Solutions

Name: _____

AP Chemistry Lecture Outline

Video 403 (11:02)

Video 404 (7:15)

Solubility Guidelines for Selected Ions in Aqueous Solution

Soluble	CH_3COO^-, Alk^+, NO_3^-, NH_4^+	*no exceptions*
	Br^-, I^-, Cl^-	*except with Hg_2^{2+}, Ag^+, and Pb^{2+}*
	SO_4^{2-}	*except with Hg_2^{2+}, Ba^{2+}, Sr^{2+}, and Pb^{2+}*
Insoluble	PO_4^{3-}, CrO_4^{2-}, CO_3^{2-}	*except with Alk^+ and NH_4^+*
	S^{2-}, OH^-	*except with NH_4^+ and "strong base cations"*

Solubility Mnemonics

1. Saul 'Chuck' Cooawlkay knows exceptions? Naaaah.

2. Saul Brickell double-hugged Agatha... and Paul Bunyan, too.

3. Saul Sulf ate two huge bars... and peanut butter, too.

4. The poor crow was cold; he huddled with everyone, but Al K. said, "Naaaah."

5. 'Soooooo.... You two are always combined.' "Naaaaht when we're strongly basic."

Video 406 (12:36)

Are the following compounds soluble or insoluble in water?

1. strontium chloride
2. silver chloride
3. lithium phosphate
4. gold(III) phosphate
5. cobalt(II) nitrate
6. tungsten(VI) sulfate
7. lead(II) sulfate
8. ammonium cyanide
9. copper(I) sulfide
10. barium sulfide
11. sodium hydroxide
12. platinum(III) hydroxide
13. cadmium carbonate
14. calcium carbonate

Precipitation reactions are reactions in solution that form an insoluble product.

The insoluble product is called a...

EX. Suppose you mix solutions of lead(II) nitrate and sodium iodide.

The ions present are...

Write the overall ionic equation…

Cancel the spectator ions to get the net ionic equation…

Video 409 (7:27)

solution: a homogeneous mixture of two or more substances

-- The _____ is present in greatest quantity.

-- Any other substance present is called a _____.

aqueous solutions: solutions in which water is the dissolving medium (i.e., the solvent)

electrolyte: any substance whose aqueous solution will conduct electricity

e.g.,

-- as opposed to a nonelectrolyte, e.g.,

As a general rule, ionic solids dissociate into ions in aqueous solution. The partial (–) charge on the O and the partial (+) charge on the H atoms allow H_2O to interact strongly with, and "pull out," ions in the crystal lattice. Thus, ionic compounds are often strong electrolytes.

For molecular compounds, structural integrity of molecules is maintained. Substance may dissolve, but generally won't split into ions. Thus, mol. comps tend to be nonelectrolytes.

-- major exceptions:

**

Video 412 (10:32)

Strong electrolytes exist almost completely as ions in aqueous solution.

e.g.,

Weak electrolytes produce only a small concentration of ions in reaching equilibrium.

e.g.,

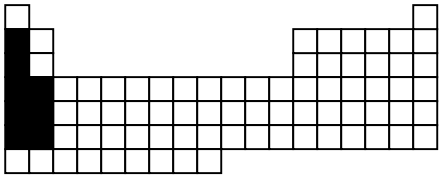
Some of the strong electrolytes are the strong acids and strong bases.

STRONG ACIDS

hydrochloric, HCl	chloric, $HClO_3$
hydrobromic, HBr	perchloric, $HClO_4$
hydroiodic, HI	nitric, HNO_3
	sulfuric, H_2SO_4

STRONG BASES

the hydroxides of...



"strong base cations"

Be careful to distinguish between dissolution and dissociation/ionization in regard to strongs or weaks. For example, CH_3COOH dissolves completely, but ionizes only slightly; it is therefore a weak electrolyte. On the other hand, $Ba(OH)_2$ dissolves relatively little, but the amount that does dissolve dissociates almost completely. $Ba(OH)_2$ is a strong electrolyte.

The question is: *Of the amount that dissolves,*
what fraction dissociates/ionizes?

EX. Classify as a...*strong electrolyte*, *weak electrolyte*, or *nonelectrolyte*.

LiOH	$C_6H_{12}O_6$
$HClO_3$	HClO

EX. If 0.40 mol of each of the following are dissolved in 2.5 L of water, rank them from least to greatest electrical conductivity.

$HBrO_2$	$Ca(CH_3COO)_2$
CH_3OH	KNO_3

Video 415 (9:59)

Acids and Bases

For now, <u>acids</u> ionize in aqueous solutions to form a hydrogen ion (H^+).

--

-- <u>monoprotic acids</u> e.g.,

-- <u>diprotic acids</u> e.g.,

(only first ionization is complete)

For now, <u>bases</u> are substances that accept hydrogen ions (i.e., protons).

-- OH^- is very basic

-- equation:

The most common weak base is ammonia, NH_3; it ionizes only about 1%.

-- equation:

A <u>neutralization reaction</u> has the form:

-- recall that “salt” means an ionic compound

EX. Write the balanced molecular equation when nitric acid reacts ^{w}/barium hydroxide.

EX. Write the net ionic equation for the above reaction.

EX. Write the balanced molecular eq. when perchloric acid reacts ^{w}/potassium hydroxide.

EX. Write the net ionic equation for the above reaction.

**

Video 418 (5:39)

Three other anions that act as bases (i.e., as p^+ acceptors) are the sulfide ion (S^{2-}), the carbonate ion (CO_3^{2-}), and the bicarbonate ion (HCO_3^-). All react w/acids to form gases.

-- sulfide ion: reacts w/acids to form $H_2S(g)$

$$HCl(aq) + K_2S(aq) \longrightarrow$$

-- carbonate and bicarbonate ions: react w/acids to form $CO_2(g)$

$$HNO_3(aq) + CaCO_3(s) \longrightarrow$$

$$HCl(aq) + NaHCO_3(aq) \longrightarrow$$

Video 421 (11:13)

Oxidation-Reduction (a.k.a., Redox) Reactions

In redox reactions, electrons are transferred between species.

Oxidation is the loss of e^-s, so when a substance is oxidized, its charge…

Reduction is the gain of e^-s, so when a substance is reduced, its charge…

$$Mg(s) + 2\ H^+(aq) \longrightarrow Mg^{2+}(aq) + H_2(g)$$

NOTE: A substance is oxidized/reduced if ANY PART of it is oxidized/reduced.

Rules for Assigning Oxidation Numbers

1. Atoms in their elemental form have an oxidation number of zero.
2. For a monatomic ion, the oxidation number is the charge on the ion.
3. Nonmetals can have variable oxidation numbers.
   a. Oxygen is usually 2–, but in the peroxide ion (O_2^{2-}) it is 1–.
   b. Hydrogen is 1+ when bonded to nonmetals, 1– when bonded to metals.
   **
   c. Fluorine is 1–. Other halogens are usually 1–, but are + when combined w/oxygen.
4. The sum of the oxidation numbers in a neutral compound is zero.

EX. Determine the oxidation number of nitrogen in each of the following.

N_2O_4 NH_3 N_2 NO_3^-

Video 424 (6:40)

Single replacement reactions have the following form:

Write molecular and net ionic equations for the calcium/hydrochloric acid reaction.

Li
Rb
K
Ba
Sr
Ca
Na
Mg
Al
Mn
Zn
Cr
Fe
Cd
Co
Ni
Sn
Pb
H_2
Sb
Bi
Cu
Hg
Ag
Pt
Au

The activity series is a list of metals. At the top of the list are the highly-reactive *active metals*. At the bottom are the not-so-reactive *noble metals*.

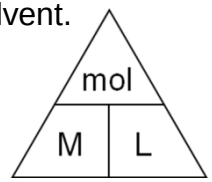
The activity series is readily available in standard references.

EX. Which of the following metals will reduce $PbCO_3$? Ag Mg Hg

Video 427 (8:31)

Molarity A solution's concentration tells us the amount of solute per solvent.

A common unit of concentration is molarity.



-- equation:

EX. What mass of magnesium nitrite is needed to make 3.25 L of a 0.35 M solution?

Steps for Properly Mixing an Aqueous Solution

1. In an appropriate container, pour water in so that you have ~80% of your final, desired volume. This is an approximate technique and takes little time.
2. Weigh out the proper amount of solute and mix it into the water from Step 1.
3. "Top off" the solution to the proper volume and mix. **DONE.**

EX. What is the conc. of sodium ions in a 0.025 M solution of sodium phosphate?

Video 430 (3:24)

Dilutions Aqueous acids (and sometimes bases) can be purchased in concentrated form and diluted to any lower concentration. A purchased bottle of acid is called a <u>concentrate</u> or a <u>stock solution</u>.

-- **Safety Tip: When diluting, add acid or base to water, not the other way around.

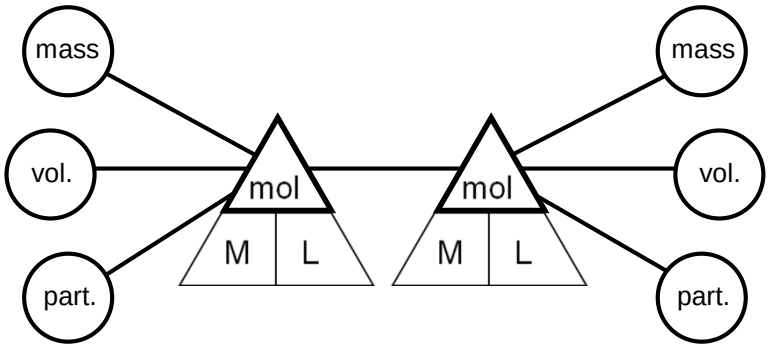
Dilution Equation:

EX. Conc. phosphoric acid is 14.8 M. What volume of concentrate is req'd to make 25.0 L of 0.500 M acid?

Video 433 (8:00)

Solution Stoichiometry

What volume of 0.150 M sulfuric acid is needed to neutralize 26 g sodium hydroxide?



EX. What mass of lead (II) nitrate will consume 85.0 mL of 0.45 M sodium iodide?

Video 436 (5:05)

Titrations

If we don't know a solution's concentration, we react a second solution of known concentration – called a <u>standard solution</u> –with the first. Based on the stoichiometry of the reaction, we can determine the unknown solution's concentration.

-- This procedure is called a <u>titration</u>.

The equivalence point of a titration occurs when stoichiometrically equivalent quantities are brought together. This point is identified by using indicators, which are chemicals whose color depends on the pH. A sudden color change indicates the end point of the titration, which coincides closely with the equivalence point, and is usually considered to be “good enough.”

EX. If 56.0 mL of sodium hydroxide neutralize 19.0 mL of 0.235 M nitric acid, find the concentration of the base.

Video 439 (10:26)

Ways of Expressing Concentration

qualitative:

quantitative:

mole fraction, X =

mass % =

ppm =

molarity, M =

ppb =

molality, m =

ppt =

Unlike molarity, molality doesn’t change with temp. because...

To go between molarity and molality, you need...

EX. A 5.5-g sample of well water contains 0.75 μg of lead ions. In ppm, find the concentration of lead ions.

EX. If a commercial bleach is 4.35% sodium hypochlorite by mass, calculate the bleach's mole fraction and molality of the sodium hypochlorite.

Video 442 (7:29)

Colligative Properties

-- these depend on the concentration of particles in a solution, but not...

*(A) Adding a **volatile**/nonvolatile solute to a solvent*
***increases**/decreases the solution's vapor pressure (VP).*

Raoult's law:

Ideal solutions obey Raoult's law.

Such solutions have...

-- a low concentration
-- solute and solvent particles that are similar in size and have similar IMFs

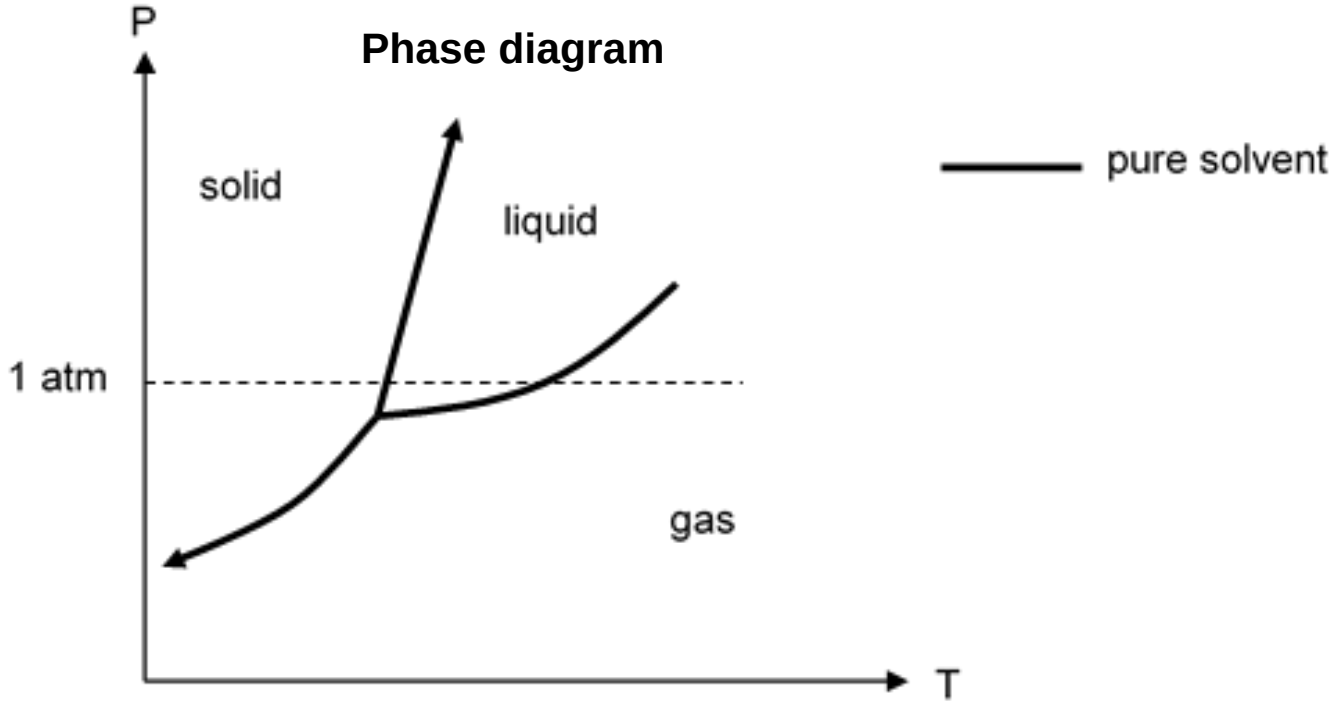
EX. A solution of sodium chloride and water has a vapor pressure of 0.854 atm at 100.^{o}C. Find the mole fraction of sodium ion in solution.

Video 445 (6:03)

A solution contains 89.7 g ethanol and 241.4 g water. What is the vapor pressure above the mixture at 100.^{o}C, if ethanol's vapor pressure at this temp. is 1694 torr?

Video 448 (7:03)

*(B) Adding a nonvolatile solute to a solvent **decreases** the solution's freezing point (FP) and **increases** its boiling point (BP).*



The freezing point depression and boiling point elevation are given by:

ΔT_x = FP depression or BP elevation

$K_x = K_f$ (molal FP depression constant) or K_b (molal BP elevation constant)

-- they depend on the solvent

-- for water: K_f = K_b =

m = molality of solution

i = van't Hoff factor (accounts for # of particles in solution)

In aq. soln., assume that…

-- i = ___ for nonelectrolytes

-- i = ___ for KBr, NaCl, etc.

-- i = ___ for $CaCl_2$, etc.

In reality, the van't Hoff factor isn't always an integer. Use the guidelines unless given information to the contrary.

Video 451 (10:10)

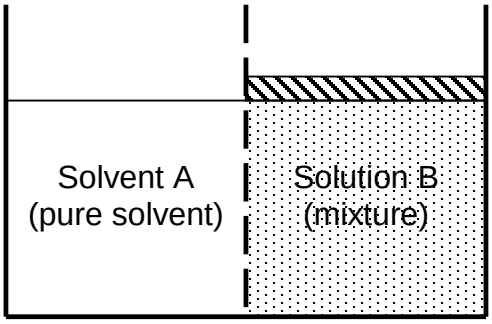
Find the FP and BP of a solution containing 360 g barium chloride and 2.50 kg of water.

EX. Camphor, $C_{10}H_{16}O$ has a normal freezing point of 179.8°C and a K_f = 40.0°C/m. When 0.186 g of a nonelectrolytic substance is dissolved in 22.01 g of camphor, the mixture's new freezing point is 176.7°C. Find the unknown's molar mass.

Video 454 (9:30)

*(C) Adding a nonvolatile solute to a solvent **increases** the solution's osmotic pressure.*

Osmosis is the net movement of **solvent** away from a soln. w/a lower solute [ ] toward a soln. w/a higher solute [ ]. Another way to say this is that osmosis is the diffusion of a solvent – i.e., from an area of higher solvent [ ] to an area of lower solvent [ ] – through a semipermeable membrane.



osmotic pressure, π: the external pressure req'd to prevent osmosis

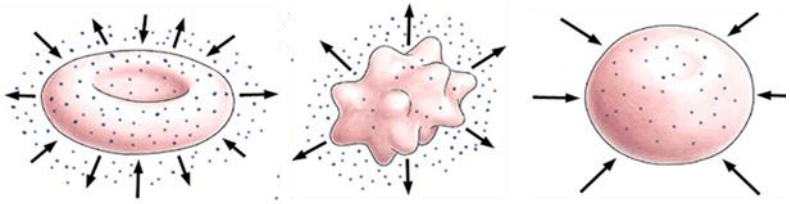
solvent tends to flow ;

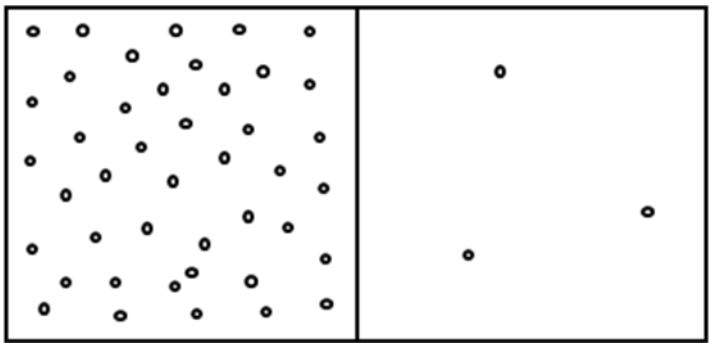
application of π…

A soln's osmotic pressure π can be thought of as a negative pressure; that is, the greater a soln's π, the greater is the tendency for solvent to flow _____ the solution.

hypertonic solutions:

hypotonic solutions:





Video 457 (6:41)

osmotic pressure equation:

n = # of moles of solute

V = solution volume, in L

R = 8.314 L-kPa/mol-K = 0.08206 L-atm/mol-K

T = absolute temp. (i.e., in K)

i = van't Hoff factor

EX. 1.5 mg of a certain protein are dissolved in water to make 10.0 mL of solution. The soln's osmotic pressure was found to be 2.35 torr at 25°C. Calculate the protein's molar mass.