# MODELING OF MASS TRANSFER OPERATIONS

➡ **Two different methods for modeling the mass transfer operations**

| Based on **Diffusion Rate Processes** | Based on **Equilibrium Stages** |
| --- | --- |

➡ **The choice depends on the kind of EQUIPMENT for the *Operation***

**Examples:**

➡ **Diffusion Rate Process Approach → *Packed Towers, etc.***

➡ **Equilibrium Stages Approach → *Plate Towers, mixer-settler trains etc.***

# EQUILIBRIUM STAGES OPERATION

- ***Equilibrium stage operations*** **are based on principles of phase equilibrium.**
- **Two phases are mixed together. Some of the components will partition between the phases as the system tries to reach equilibrium.**
- **When the phases are separated, one is enriched with the solute and the other depleted.**
- **This combination of mixing, approach to equilibrium, and separation is called an *equilibrium stage*.**

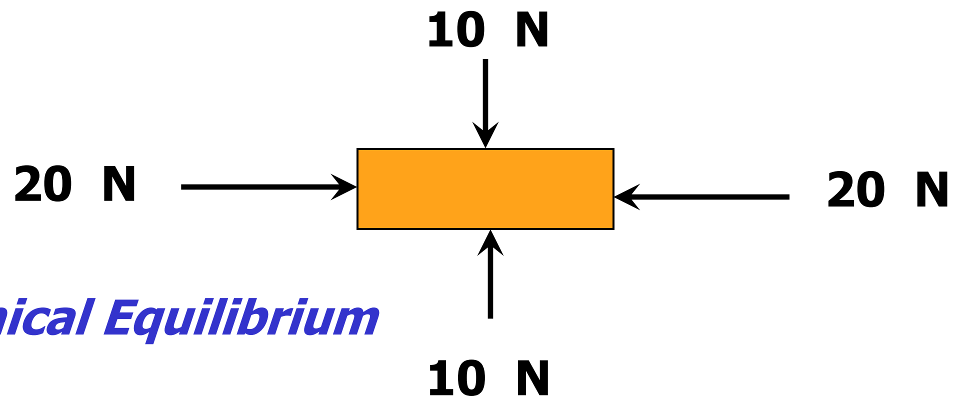
# PHASE EQUILIBRIA

## PHASE

- A ***PHASE*** is a homogeneous region of matter. e.g., a gas or a mixture of gases, a liquid or a liquid solution, a solid crystal
- A phase need not be continuous; e.g., a gas dispersed as bubbles in a liquid, a liquid dispersed as droplets in another liquid with which it is immiscible, etc.
- An abrupt change in properties always occurs at the boundary b/w phases.
- Various phases can coexist. e.g., boiling saturated solution of a salt in water with excess salt crystals.

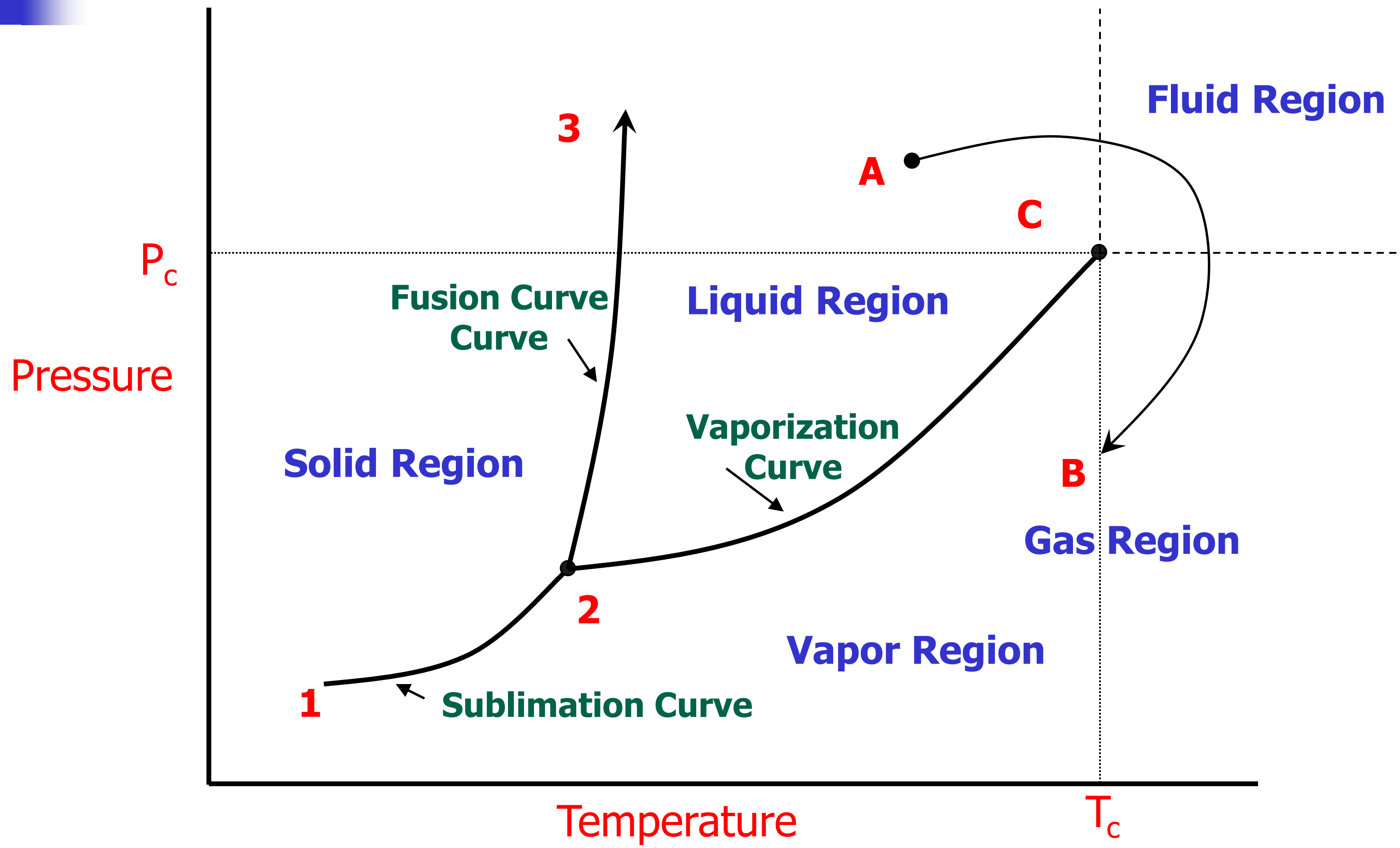
# PHASE EQUILIBRIA

- **EQUILIBRIUM:**
  - **Equilibrium is a word denoting a static condition, the absence of change**
- **SYSTEM AT EQUILIBRIUM:**
  - **A system which exists under such conditions that there is no tendency for a change in state to occur.**




*Mechanical Equilibrium*

# PHASE EQUILIBRIA




*Think where is VOLUME axes?*

# PHASE EQUILIBRIA

## IMPORTANCE OF PHASE EQUILIBRIA

- A limit to mass transfer is reached if the two phases come to equilibrium and the net transfer of material ceases.

Rate of mass transfer (at any point) $\propto$ Driving Force (at that point)

- To evaluate driving forces, a knowledge of equilibria b/w phases is therefore of basic importance.
- Several kinds of equilibria are important in mass transfer.
- In nearly all situations two phases are involved, and all combinations are found except two solid phases.
- In phases in bulk the controlling variables are the intensive properties of *temperature, pressure,* and *concentrations*.

# CLASSIFICATION OF EQUILIBRIA

- To *classify equilibria* and to establish the *number of independent variables* or *degrees of freedom* available in a specific situation, the **PHASE RULE** is useful.

**PHASE RULE**

$$F = C - P + 2$$

Where,

| | | |
|---|---|---|
| F | = | Number of degrees of freedom |
| C | = | Number of components |
| P | = | Number of phases |

**Number of degrees of freedom, or variance F**, is the number of independent intensive variables → temperature, pressure and concentrations – that must be fixed to define the equilibrium state of the system.

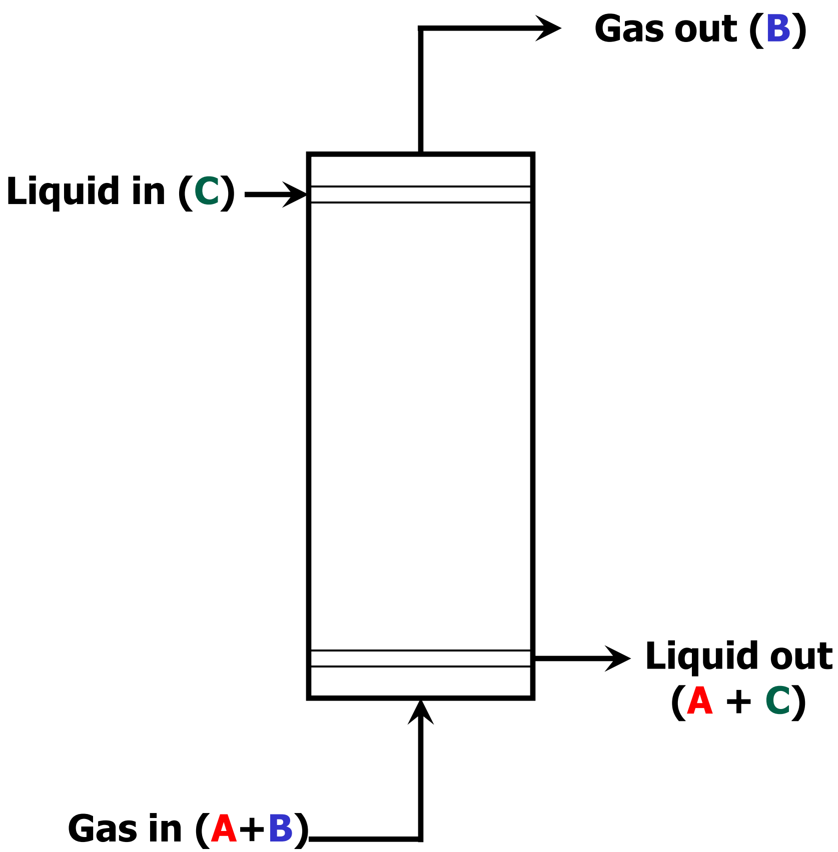
# CLASSIFICATION OF EQUILIBRIA

- Usual Case, Only two phases → F = C
  - In system of two components → F = 2.
    - If Pressure is fixed, only one variable – the liquid-phase concentration, for example be changed independently;
    - The temperature and gas-phase concentration must follow.
- for such systems equilibrium data are presented in temp-composition diagrams which apply at constant pressure, or by plotting $y_c$ the V-phase concentration, against $x_c$ the L-phase composition.
- Such plots are called *equilibrium curves*
- If there are more than two components, the equilibrium relationship cannot be represented by a single curve.

# APPLICATION OF PHASE RULE IN MASS TRANSFER OPERATIONS

## GAS ABSORPTION

- Number of phases = 2 (liquid & gas)
- Number of total components = 3(A, B, C)
- Apply phase rule, F = C – P + 2, so we get F = 3
- The component which is being transferred from one phase to another: A
- Total number of variables: Temperature, Pressure, concentration of A in liquid phase & gas phase.
- The independent variables: Temperature, Pressure, Either concentration of A.
- Equilibrium curve can be drawn b/w $y_c$ and $X_c$.

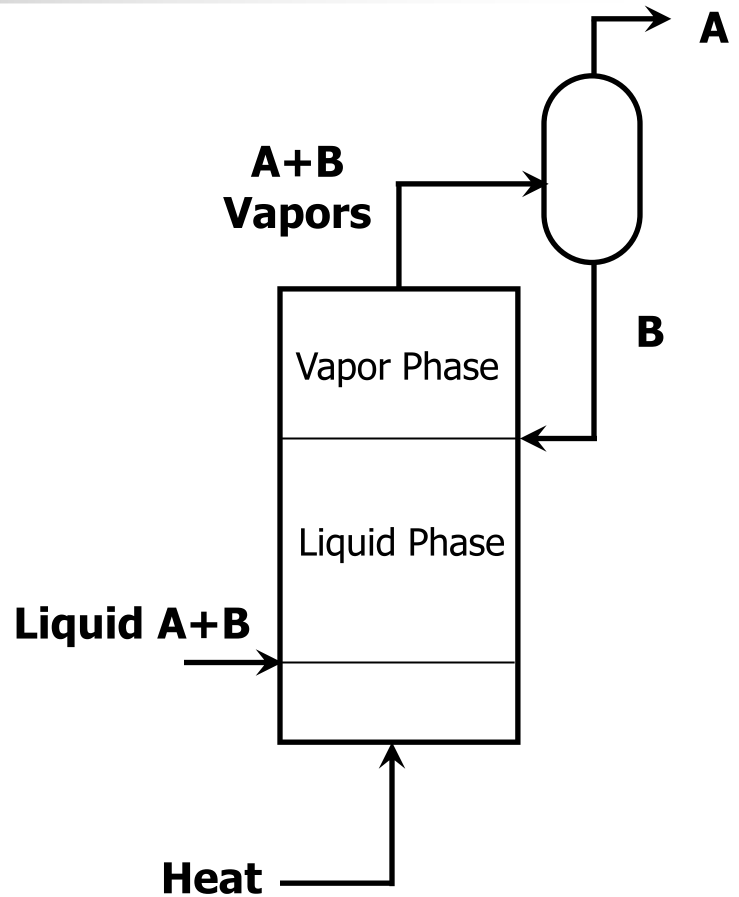



Gas Absorption Column

# APPLICATION OF PHASE RULE IN MASS TRANSFER OPERATIONS

## DISTILLATION

- **Number of phases = 2 (liquid & vapor)**
- **Number of total components = 2(A, B)**
- **Apply phase rule, $F = C - P + 2$, so we get $F = 2$**
- **The component which is being transferred from one phase to another: A**
- **Total number of variables: Temperature, Pressure, mole fraction of A in liquid phase & vapor phase.**
- **The independent variables: Pressure, liquid-phase mole fraction of A. (remaining variables follows).**
- **Fixing the two variables define the system.**
- **(Explanation of 3 components system).**



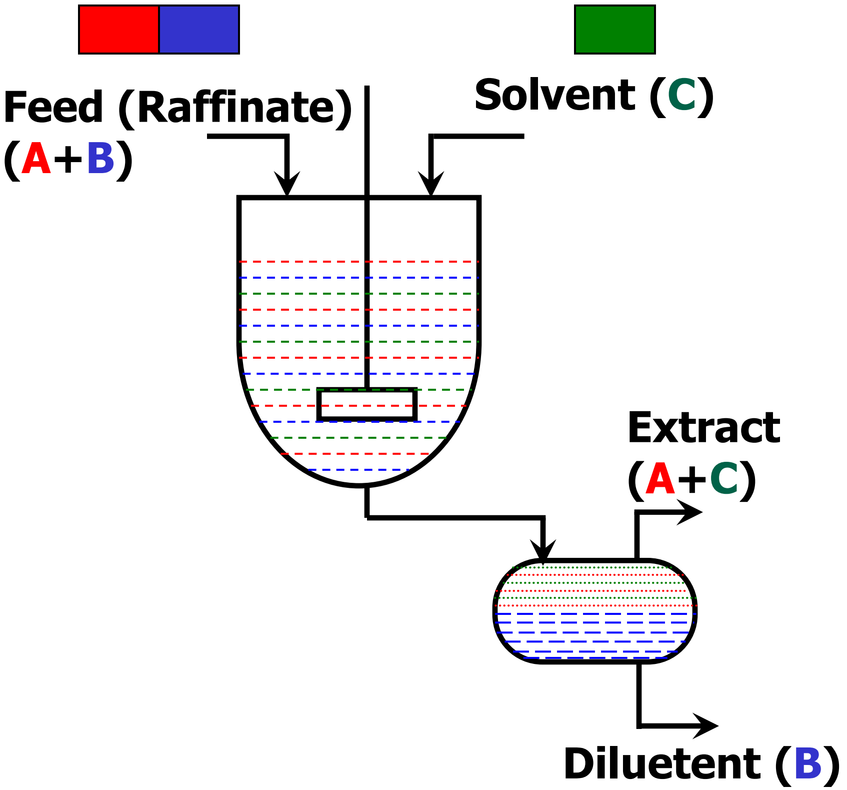
Distillation Column

# APPLICATION OF PHASE RULE IN MASS TRANSFER OPERATIONS

## LIQUID EXTRACTION

- **Number of phases = 2**

  **(2 immiscible liquids)**
- **Number of total components = 3 (A, B,C)**
- **Apply phase rule, F = C – P + 2, so we get F = 3**
- **The component which is being transferred from one phase to another: A**
- **All three components may appear in both phases.**
- **Total number of variables: Temperature, Pressure, and four concentrations.**
- **The independent variables: Any two concentrations (usually pressure is kept constant).**
- **Variations of temperature are there by keeping pressure constant.**




Mixer-settler extraction