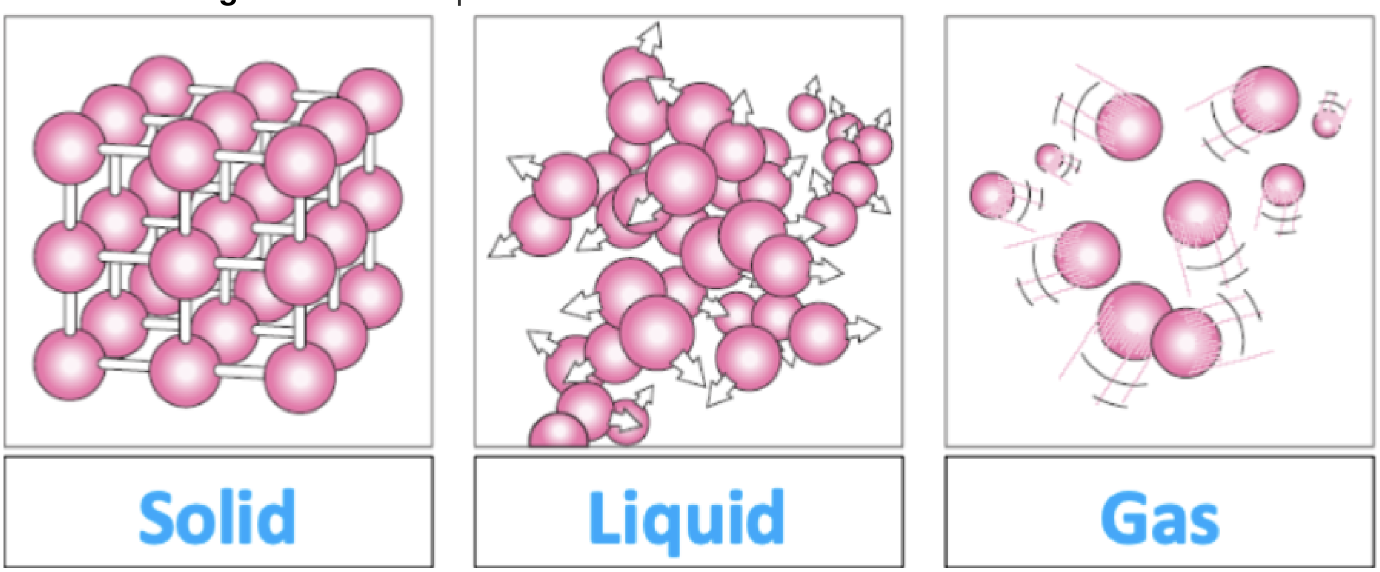
XII: Substances,Phase Changes and Ideal Gases

1: Substances

1.1: Pure Substance

- A pure substance has a fixed chemical composition.
- A homogeneous mixture qualifies

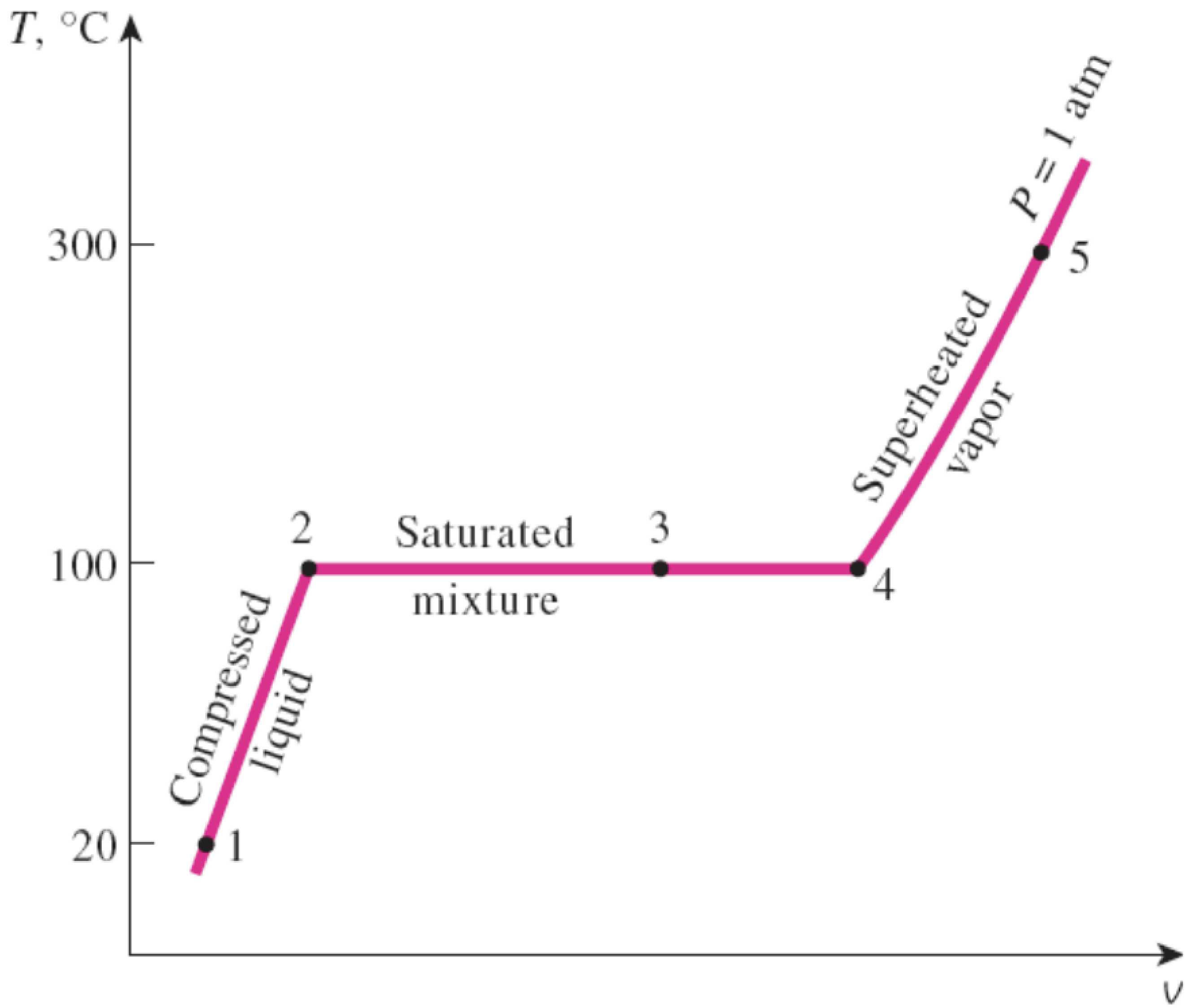
1.2: Phases of Pure Substance

- Possible to have different molecular structure in the same phase, such as **graphite or diamond**.
- Molecules in a **solid** are kept in place by strong intermolecular forces.
- Weaker intermolecular force in a **liquid**.
- Molecules in a **gas** are further apart and move about at radom.
- 

- Phase equilibrium:
  - A system involves two phases and when the mass of each phase reached an equilibrium level asn stays on.
- State postulate
  - The state postulate for a simple, pure substance states that the equilibrium state can be determined by specifying any two independent intensive properties.

2: Phases of Changes

2.1: Phase-Change Processes

- Example-Water:
  Compressed liquid $\Rightarrow$ **Saturated Liquid** (About to vaporise) $\Rightarrow$ **Saturated liquid-vapour mixture** $\Rightarrow$ **Saturated Vapour** $\Rightarrow$ **Superheated vapour**
- 

2.2: Saturation Temperature and Saturation Pressure

- The temperature at which change occurs depends on the pressure.
- Saturation temperature T_{sat}
  - Temperature at which a substance changes phase at a given pressure.
- Saturation pressure p_{sat}
  - Pressure at which a substance changes phase at given temperature.
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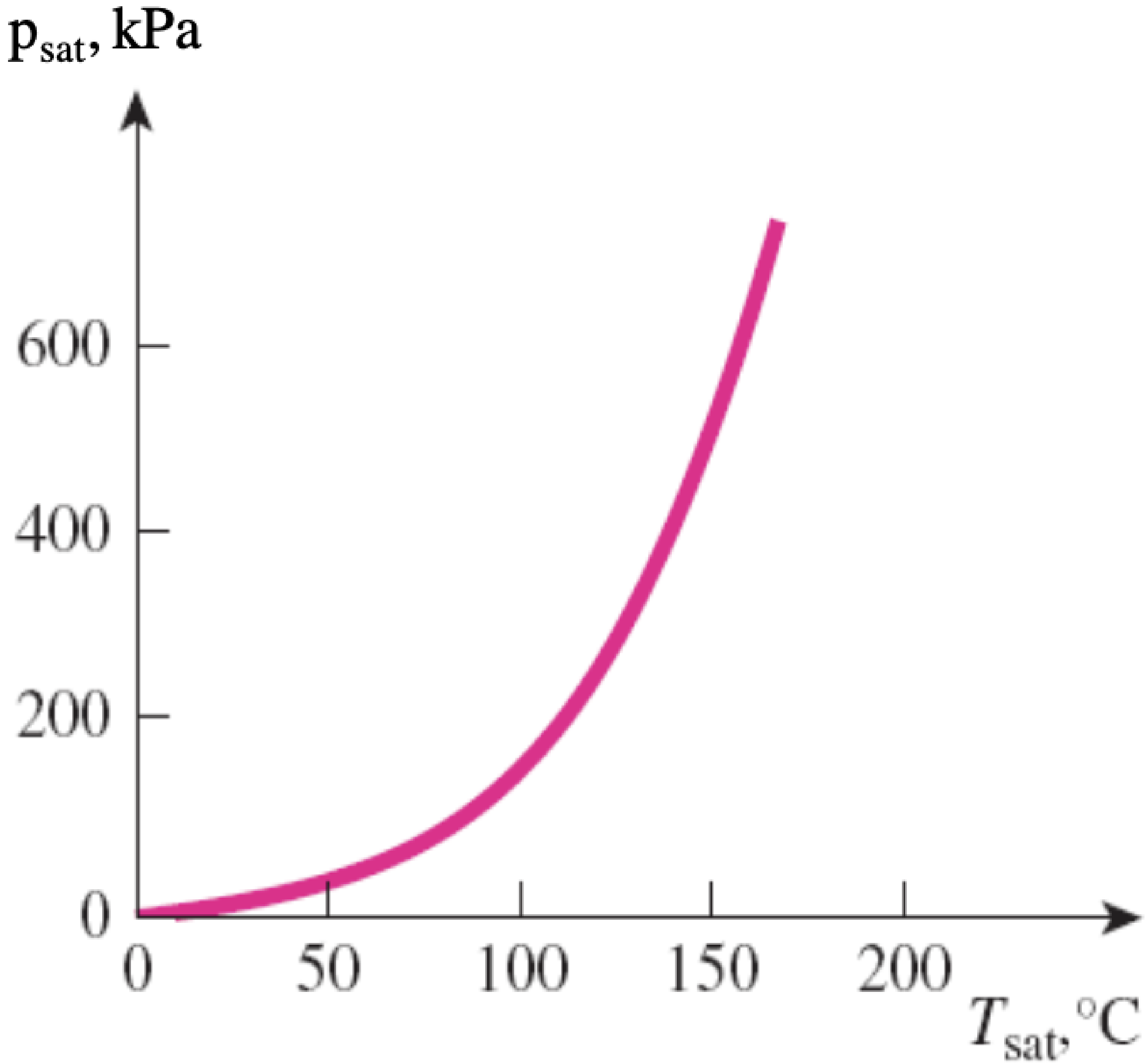
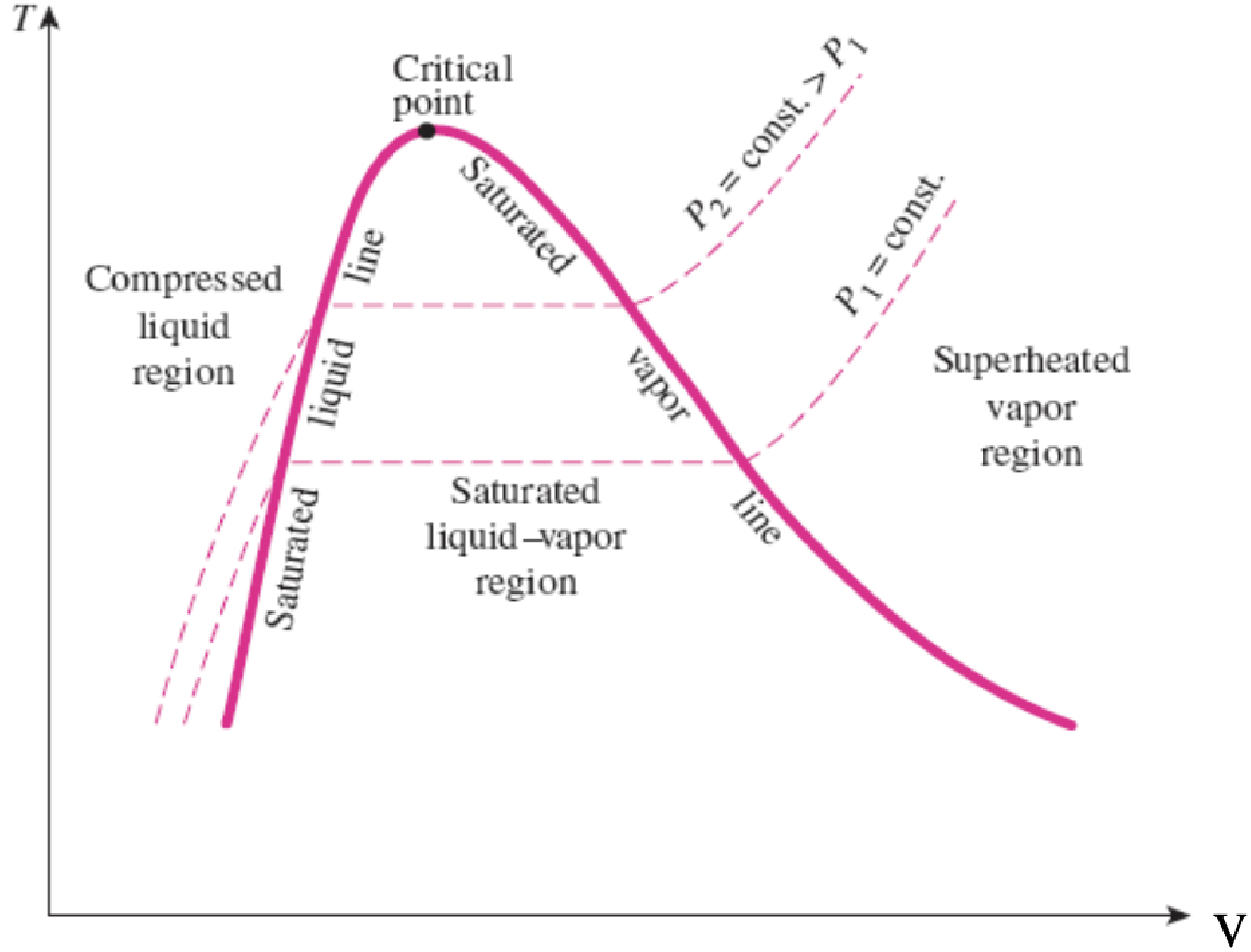


2.3: Latent and Sensible Heat

- **Latent heat**:
  - Energy absorbed or released during a phase-change process:
  - $Q = m\lambda$
  - λ is specific latent heat
- **Sensible heat**
  - Energy transferred in single phase resulting in temperature change.
  - $Q = mc\Delta T$
  - c is specific heat capacity.

2.4: Property diagrams fro phase-change processes

- T-v or P-v diagram could be helpful.
- 

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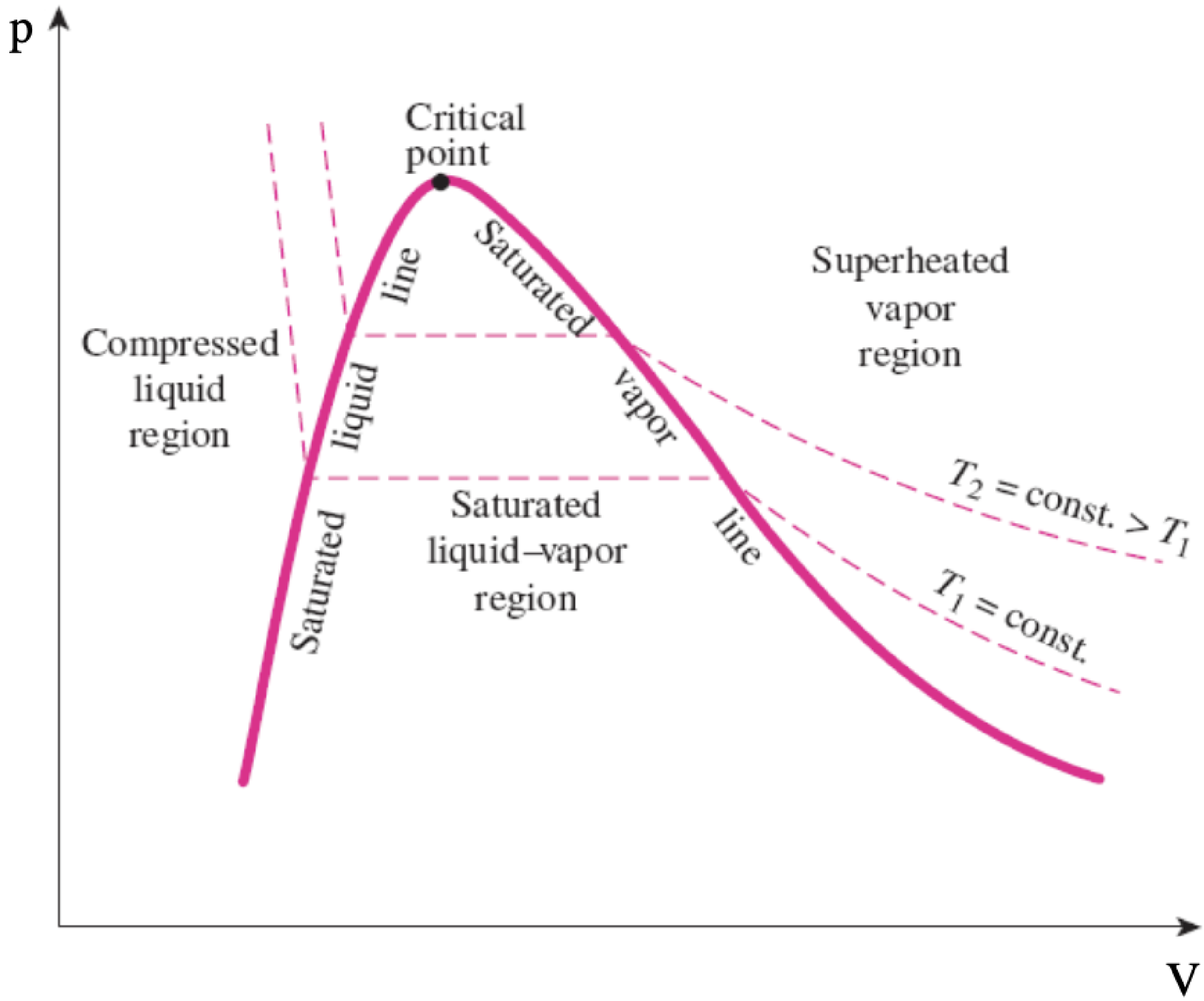

3: Ideal Gases

3.1: Equation of State

- An equation of state(EOS) is any equation that relates the pressure, temperature and volume of substance.
- The simplest EOS is the ideal-gas equation of state.
- Boyle's Law:
  - p $\propto v^{-1}$ at constant T
- Charles's Law:
  - v $\propto T$ at constant p.
- Gay-Lussac's Law:
  - p $\propto T$ at constant V.
- Avogadro's Law:
  - 1 mol all gases at same T and P occupy same volume.

- The volume of 1 mol of a gas is $V = 24.5 * 10^{-3}$ L
- Avogadro's constant: $n_A = 6.022 \times 10^{23}$ particles/mol
- Molar mass:$m = n\widetilde{m}$

- Ideal gas law:
  - $pV = nR_0T$
  - $R_0 = 8.314$kJ/kmol K (Universal gas constant)
  - $R = \frac{R_0}{\widetilde{m}}$, **Special gas constant**

3.2: Real gases: other equations of state

$$(p + \frac{a}{V^2})(V - b) = mRT$$

4: Mixtures of Ideal Gases

4.1: Mole and Mass Fraction

- There is a mixture of ideal gases with a number of components($i = i...n$)
- Mass m of mixture = sum of masses m_i of components: $m = \Sigma_i m_i$
- Amount of substance n of mixture = sum of n_i of components: $n = \Sigma_i n_i$
- Mass (gravimetric or ultimate) fraction Y_i and mole X_i fraction:
  - **mass fraction**: $Y_i = \frac{m_i}{m}$
  - **mole fraction**: $X_i = \frac{n_i}{n}$

4.2: Molar Mass

$$\widetilde{m_{mix}} = \frac{m}{n} = \frac{\Sigma_i m_i}{n} = \Sigma X_i \widetilde{m_i}$$

4.3: Specific Heat Capacity

- It is the sum of the **heat capacities** of the components:

$$m_{mix} c_{mix} = \Sigma_i m_i c_i$$

$$c_{mix} = \Sigma_i \frac{m_1}{m_{mix}} c_i$$

$$c_{mix} = \Sigma_i Y_i c_i$$

4.4: Partial Pressure

- Define partial pressure using mole fraction: $p_i = X_i p$
- Total pressure is the sum of partial pressures: $p = \Sigma p_i$
- This is known as **Dalton's Law** fro am ideal gas.

4.5: Partial Volume

- $V_i = X_i V$
- $V = \Sigma V_i$
- This is **Amagat's Law** for a ideal gas.