Lecture 27: More Solutions

Henry's Law, Solution Accounting, Phase Diagrams

Solution Accounting

Solution Accounting Definitions

Quantity	Definition
Mole fraction	$\chi_n = \frac{\text{mol n}}{\text{mol total}}$
Molality	$m = \frac{\text{mol solute}}{\text{kg solvent}}$
Molarity	$M = \frac{\text{mol solute}}{\text{L solution}}$
Mass percent	$\%\text{ by mass} = \frac{\text{mass solute}}{\text{total mass}} \times 100\%$

Example: Solution Accounting

An aqueous solution of H_2O_2 is 30.0% by mass and has a density of $1.11\,\frac{\text{g}}{\text{mL}}$. Calculate its molarity, molality, and mole fraction of H_2O_2.

Key idea: Ratios, so can assume $\boxed{1000\,\text{mL solution}}$

$$1.11\,\frac{\text{g}}{\text{mL}} \times 1000\,\text{mL} = \boxed{1110\,\text{g solution}}$$

$$\frac{x\,\text{g}}{1110\,\text{g}} \times 100\% = 30\% \implies x = \boxed{333\,\text{g } H_2O_2}$$

$$333\,\text{g } H_2O_2 \times \frac{1\,\text{mol}}{34\,\text{g}} = \boxed{9.79\,\text{mol } H_2O_2}$$

$$1110\,\text{g solution} - 333\,\text{g } H_2O_2 = \boxed{777\,\text{g } H_2O}$$

$$777\,\text{g } H_2O \times \frac{1\,\text{mol}}{18\,\text{g}} = \boxed{43.17\,\text{mol } H_2O}$$

Example: Solution Accounting

$$n_{\mathrm{H_2O_2}} = 9.79\,\mathrm{mol} \quad n_{\mathrm{H_2O}} = 43.17\,\mathrm{mol} \quad \text{kg solution} = 0.777\,\mathrm{kg} \quad \text{L solution} = 1.000\,\mathrm{L}$$

$$\chi_{\mathrm{H_2O_2}} = \frac{n_{\mathrm{H_2O_2}}}{n_{\mathrm{total}}} = \frac{9.79\,\mathrm{mol}}{9.79\,\mathrm{mol} + 43.17\,\mathrm{mol}} = \boxed{0.185}$$

$$m = \frac{n_{\mathrm{H_2O_2}}}{\text{kg solvent}} = \frac{9.79\,\mathrm{mol}}{0.777\,\mathrm{kg}} = \boxed{12.6\,\frac{\mathrm{mol}}{\mathrm{kg}}\,\mathrm{H_2O_2}}$$

$$M = \frac{n_{\mathrm{H_2O_2}}}{\text{L solution}} = \frac{9.79\,\mathrm{mol}}{1.000\,\mathrm{L}} = \boxed{9.79\,\frac{\mathrm{mol}}{\mathrm{L}}\,\mathrm{H_2O_2}}$$

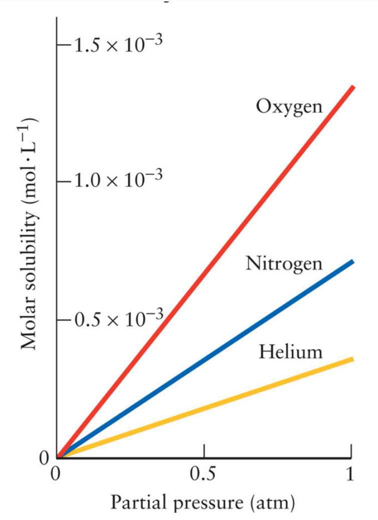
Henry's Law

Henry's Law

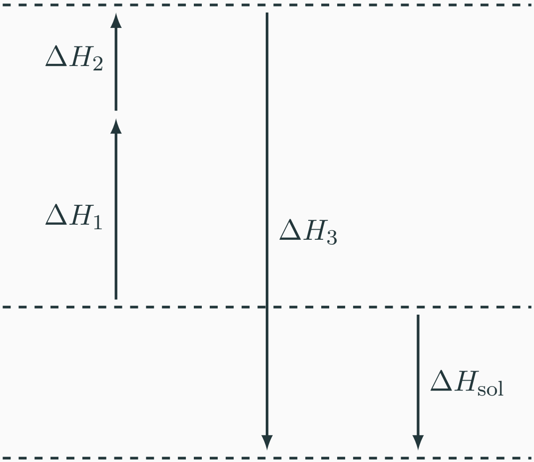
Solubility of a gas in solution is proportional to partial pressure

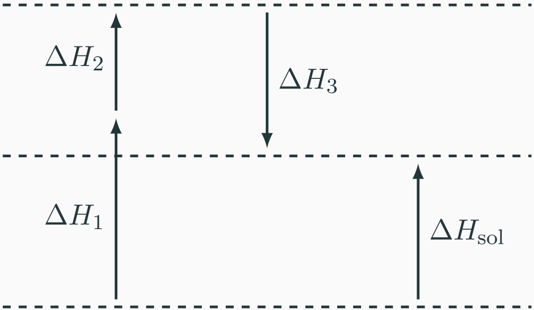
$$s = k_H \cdot P$$

k_H: Henry's Law constant, T dependent



Sign of ΔH_{sol}





ΔH_1: break solute IMF
ΔH_2: break solvent IMF
ΔH_3: form solute–solvent IMFs

$\Delta H_{\text{sol}}^{(\text{solid})}$ can be posistive or negative, but $\Delta H_{\text{sol}}^{(\text{gas})} < 0$

Example: Henry's Law

Water is added to an empty 1.0 L container. $H_2S\,(g)$ is then added. When equilibrium is reached at 298 K, the pressure of $H_2S\,(g)$ reads 0.85 bar and there is 250 mL of solution. How many moles of H_2S are in each of the gas and aqueous phases? $k_H\,(\mathrm{H_2S},\ 298\,\mathrm{K}) = 0.10\,\frac{\mathrm{mol}}{\mathrm{L\cdot bar}}$

Aqueous phase mols

$$\begin{aligned} s &= k_H P \\ s &= \left(0.10\,\frac{\mathrm{mol}}{\mathrm{L\cdot bar}}\right)(0.85\,\mathrm{bar}) \\ &= 0.085\,\frac{\mathrm{mol}}{\mathrm{L}} \\ n_{\mathrm{H_2S\,(aq)}} &= 0.085\,\frac{\mathrm{mol}}{\mathrm{L}}\cdot 0.250\,\mathrm{L} \\ &= \boxed{0.021\,25\,\mathrm{mol}} \end{aligned}$$

Gas phase mols

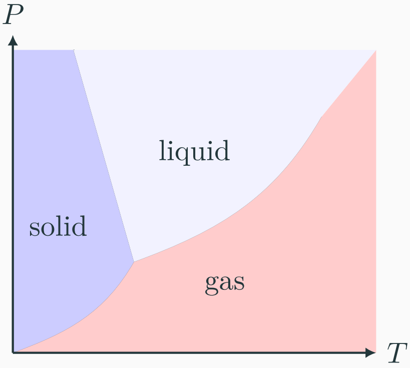
$$\begin{aligned} n_{\mathrm{H_2S\,(g)}} &= \frac{PV}{RT} \\ &= \frac{(0.85\,\mathrm{bar})(0.75\,\mathrm{L})}{(0.083\,14\,\frac{\mathrm{L\cdot bar}}{\mathrm{mol\cdot K}})(298\,\mathrm{K})} \\ &= \boxed{0.0257\,\mathrm{mol}} \end{aligned}$$

Effect of Pressure on Boiling Point

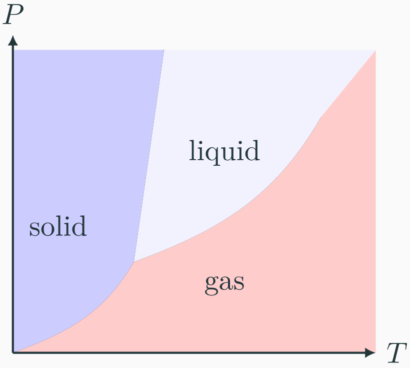
$$\text{liquid} \rightleftharpoons \text{gas}$$

Higher external pressure favors liquid, more heat required, higher T_b

Water phase diagram



Most things phase diagram



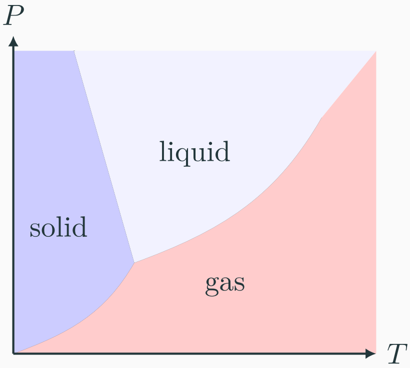
Effect of Pressure on Melting Point

$$\text{solid} \rightleftharpoons \text{liquid}$$

Higher external pressure favors denser phase

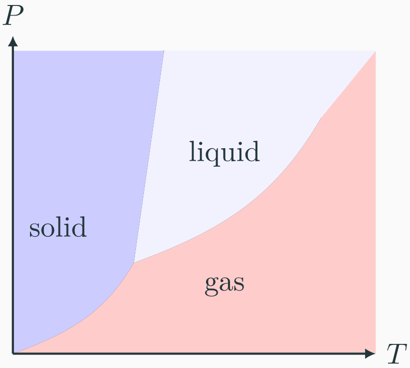
Density liquid > Density solid

$\uparrow P \implies \downarrow T_m$



Density solid > Density liquid

$\uparrow P \implies \uparrow T_m$



Exam Details

Exam 3: Lecture 19 – 27 (Up through solutions)

Lecture 28: Colligative

Activity 28: Applications of solutions, Colligative

Exam 4: Cumulative, emph on Lecture 29 – 37 (Colligative, Kinetics, Mechanisms)