

PHASE RULE

- **Phase:** Homogeneous physically distinct state (solid, liquid, gas).
- **Degree of Freedom (F):** Number of variables (T, P, composition) that can be changed independently without changing the number of phases.
- **Component (C):** Minimum number of chemical constituents to describe the system.
- **Gibbs Phase Rule:**

$$F = C - P + 2,$$

Where P = number of phases.

One Component System (C=1)

Water System (H₂O)

- Phases: Ice (solid), liquid water, and vapor (gas).
- Triple Point: The unique combination of temperature and pressure at which all three phases coexist in equilibrium.
- Phase Diagram: Shows melting, boiling, sublimation, and the critical point (beyond which liquid and vapor phases become indistinguishable)

Two Component System (C=2)

- Reduced Phase Rule: $F = C - P + 1$ (for fixed pressure/temperature).
- **Eutectic Temperature:** Lowest temperature at which a mixture of components can coexist in liquid phase.
- **Lead & Silver System:** Forms eutectic; Pb & Ag solidify together at eutectic composition.
- **Congruent Melting Point:** Melts without decomposition (e.g., Mg- Zn system).
- **Incongruent Melting Point:** Decomposes on melting (e.g., NaCl-H₂O system).
- For a system of two partially miscible liquids, **the critical solution temperature (CST)** is the temperature at which the liquids become completely miscible and form a single phase.
- At room temperature, **phenol and water** are only partially miscible, forming two layers. As the temperature rises, their mutual solubility increases until they become a single, homogeneous liquid phase at the UCST of about 66°C.

Henry's Law

- Solubility of gas in liquid is proportional to pressure:

$$C = k_H P$$

Raoult's Law

- Partial vapor pressure of a component in solution:

$$P_i = X_i P_i^0$$

- Ideal solutions; used in distillation.

Nernst Distribution Law

- Ratio of solute concentrations in two immiscible solvents at equilibrium:

$$\{[\text{solute}]_{\text{organic}}\} / \{[\text{solute}]_{\text{aqueous}}\} = K$$

Applications

- Solvent Extraction: Separation based on solubility differences.
- Steam Distillation: Separate volatile liquids from non-volatile (e.g., essential oils).
- Fractional Crystallization: Purify solids by selective crystallization.
- Parke's Process: Purification of silver from lead using molten zinc

COLLOIDS AND SURFACES

- Colloids:** Dispersed phase (1–500 nm) in a medium.
- Stability:** Prevent aggregation by electrostatic or steric stabilization.
- Gold Number:** Minimum mg of stabilizer to prevent coagulation of 10 mL gold sol.
- Smaller Gold number → more effective stabilizer
- Adsorption Types:**
 - Physical (physisorption): Weak, reversible, low heat.
 - Chemical (chemisorption): Strong, often irreversible.
- Adsorption Isotherms:**
 - Freundlich: $x/m = kP^{1/n}$ (heterogeneous surface), Multilayer adsorption
 - Langmuir: Monolayer adsorption, homogeneous
 $\theta = bP/(1+bP)$
- Surface Area:** Calculated using adsorption data.
- Heterogeneous Catalysis:** Reaction occurs on solid surface (e.g., Haber process, hydrogenation).