Concentration units

Mole fraction **Molarity** **Molality**

Percentage by mass

Parts per Million and
Parts per Billion

Concentration

Mole fraction (X_n)

Moles of substance / total moles of all materials

moles of solute

Mole fraction

$$X_A = \frac{n_A}{n_A + n_B + n_C \ldots}$$

total moles

Example

Calculate the mole fractions of benzene (X_B) and of toluene (X_T) in mixture of 0.884 mol of benzene and 1.657 mol of toluene.

$$X_B = \frac{n_B}{n_B + n_T} = \frac{0.884\ \text{mol}}{0.884\ \text{mol} + 1.657\ \text{mol}} = 0.348$$

$$X_T = \frac{n_T}{n_B + n_T} = \frac{1.657\ \text{mol}}{0.884\ \text{mol} + 1.657\ \text{mol}} = 0.652$$

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Concentration

Molarity (M)

moles of solute /1L of solution

What is the molarity of a solution made up by dissolving 9.52g of NaCl in enough H_2O to form 575 mL of solution?

M = n/L

$$9.52\text{g NaCl} \times \frac{1\text{ mol}}{58.4\text{g NaCl}} \times \frac{1}{575\text{ mL}} \times \frac{10^3\text{ mL}}{1\text{ L}}$$

$$= 0.284\text{ mol/L}$$

Important point about concentration

Given: Na_2SO_4 concentration = 0.683 M

What is the concentration of Na^+

What is the concentration of SO_4^{2-} ?

Na^+ = 2 x 0.683 M = 1.37 M

SO_4^{2-} = 0.683 M

Concentration

Molality (m)

Moles of solute /kg solvent

Determine the molality of a solution made by adding 0.345 mol of C_2H_5OH to 168 g of H_2O

$$m = n_{sol} / (\text{kg solv})$$

$$m = \frac{0.345 \text{ mol } C_2H_5OH}{168 \text{ g } H_2O} \times \frac{10^3 \text{ g}}{1 \text{ kg}}$$

$$= 2.05 \text{ mol / kg}$$

Concentration

Percentage by mass

$$\text{Mass \%} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100\ \%$$

Determine the percentage by mass of 1.4g cane sugar in 50.0g of sugar syrup (sugar + water).

$$\text{Mass \% (sugar)} = \frac{1.4\ \text{g sugar}}{50.0\ \text{g (sugar + water)}} \times 100\ \%$$

$$= 2.8\ \%$$

Parts per Million and Parts per Billion

Parts per million (ppm)

$$\text{ppm} = \frac{\text{mass of } A \text{ in solution}}{\text{total mass of solution}} \times 10^6$$

Parts per billion (ppb)

$$\text{ppb} = \frac{\text{mass of } A \text{ in solution}}{\text{total mass of solution}} \times 10^9$$

Dilution of solutions

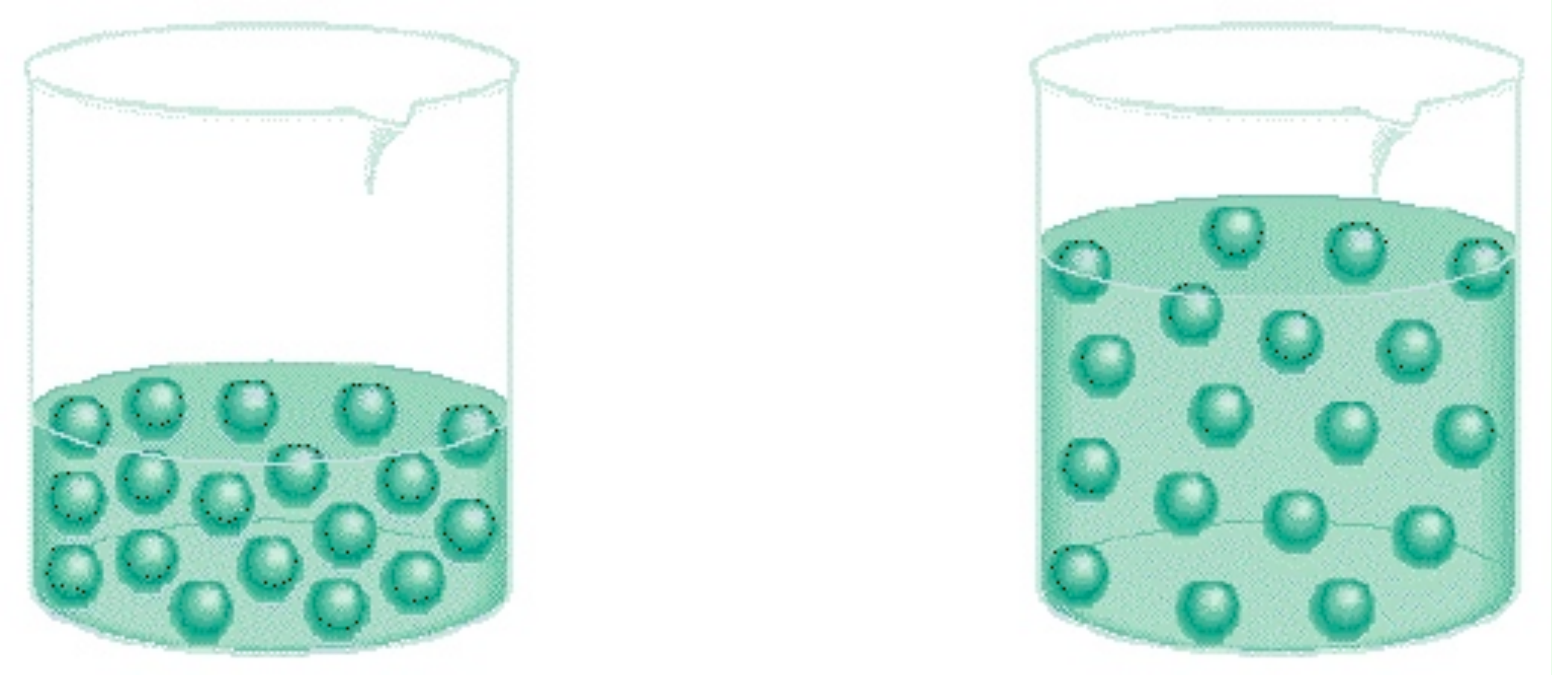
Dilution of solutions

Preparation of a less concentrated solution from a more concentrated one

$$M_{initial} \times V_{initial} = M_{final} \times V_{final}$$

$$\frac{mol_{(solute)}}{\cancel{L}} \times \cancel{L} = \frac{mol_{(solute)}}{\cancel{L}} \times \cancel{L}$$

$$\text{Moles of solute}_{initial} = \text{Moles of solute}_{final}$$



The dilution of a more concentrated solution to a less concentrated one does not change the number of moles of solute

Dilution of solutions

How much concentrated HCl (12.5 M) is required in order to prepare 1 L of a 1 M solution?

$$M_{initial} \times V_{initial} = M_{final} \times V_{final}$$

$$(12.5 \text{ mole / L})\, V_{initial} = (1 \text{ mol / L})(1 \text{ L})$$

$$V_{initial} = \frac{(1 \text{ mol / L})(1 \text{ L})}{12.5 \text{ mole / L}}$$

$$V_{initial} = 0.080 \text{ L} = 80 \text{ ml}$$

Effects of Temperature on Solubility

Effect of temperature

Gas in water

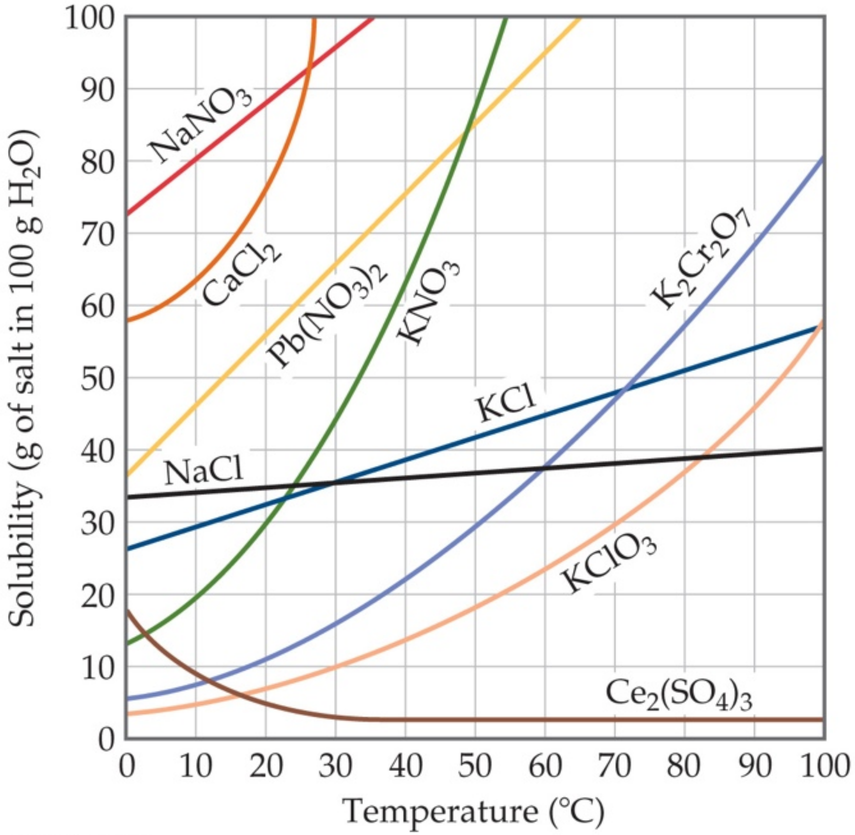
gases are almost always less soluble at higher temperatures than at lower temperatures

Solid in water

varies with substance

generally the solubility of solid solutes in liquid solvents increases with increasing temperature

Temperature



Effect of temperature

The variation in solubility has <u>some correlation</u> with enthalpy of solution (ΔH_{soln})

If ΔH_{soln} is positive, the solubility increases with increases in temperature.

If ΔH_{soln} is negative, the solubility decreases with increases in temperature.

Effects of Pressure on Solubility of Gases

Effect of pressure

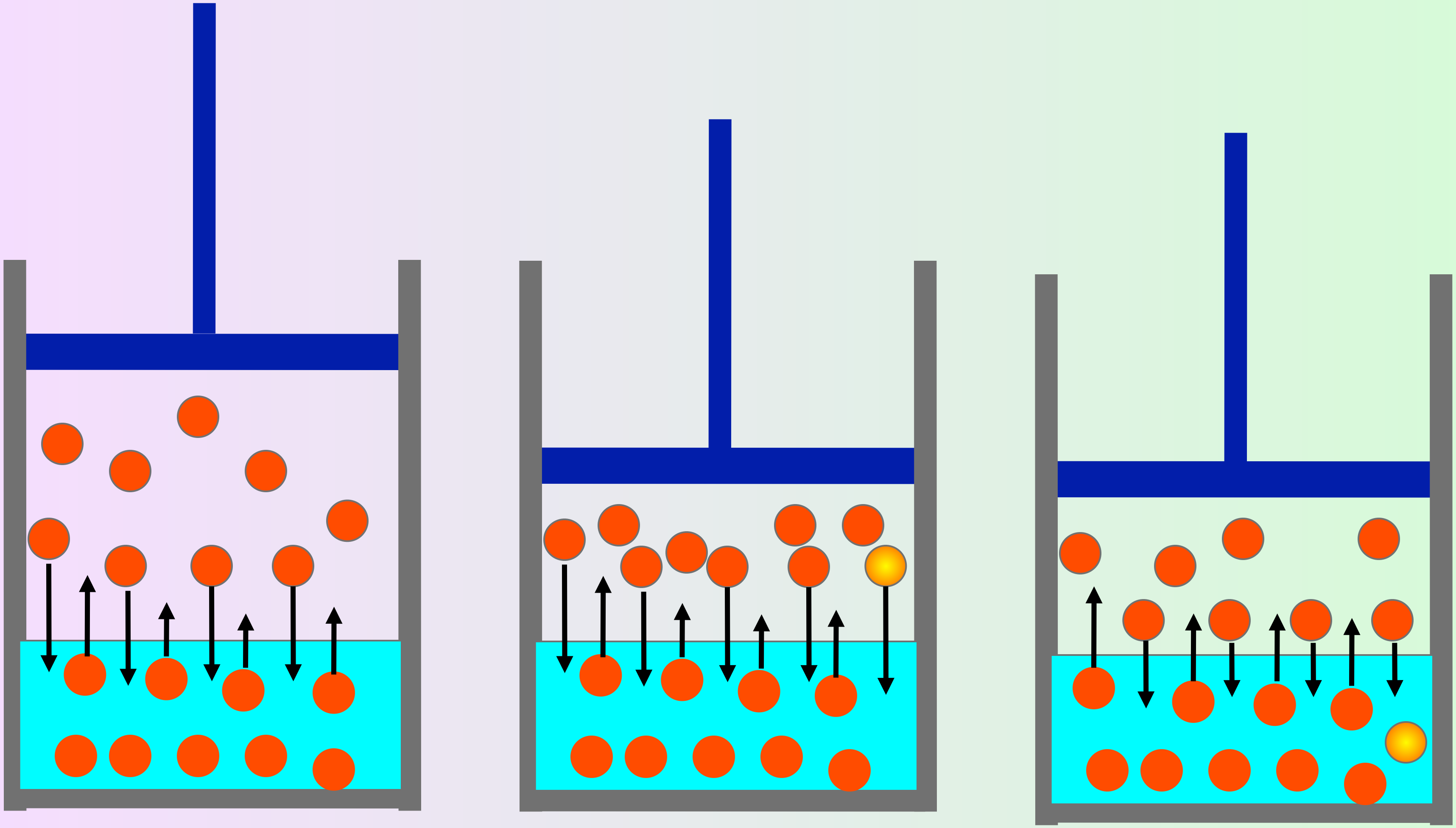
Pressure has little effect on solubility of solids or liquid in liquids

large effect on solubility of gas in liquid

Solubility of gas increases with increased pressure

Example: carbonated beverages

Gas solubility versus Pressure



Henry's Law

$$S_g = kP_g$$

where

- S_g is the solubility of the gas,
- k is the Henry's Law constant for that gas in that solvent, and
- P_g is the partial pressure of the gas above the liquid.

Henry's Law

$$S_g = kP_g$$

(holds only when there is no chemical reaction between the solute and the solvent)

Example

What is the concentration of oxygen in water at 25°C for a partial pressure of 0.22 atm ? The Henry's law constant Oxygen is 3.5×10^{-4} mol· L^{-1} · atm^{-1}

$$S_g = kP_g$$

$$S_g = (3.5 \times 10^{-4}\ \text{mol}\cdot \text{L}^{-1}\cdot \text{atm}^{-1}) \times (0.22\ \text{atm})$$

$$S_g = 7.7 \times 10^{-5}\ M$$