

Lecture 28: Vapor Pressure, Colligative Properties

Vapor Pressure, Freezing Point Depression, Boiling Point Elevation

Solution Chemistry Recap

- **How much solid dissolves or precipitates?**
ICE Tables since both change stoichiometrically
- **Do I get a precipitate?**
Compare Q to K
- **What concentration to get a precipitate?**
Use K directly, changing ion concentrations separately, no ICE coeffs
- **Dissolving a gas in solution?**
Use Henry's Law

Example: Comparing k_H

Circle the system with the larger k_H , or indicate they are equal

- $\text{CO}_2(\text{g})$ in soda: 25°C vs 30°C
- $\text{O}_2(\text{g})$ in hexane: 1 atm vs 2 atm at 25°C
- $\text{N}_2(\text{g})$ vs $\text{CO}(\text{g})$ in water at 50°C , 1 atm

Colligative Properties

Properties that depend how much solute is dissolved in the solvent

- Vapor pressure lowering:

$$P = x_{\text{solvent}} \cdot P_{\text{pure}}$$

- Freezing point depression: $\Delta T_f = i k_f m$
- Boiling point elevation: $\Delta T_b = i k_b m$
- Osmotic pressure: $\Pi = i R T c$

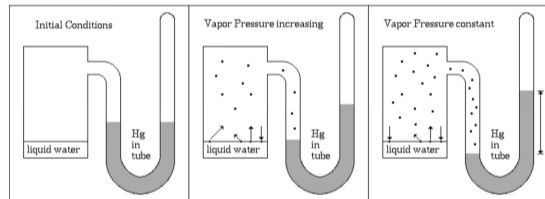
Vapor Pressure

Vapor Pressure

The partial pressure exerted by the vapor when the vapor and its liquid are in dynamic equilibrium is its vapor pressure.



Boiling point: vapor pressure = external pressure



Vapor Pressure, IMFs, Boiling Point



- Vapor pressure (K) increases with **decreasing intermolecular forces**
- Weaker IMFs \implies more vapor molecules \implies higher vapor pressure
- Lower boiling point \implies weaker IMFs \implies higher vapor pressure

Vapor Pressure and Temperature

Clausius–Clapeyron Equation

Finding P at a new temperature

$$\ln \left(\frac{P_2}{P_1} \right) = -\frac{\Delta H_{\text{vap}}}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

van't Hoff Equation



$$\ln \left(\frac{K_2}{K_1} \right) = -\frac{\Delta H_{\text{rxn}}^{\circ}}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

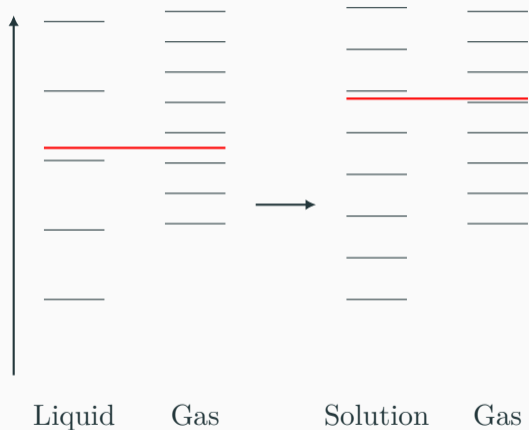
Freezing Point Depression



- Dissolving a solute increases entropy
- Less thermal energy required to reach point where equal number of microstates in solid vs in solution
- Freezing point decreases

$$\Delta T_f = ik_f m$$

Boiling Point Elevation / Vapor Pressure Lowering



- Dissolving a solute increases entropy
- More thermal energy required to reach point where equal number of microstates in gas vs in solution
- Boiling point increases

$$\Delta T_b = ik_b m$$

Example: Change in Freezing and Boiling Point

Find the freezing point and boiling point of a 4.03 *m* sucrose(aq) solution. $i = 1$

$$k_f = 1.86 \frac{^{\circ}\text{C} \cdot \text{kg}}{\text{mol}} \quad k_b = 0.51 \frac{^{\circ}\text{C} \cdot \text{kg}}{\text{mol}}$$

Freezing point depression

$$\begin{aligned}\Delta T_f &= i \cdot k_f \cdot m \\ &= 1 \left(1.86 \frac{^{\circ}\text{C} \cdot \text{kg}}{\text{mol}} \right) \left(4.03 \frac{\text{mol}}{\text{kg}} \right) \\ &= 7.49 ^{\circ}\text{C} \\ T_f &= 0 ^{\circ}\text{C} - 7.49 ^{\circ}\text{C} \\ &= -7.49 ^{\circ}\text{C}\end{aligned}$$

Boiling point elevation

$$\begin{aligned}\Delta T_b &= i \cdot k_b \cdot m \\ &= 1 \left(0.51 \frac{^{\circ}\text{C} \cdot \text{kg}}{\text{mol}} \right) \left(4.03 \frac{\text{mol}}{\text{kg}} \right) \\ &= 2.05 ^{\circ}\text{C} \\ T_b &= 100 ^{\circ}\text{C} + 2.05 ^{\circ}\text{C} \\ &= 102.05 ^{\circ}\text{C}\end{aligned}$$