

# **Concentration units**

**Mole fraction**

**molarity**

**molality**

**Percentage by mass**

# Concentration

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**Mole fraction (  $X_n$  )**

**Moles of substance / total moles of all materials**

Mole fraction  $X_A$  =  $\frac{\text{moles of solute } n_A}{\text{total moles } n_A + n_B + n_C \dots}$

# Example

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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.

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

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

# Concentration

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## 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<sub>2</sub>O 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

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**Given:  $\text{Na}_2\text{SO}_4$  concentration = 0.683 M**

**What is the concentration of  $\text{Na}^+$**

**What is the concentration of  $\text{SO}_4^{2-}$  ?**

$$\text{Na}^+ = 2 \times 0.683 \text{ M} = 1.37 \text{ M}$$

$$\text{SO}_4^{2-} = 0.683 \text{ M}$$

# Concentration

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## Molality ( m )

Moles of solute /kg solvent

Determine the molality of a solution made by adding 0.345 mol of C<sub>2</sub>H<sub>5</sub>OH to 168 g of H<sub>2</sub>O

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

$$m = \frac{0.345 \text{ mol C}_2\text{H}_5\text{OH}}{168 \text{ g H}_2\text{O}} \times \frac{10^3 \text{ g}}{1 \text{ kg}} = 2.05 \text{ mol / kg}$$

# Concentration

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## 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).

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

$= 2.8 \%$

# **Dilution of solutions**

# Dilution of solutions

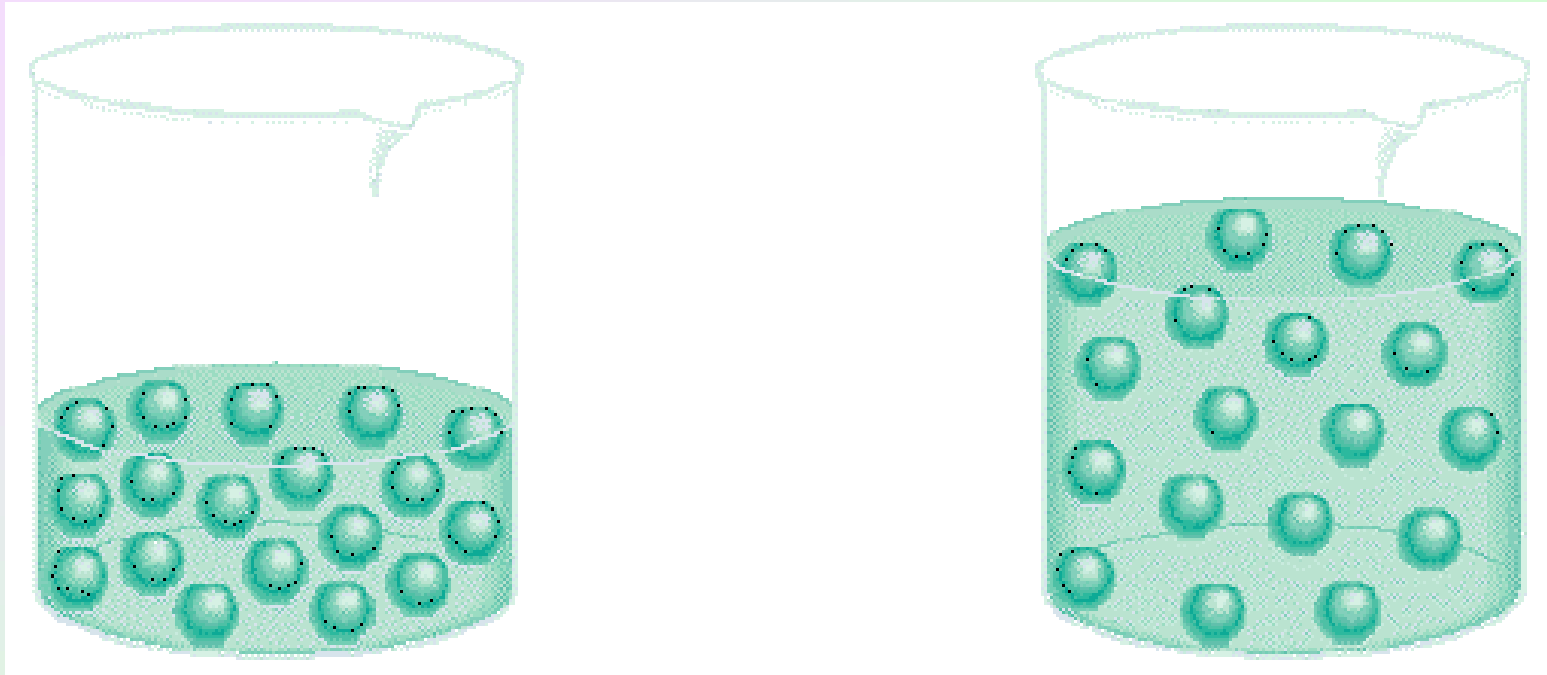
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**Preparation of a less concentrated solution from a more concentrated one**

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

$$\frac{\text{mol (solute)}}{\text{L}} \times \text{L} = \frac{\text{mol (solute)}}{\text{L}} \times \text{L}$$

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



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

## Dilution of solutions

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

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

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

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

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

# **Effects of Temperature on Solubility**

# Effect of temperature

## Gas in water

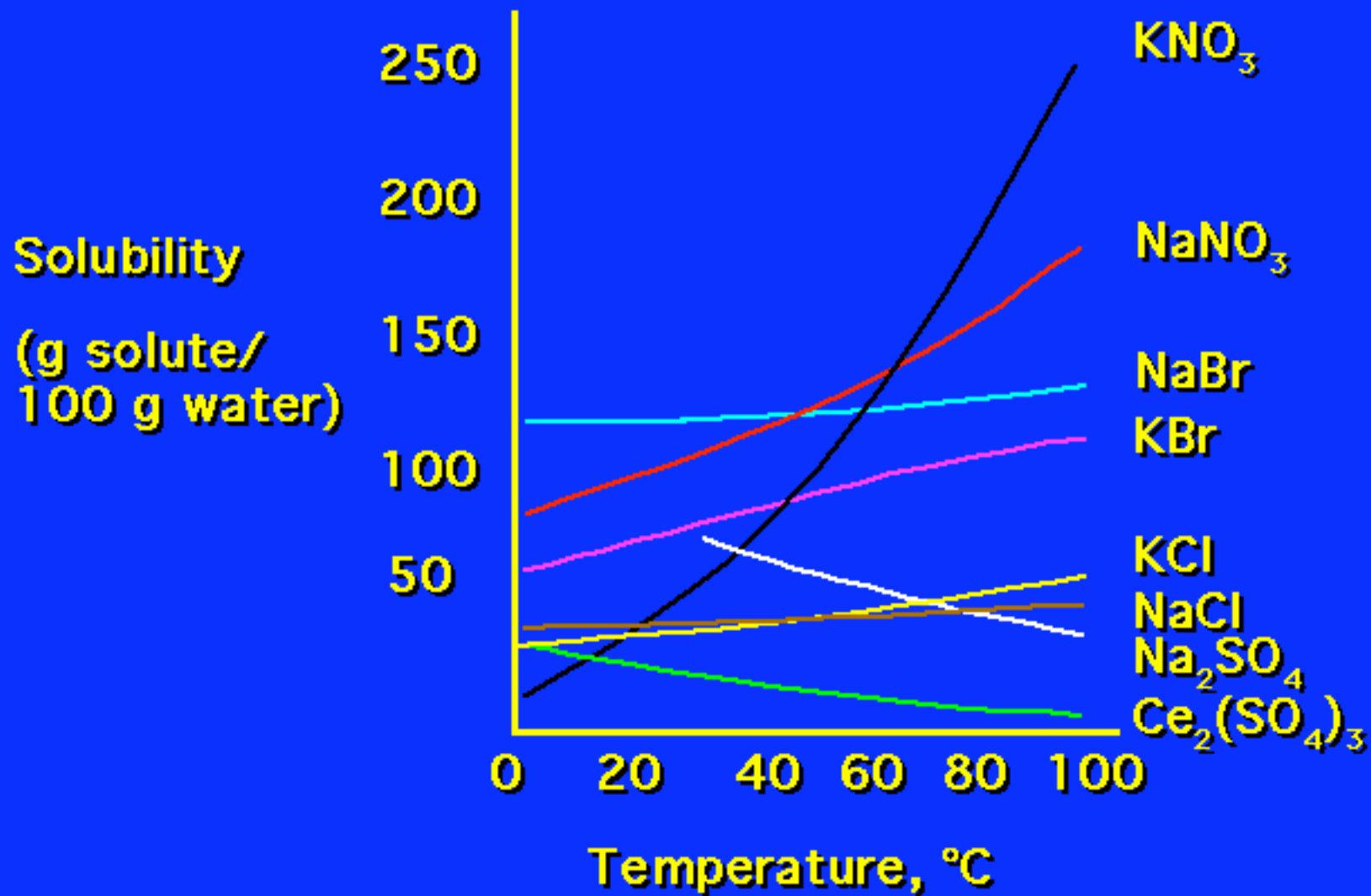
**gases are almost always less soluble at higher temperatures than at lower temperatures**

## Solid in water

**varies with substance**

**the solubility of some substances increases with temperature**

**the solubility of some substances decreases with temperature**



# Effect of temperature

The variation in solubility has some correlation with enthalpy of solution ( $\Delta H_{soln}$ )

If  $\Delta H_{soln}$  is positive, the solubility increases with increases in temperature.

If  $\Delta H_{soln}$  is negative, the solubility decreases with increases in temperature.

# **Effects of Pressure on Solubility of Gases**

# **Effect of pressure**

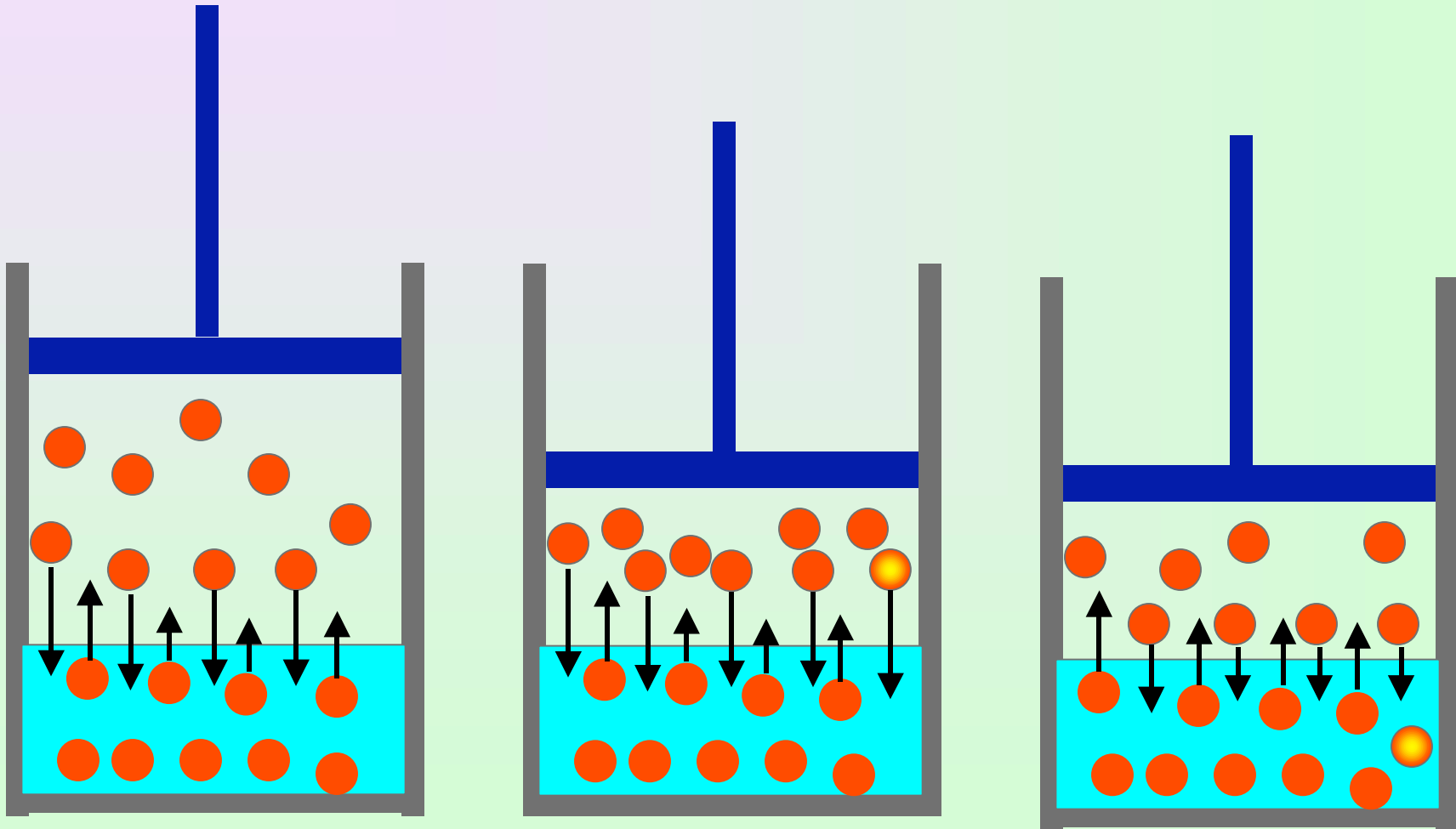
**Pressure has little effect on solubility of solids or liquid in liquids**

**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

**The amount of gas dissolved in a solution is directly proportional to the pressure of the gas above the solution.**

$$C = kP$$

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

# Example

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**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  $3.5 \times 10^{-4} \text{ mol} \cdot \text{L}^{-1} \cdot \text{atm}^{-1}$**

$$C = kP$$

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

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