

Solutions (Concentration & Units)

I. INTRODUCTION

A. Types of matter (see figure at start of Compounds)

1. Pure substances: diamond is pure _____
really clean water is pure _____
table salt is pure ??? _____

2. Mixtures

- a) *heterogeneous* (not same all over, ex.: pepperoni pizza)
- b) *homogeneous* (same all over, but view? example: Kool-aide, sweet tea ?)
- c) *colloids* between hetero- & homogeneous in chunk size

B. Homogeneous mixture: *solution* (soln.), important in medicine.

II. SOLUTIONS (phases & definitions)

A. We often think of solns. as liquids, other phases are possible. Ex??

B. It is useful to define 2 components of a soln.:

1. The solvent is (usually) the component present in greater amount.
2. The solute (or solutes) is the component present in lesser amount. There may be more than one solute.

III. CHARACTERISTICS OF SOLUTIONS

A. Distribution of components is uniform.

B. Components do not settle on standing.

C. Components cannot be separated by filtration.

D. You can mix solute-solvent pairs in a continuous range of ratios.

(Example: strong vs. weak coffee.)

E. Solns. are “clear.” Do not scatter light. *Clear*: opposite of *cloudy*.

F. Solns. *can* be separated into pure components by *physical means*.

IV. SOLUBILITY (usually has limits)

A. Solubility has a number of meanings:

1. the general process of a solute dissolving in a solvent
2. the quantity of solute that will dissolve in a solvent:
 - a) Is there a max. amount of solute that can dissolve (sweet tea?)
 - b) When the max. amount is dissolved, soln. is *saturated*.
 - c) A soln. can be *supersaturated* for short periods of time (Coke that “explodes” when bumped), but a supersaturated soln. is not at equilibrium., *etc.*)
 - d) Comment on completely *miscible* liquids.

B. Nature of Solute and Solvent

1. “Like dissolves like!”
2. Usual focus is on polarity, but consider Hydrogen Bonding too.
3. You are really try to compare 2 possible outcomes. Then, which has lower Gibbs’ Free Energy (G value) (*i.e.*, stability).

Imagine salt dissolving in water:
$$\text{NaCl}(s) \xrightarrow{\text{H}_2\text{O}} \text{Na}^+(aq) + \text{Cl}^-(aq)$$

$$\Delta G = \Delta H - T\Delta S \quad (\text{Return to this point later.})$$

Remember what this means:

$$\Delta H = H_{\text{final}} - H_{\text{initial}}$$

H_{final} = all bonding, heat, *etc.* interactions in the final state

$H_{initial}$ = all bonding, heat, *etc.* interactions in the initial state

C. Temperature Effects on Solubility

1. Often, for solids & liquids dissolving in a liquid, solubility increases as temp. increases (sugar/tea).
2. For gases dissolving, solubility often decreases as T increases:
 - a) Pepsi, Coke, *etc.*
 - b) Thermal pollution by industrial heat sources.

D. Pressure

1. As pressure increases, gas solubility increases.
2. Quantitatively, Henry's Law:

$$k_H \cdot C_{\text{dissolved gas molecules}} = P_{\text{of gas above liquid}}$$

C = concentration

P = pressure

k_H = Henry's Law constant, which is specific for a given gas solute and a given solvent at a specific temp

<u>solute</u>	<u>k_H (atm/M)</u>	for H ₂ O as solvent @ 25°C
O ₂	756.70	
N ₂	1600	
CO ₂	29.76	

Examples at water depth = 99 ft?

We'll come back to this after we learn what "M" is.

3. Applications:

- a) Hyperbaric O₂: gangrene, CO poisoning, *etc.*
- b) the bends: N₂ solubility, scuba and "the bends"
diving http://en.wikipedia.org/wiki/Decompression_sickness re. Boyle!!!
- c) human respiratory (biochemical) adaptation to high altitude

V. CONCENTRATION UNITS & DILUTION

A. This is tremendously important when we apply solutions to life.

1. Examples:

- a) How strong do you like your coffee (tea)?
- b) Effective drug dose vs. overdose

2. All concentration units are some type of ratio, for us: quantity of solute/quantity of solution

B. Percent Concentration (nice for making solns.)

Definition of % is ratio to 100: $\frac{\text{part}}{\text{whole}} = \frac{\%}{100}$

1. percent weight: solute weight to volume soln. (% w/v)

$$\% (w/v) = (\text{g solute} / \text{mL of solution}) \times 100$$

Problem: Calculate % (w/v) of soln containing 351.0 g NaCl in volume of 2.831 L.

2. percent volume solute to volume soln. (Alcohol in drinks)

$$\% (v/v) = (\text{mL solute} / \text{mL of solution}) \times 100$$

3. percent weight solute to weight soln. (% w/w)

$$\% (w/w) = (\text{g solute} / \text{g of solution}) \times 100$$

C. Molarity (*chemists like molarity!*), abbreviated M

- 1. Definition: molarity = **mole** solute/**L** solution
- 2. I recommend: use mol/L instead of M. Helps w/ cancelling.

Problem: Calculate the concentration in molarity of a solution whose volume is 855 mL that contains 4.500 g of KCl.

D. Parts per million (ppm) Ratio to 10^6 , usually by wt. Compare to %, that was ratio to 100. Used in environmental/toxicity settings.

E. Dilution (like with concentrated orange juice?)

$$M_1 V_1 = M_2 V_2 \quad \text{where } M = \text{conc. } V = \text{volume} \quad 1 = \text{initial } 2 = \text{final}$$

Problem: If you dilute 65.0 mL of 8.0 M HCl, to a final volume of 0.400 L, what will be the concentration of the diluted solution.

VI. Solutions & Water as a Solvent 1st see H₂O as a liquid:

“Molecular Motion in Water:” <http://www.youtube.com/watch?v=t5ZFoU0S5iE&feature=related>

A. How does water dissolve ionic compounds?

1. Draw a picture of a cation dissolved in H₂O Animations:
<http://www.mhhe.com/physsci/chemistry/essentialchemistry/flash/molvie1.swf>

2. Compare initial & final states, *all* components re. $\Delta G = \Delta H - T\Delta S$

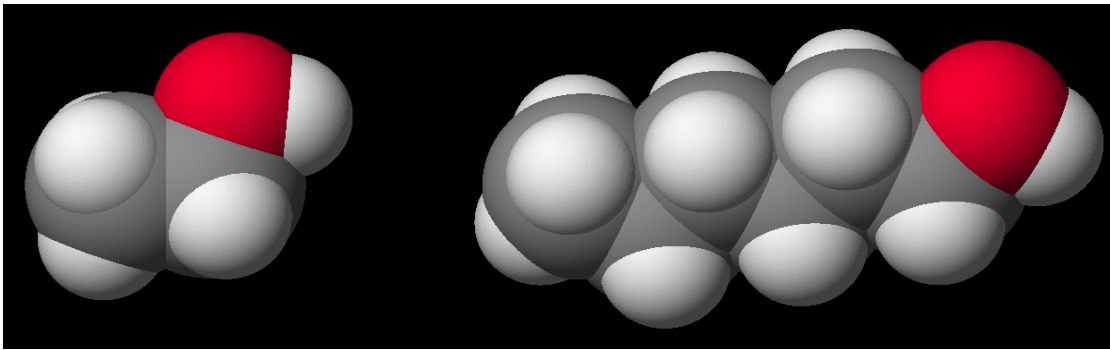
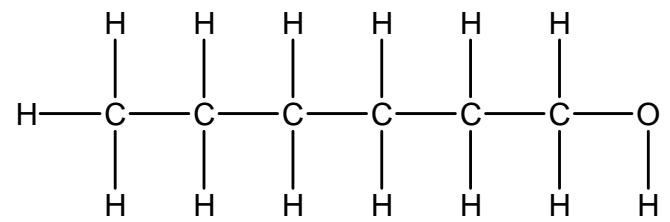
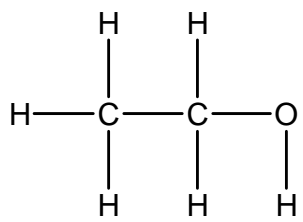
- If substance dissolves readily, ΔG for that process is - (sign).
- The ΔH term relates to bonding interactions (ex. H Bonding)
- For substances dissolving in water, ΔS term often dominates.

B. Electrolytes (Strong, ex.: NaCl falls apart *completely* to give Na⁺ & Cl⁻)
(Weak, ex.: acetic acid (CH₃COOH) falls apart *partially*)

C. How water dissolves covalent compounds

1. Draw picture of dissolved ethanol, C₂H₅OH, in water. Compare dissolved state vs. two separate phases.

- Hydrogen Bonds do form.
- Does Hydrogen Bond formation between water and ethanol new Hydrogen Bond formation (which would contribute favorable to ΔH), or are we just swapping one H Bond for another (which would give no net gain in ΔH)?
- Ethanol is so soluble in water because it has relatively small ***non-polar surface area***. Identify the non-polar part C₂H₅OH. Is C₆H₁₃OH more or less soluble in water than C₂H₅OH?



Alcohol Chain Length: Water Solubility & Boiling Point

<u>Name</u>	<u>Structure</u>	solubility in H ₂ O (g/100 mL)	<u>b.p. (C°)</u>
1-propanol	$ \begin{array}{ccccccc} & & \text{H} & & \text{H} & & \text{H} \\ & & & & & & \\ \text{H} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{O} \\ & & & & & & & & \\ & & \text{H} & & \text{H} & & \text{H} & & \text{H} \end{array} $	completely miscible	101.6
1-butanol	$ \begin{array}{cccccccc} & & \text{H} & & \text{H} & & \text{H} & & \text{H} \\ & & & & & & & & \\ \text{H} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{O} \\ & & & & & & & & & & \\ & & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} \end{array} $	7.4	~117.5
1-pentanol	$ \begin{array}{ccccccccc} & & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} \\ & & & & & & & & & & \\ \text{H} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{O} \\ & & & & & & & & & & & & \\ & & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} \end{array} $	2.7	135.5
1-hexanol	$ \begin{array}{cccccccccc} & & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} \\ & & & & & & & & & & & & \\ \text{H} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{O} \\ & & & & & & & & & & & & & & \\ & & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} & & \text{H} \end{array} $	0.59	157

All values from the 10th edition of the Merck Index except for the solubility of 1-hexanol. That value is from: <http://www.inchem.org/documents/icsc/icsc/eics1084.htm>

Based on the table on p. 7: Is non-polar surface area or Hydrogen Bonding (by the alcohol) more important in determining the solubility of organic alcohols in water? Circle one

non-polar surface area

Hydrogen Bonding

1. What about dissolving large non-polar molecules? “*The Hydrophobic Effect.*” Does gasoline dissolve in water?
Use octane (C_8H_{18}) to represent gasoline.
- a) A bit tricky, because it can't be viewed strictly as bonding.
 - b) Relates to the ordering of H_2O molecules into cage-like structures around non-polar solutes.

Let's look at an animation:

“Hydration shell dynamics of a hydrophobic particle:”

<http://www.youtube.com/watch?v=ETMmH2trTpM&feature=related>

c) Is the formation of ordered structures inherently favorable?

d) Draw pictures of the two states:

C_8H_{18} and water as separate phases \longleftrightarrow C_8H_{18} dissolved in water.

Which state has more favorable ΔH and ΔS terms? Try making a list for each state!

Closing note: We will look at colligative properties, particularly osmosis, after we understand more about biological membranes.