

Solutions → homogeneous mixture of 2 or more substances  
Solute vs. solvent

Water - Universal solvent = Ion-dipole interaction  
= Strong enough to overcome the lattice of energy of an ionic solid.

## ① Energy of Solution Formation

Like dissolves like - Polar dissolves in polar  
Strong forces (IMF) between solute & solvent

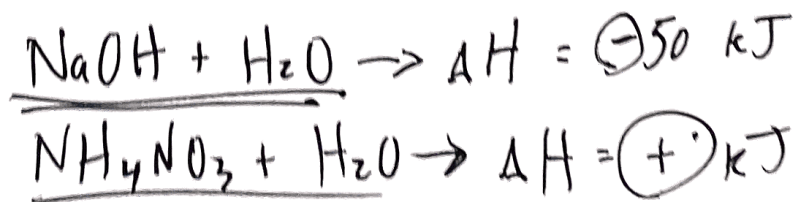
$\Delta H_1$  = Breaking the solute into individual comp.  
Endothermic (+)

$\Delta H_2$  = Overcoming the IMF in the solvent to make room for the solute  
Endothermic (+)

$\Delta H_3$  = Allowing the solute & solvent to interact to form solution  
Exothermic (-) (forming bonds = stability)

## ↳ Enthalpy of Soln

$$\Delta H_{soln} = \Delta H_1 + \Delta H_2 + \Delta H_3$$



## Types of Solutions

Saturated - Solvent holds as much solute as possible at given T

Unsaturated - Less solute than can dissolve.

Supersaturated - hold more solute than is possible at a given T

## Factors Affecting Solubility

① Structural Effects - Like dissolves like  
↳ More polar = more dissolve in  $H_2O$

② Pressure Effects (Henry's Law -  $P = kC$ )

↑ Pressure of Solute (g) above the solution

↑ constant

← Concentration of dissolved gas

③ Temperature Effects - ↑ temp = ↑ solubility.

⊛ ALWAYS liquid - Solid

In a gas ↑ in Temp leads to decrease in solubility

Concentration: Express it

$$(A) \text{ Molarity } (M) = \frac{\text{moles solute}}{\text{L of solution}} \quad * \text{ Temp dependent } (\Delta T = \Delta M)$$

$$(B) \text{ Molality } (m) = \frac{\text{moles of solute}}{\text{Kg of Solvent}}$$

$$(C) \text{ Mole Fraction } (X_A) = \frac{N_A}{N_A + N_B} = \text{ex: } 0.25$$

Annotations: "moles of solute" points to  $N_A$ ; "Total of moles of solution" points to  $N_A + N_B$ .

$$(D) \text{ Parts Per Million (PPM)} = \frac{\text{Mass of "A" in sln}}{\text{Total of Mass Slu}} \times 10^6$$

$$\text{Parts per Billion (PPB)} = \quad \times 10^9$$

$$(E) \text{ Mass Percent } = \frac{\text{Mass of Solute}}{\text{Mass of Solution}} \times 100$$

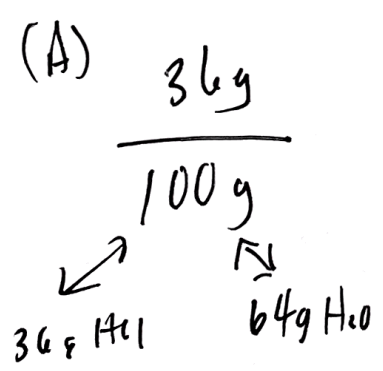
(Mass %)

Ex: 2.5 g sample of ground H<sub>2</sub>O has 5.4 μg Zn<sup>2+</sup> 1g = 10<sup>6</sup> μg  
 What is the concentration in PPM?

$$\frac{5.4 \mu\text{g}}{2.5 \text{ g}} \rightarrow \frac{5.4 \times 10^{-6} \text{ g}}{2.5 \text{ g}} \times 10^6 \quad \text{2.16 ppm}$$

Ex: Solution of HCl - contains 36% HCl by mass

- A) Calculate the Mole fraction of HCl in Soln.
- B) Calculate the Molality of HCl in Soln.



$$\frac{36 \text{ g HCl}}{36.45 \text{ g HCl}} \times \frac{1 \text{ mol}}{1} = 0.987 \text{ mol HCl}$$

$$\frac{64 \text{ g H}_2\text{O}}{18.00 \text{ g}} \times \frac{1 \text{ mol}}{1} = 3.55 \text{ mol H}_2\text{O}$$

$$X_{\text{HCl}} = \frac{0.987 \text{ mol HCl}}{0.987 \text{ mol} + 3.55 \text{ mol H}_2\text{O}} = \boxed{0.23}$$

(B)  $m = \frac{\text{mole solute}}{\text{kg solvent}} = \frac{0.987 \text{ mol HCl}}{0.064 \text{ kg H}_2\text{O}} = 15.4 \text{ m}$

↓  
 15 m  $\frac{\text{mol}}{\text{kg}}$

↓  
 12M

③ Colligative Properties - depend on collective effect of # of particles, not the kind of particles.  
(solutions)

- Ⓐ Lowering Vapor Pressure
- Ⓑ Boiling Point Elevation
- Ⓒ Freezing Point Depression
- Ⓓ Osmotic Pressure

Ⓐ Because IMF of solute-solvent, higher concentrations of non-volatile solutes make it harder for solvent to escape vapor phase.

(no vapor) → ∴ Vapor pressure of solution is lower than of pure solvent = IMF of solution holds molecules of solvent, reducing their leaving therefore vapor press.

= Raoult's Law

$$P_A = X_A P_A^0$$

(soln)  
(reduced P)

← mole fraction of compound A (solvent) (NOT solute)  
← Original Vapor Pressure of A at that temp

EX: Calc mass of  $C_3H_9O_2$  needed to add to 0.340 kg of  $H_2O$  to reduce VP by 2.80 torr at  $40^\circ C$   
The VP of  $H_2O$  at this temp is 55.3 torr

a)  $P_A = X_A \cdot P_A^0 = 55.3 - 2.88 = X_A \cdot 55.3 \text{ torr}$   
 $52.42 \text{ torr} = X_A \cdot 55.3 \text{ torr}$   
 $X_A = 0.9479$

↓ reduced P

b)  $X_A = \frac{\text{mol A}}{\text{total mol}}$  ← solvent =  $H_2O$

$0.340 \text{ kg } H_2O \rightarrow \frac{340 \text{ g } H_2O}{18 \text{ g}} = 18.87 \text{ mol } H_2O$

↓

$$0.9479 = \frac{18.87 \text{ mol } H_2O}{(18.87 \text{ mol} + X)}$$

$1.04 \text{ mol } C_3H_9O_2 \cdot \frac{77.11}{\text{mol}} = 80.59$

$(18.87 + X)(0.9479) = 18.87$

$17.88 + 0.9479X = 18.87 \rightarrow 0.9479X = 0.99$   
 $X = 1.04 \text{ mol}$

Nonvolatile solute-solvent interactions cause sln to have  $\uparrow$ BP &  $\downarrow$ FP than pure solvent = in solutions

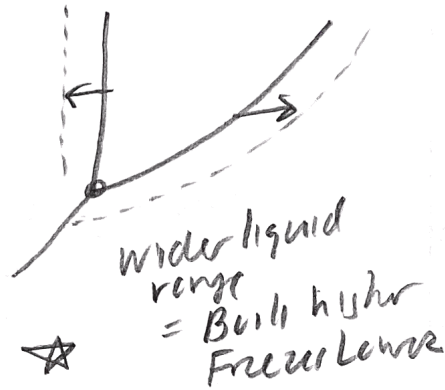
(B) Boiling Point Elevation - Solute raise BP of solvent

$\Delta$  in BP proportional to  $\frac{n/\text{kg solv}}{\text{the molality of the solution}}$

$$\Delta T_b = K_b \cdot m$$

change in BP  $\nearrow$

$K_b$  = molal boiling point elevation constant of solvent



(C) Freezing Point Depression - Solute lower FP of solvent

$$\Delta T_f = K_f \cdot m$$

Subtracted from the normal BP of the solvent  $\nearrow$

$K_f$  = molal FP depression constant of solvent

Note that both equations,  $\Delta T$  does not depend on what the solute is, but how many particles dissolved

EX: Calc the FP of a glycerol ( $C_3H_8O_3$ ) in etherol ( $C_2H_6O$ ) sln if 8.27g of glycerol is dissolved in 250. g of etherol. The FP of etherol =  $-114.6^\circ C$  &  $K_f = 1.99^\circ C/m$

- wt - glycerol -  
- wt - etherol

$$\Delta T_f = K_f \cdot m \quad m = \frac{\text{mol glycerol}}{\text{kg etherol}}$$

$$m = \frac{n_{C_3H_8O_3}}{\text{kg}} = 8.27 \text{ g } C_3H_8O_3 \times \frac{1 \text{ mol}}{92.11 \text{ g}} = 0.08978 \text{ mol } C_3H_8O_3$$

$$m = \frac{0.08978 \text{ mol}}{.250 \text{ kg etherol}} = 0.3591 \text{ m}$$

$$\Delta T_f = (1.99)(.3591)$$

$$\Delta T_f = 0.7146^\circ C \text{ decrease}$$

$$T_f = -114.6^\circ C$$

$$-0.7146^\circ C$$

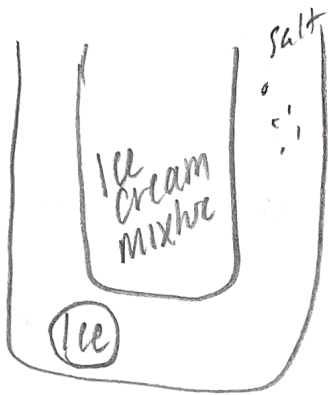
$$\underline{-115.3^\circ C}$$

CONT  $\rightarrow$

# Ice Cream

## Extra Note

Sln much lower FP



← Add Salt  
Ice melts

(Sln of ice + salt = lower FP = should be liquid at that temp)

Melt = endo  
particle speed - absorb energy from mixture = freeze it.

## Ionic Solids

Electrolytes dissociate to give 2 - 4x the solute.

NaCl - 2 ions per formula unit

CaCl<sub>2</sub> - 3 ions per formula unit



2x particles

↑ effective FP/BP

vs. Sugar (no ions)

EX: List of solutions in order of expected FP (ie highest concentration)

0.050 m CaCl<sub>2</sub> = 3 units = 0.150 m (3)

0.15 m NaCl = x 2 = 0.30 m (1)

0.10 m HCl = x 2 = 0.20 m (2)

0.050 m HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub> = 0.055 m (4)

0.10 m C<sub>12</sub>H<sub>22</sub>O<sub>11</sub> = 0.10 m (5)  
(sucrose)  
(no diss)

↑  
real concentration

CaCl<sub>2</sub> for icing  
reeds  
= instead of NaCl  
(3 units)

Week A  
= not all  
3-57 dissociate

Bond Enthalpies (1/31) | Enthalpy of Rxn (2/2) | Hess's Law (2/4) | Heat Total / 9 | IMF (2/11) | Properties of Solids (2/15) | Energy of Phase Chg (2/18)