CHEM 115
Introduction to Solutions

Lecture 7
Prof. Sevian

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Conclusions about solving stoichiometry problems

- Mass is what is conserved
- Converting from how much of one chemical to how much of another requires knowing how many moles
- Figure out what is given and what you're looking for
  - Is the given information in mass or moles?
  - Is the answer sought in mass or moles?
  - Which reactant is limiting?
- For complicated problems, it sometimes helps to set up a "before-change-after" table…remember that quantities in this table must be in moles
- Mass is conserved overall, but moles are what is counted when figuring out how much reacts
- More worked examples are on the website

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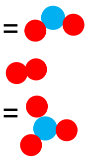
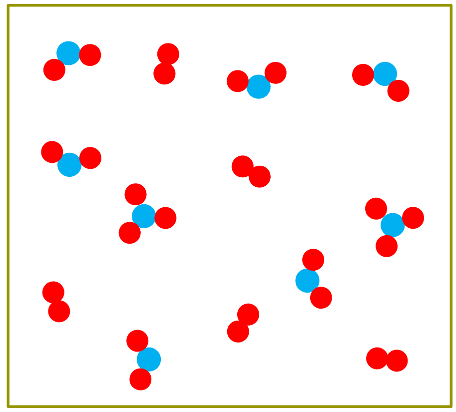
Which is the limiting reactant in the representation below of the reaction?

$2\ NO_2 + O_2 \rightarrow 2\ NO_3$

Legend:
NO_2 =
O_2 =
NO_3 =





A. NO_2 is limiting
B. O_2 is limiting
C. NO_3 is limiting
D. There is not enough information to tell

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Which is the limiting reactant in the reaction below?

$4\ NH_3\ (g) \quad + \quad 5\ O_2\ (g) \quad \rightarrow \quad 4\ NO\ (g) \quad + \quad 6\ H_2O\ (g)$

In a certain experiment, 8 moles of NH_3 react with 12 moles of O_2.
Which is the limiting reagent?

A. NH_3 is limiting
B. O_2 is limiting
C. NO is limiting
D. H_2O is limiting
E. There is not enough information to tell

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Starting chapter 4 today…
the parts of ch. 4 that will be on the exam are:

- What is a solution made of?
- Solubility of ionic compounds (salts), acids, and molecular compounds
- Exchange reactions that produce a precipitate
- Complete vs. net ionic reactions

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Solutions

- Almost nothing in nature occurs naturally as a pure substance
- Most chemical reactions of interest take place in *solution,* between chemicals that are dissolved in water
- Medium in which something is dissolved is called a *solvent*
- Water is often called the "universal solvent"
  - It is possible to have solvents other than water (*e.g.*, tincture of iodine is solid iodine crystals dissolved in ethanol)
  - It is possible to have solutions that are not liquids (*e.g.*, air is a bunch of different gases dissolved in N_2)
- The chemical that dissolves is called the *solute*
- In this course, we will focus on *aqueous solutions*

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What is electrical conductivity?

- Electrical = charged parts due to electrons not balanced with protons on particles
- Conductivity = parts can circulate so that complete circuit can form

Two conditions exist for something to be electrically conductive:

1. Must have charged parts
2. The parts must be mobile

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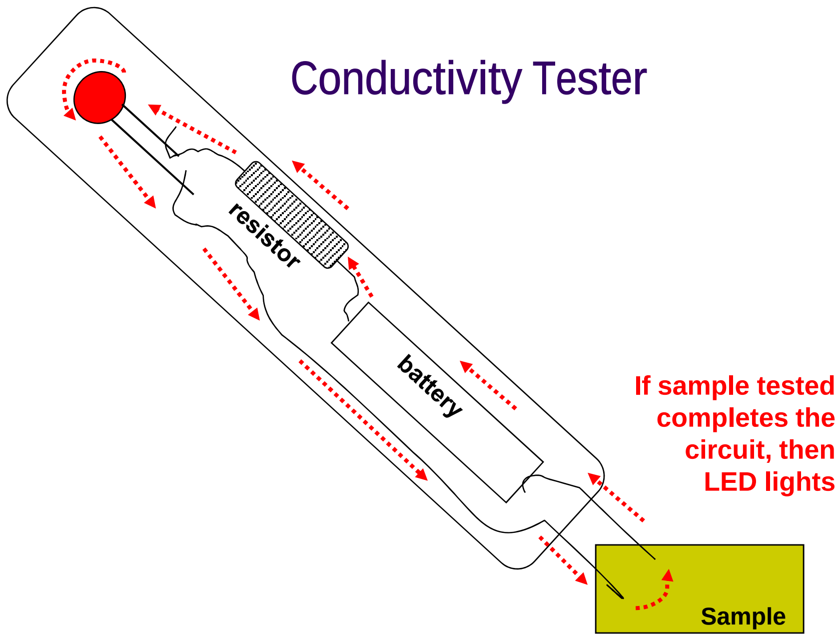
Conductivity Tester



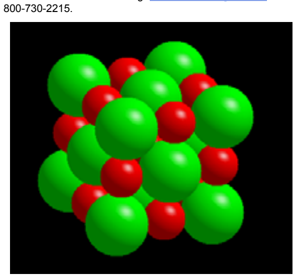
Which of these systems are *solutions*?

Demonstration

System	Symbol	Has charged parts?	Parts can move?	Electrically conductive?
Pure water	H_2O (*l*)			
Aqueous sugar solution	$C_6H_{12}O_6$ (*aq*)			
Salt crystals at room temperature	NaCl (*s*)			
Aqueous salt solution	NaCl (*aq*)			
Aqueous sodium bicarbonate solution	$NaHCO_3$ (*aq*)			

Electrolytes

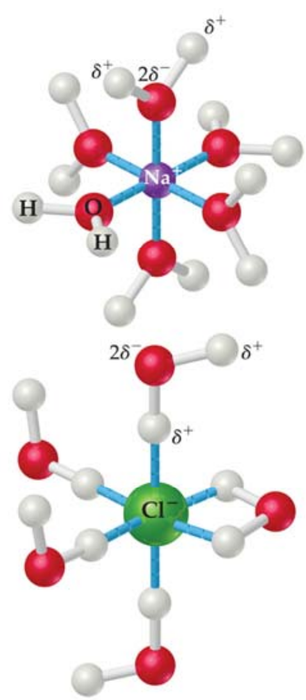
Electro – lyte
(electricity) – (break apart)



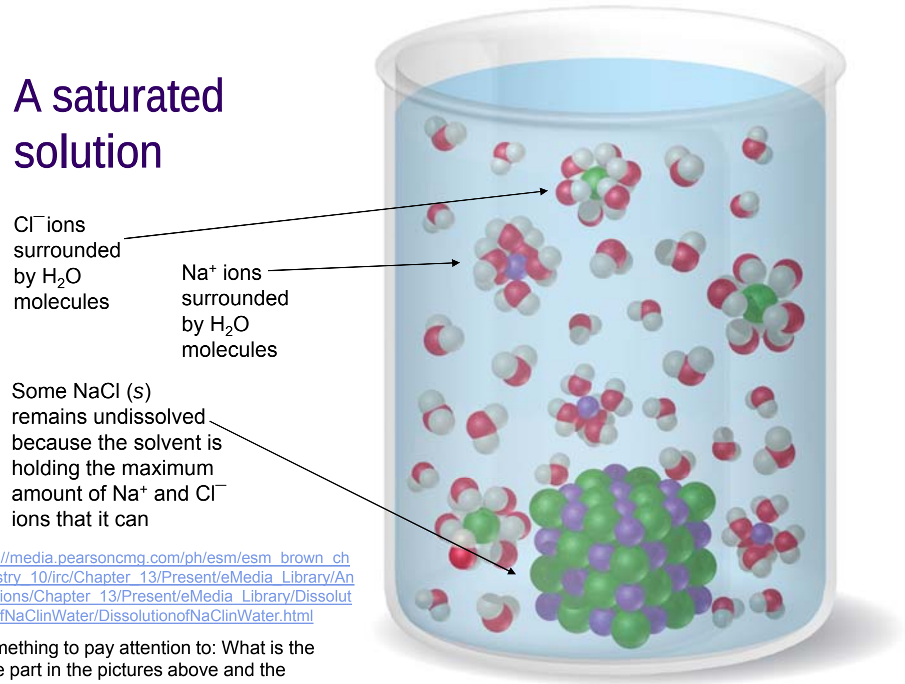
NaCl, salt

When ions dissolve into water →

(how? stay tuned 'til ch. 13)



A saturated solution



http://media.pearsoncmg.com/ph/esm/esm_brown_chemistry_10/irc/Chapter_13/Present/eMedia_Library/Animations/Chapter_13/Present/eMedia_Library/DissolutionofNaClinWater/DissolutionofNaClinWater.html

Something to pay attention to: What is the blue part in the pictures above and the animation supposed to represent?

Some Ions Dissolve in Water Better Than Others

Definitions are fuzzy

Very soluble

- More than 0.10 mol can dissolve in 1 L of water

Moderately soluble

- Something in between

Pretty much insoluble

- Less than 0.01 mol can dissolve in 1 L of water

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Understanding Solubility

- "Solubility" refers to the ability of an ionic compound to dissolve in water. More soluble means more dissolves.
- There is no such thing as "completely insoluble." Solubility is relative. Rather than applying the dualism of soluble vs. insoluble, it is more accurate to talk about *degree of solubility*.
- At the macroscopic level, a common threshold for determining solubility is 0.1 to 1 gram per 100 mL of water.
- At the particle level, when an ionic solid dissolves in water, it breaks apart into single ions which then become surrounded by water molecules.

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Solubility of Some Common Sulfate Compounds (at 25ºC)

Formula	Solubility ($g/100cm^3$)	Solubility (mol/L)
$BaSO_4$	0.00246	0.00010
$PbSO_4$	0.00425	0.00014
$SrSO_4$	0.0113	0.00060
Hg_2SO_4	0.060	0.0012
$CaSO_4$	0.209	0.0150
Ag_2SO_4	0.57	0.018
Na_2SO_4	4.76	0.335
$MgSO_4$	26.0	2.16

Solubility guidelines

If one ion from the "Soluble Compounds" list is in an ionic compound, then the ionic compound will dissolve in water

TABLE 4.1 Solubility Guidelines for Common Ionic Compounds in Water

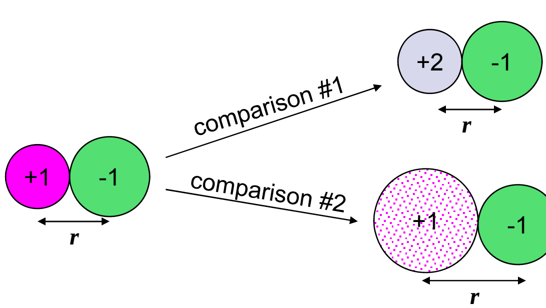
Soluble Ionic Compounds		Important Exceptions
Compounds containing	NO_3^-	None
	$C_2H_3O_2^-$	None
	Cl^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	Br^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	I^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	SO_4^{2-}	Compounds of Sr^{2+}, Ba^{2+}, Hg_2^{2+}, and Pb^{2+}
Insoluble Ionic Compounds		**Important Exceptions**
Compounds containing	S^{2-}	Compounds of NH_4^+, the alkali metal cations, and Ca^{2+}, Sr^{2+}, and Ba^{2+}
	CO_3^{2-}	Compounds of NH_4^+ and the alkali metal cations
	PO_4^{3-}	Compounds of NH_4^+ and the alkali metal cations
	OH^-	Compounds of the alkali metal cations, and NH_4^+, Ca^{2+}, Sr^{2+}, and Ba^{2+}

What Holds Ionic Solids Together?

Coulomb's Law:

$$F = \frac{k\, Q_+\, Q_-}{r^2}$$

- F: Force of attraction
- k: proportionality constant
- Q_+: Charge on positive ion
- Q_-: Charge on negative ion
- r: distance between ions



Comparison #1: Is the force of attraction stronger or weaker? Should this ionic compound be more or less soluble than the (+1)(-1) original?

Comparison #2: Is the force of attraction stronger or weaker? Should this ionic compound be more or less soluble than the (+1)(-1) original?

Solubility: Physical Principles

- The force of attraction between oppositely charged ions is proportional to the magnitude of the charges of those ions.
- During dissociation, oppositely charged ions in the solid phase are separated from each other and dissolved in water.
- This suggests that:
  - If a salt is composed of highly charged ions, it is not very soluble.
  - If a salt is composed of ions with lower charges, it is probably soluble.
- General rule to use as a starting point: any salt involving a +1 cation or a -1 anion is *likely* to be soluble.

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Acknowledgment: Blake, B. (2003) *J. Chem. Ed.* **80**, 1348.

What we have learned so far

- A solution is a mixture that is made of a solvent and solute(s)
- In an aqueous solution, the solvent is water
- We explain solubility with a particle level model for how ionic solute particles (individual + and - ions) are "solvated" by water molecules
- If the solute in an aqueous solution is ionic, then the solution will conduct electricity (charged particles must be mobile)
- All solutes dissolve to some extent
- The extent to which a solute dissolves can be arbitrarily categorized as
  - Minimally soluble – we often (and misleadingly) call this "insoluble"
  - Somewhat soluble } we often call these "soluble"
  - Very soluble }
- To remember whether an ionic compound is soluble in water, you have to memorize the solubility rules

Where we are going next

- If two different aqueous ionic solutions are mixed, a chemical reaction might occur
- If a reaction occurs, one (or both) of the products might be a precipitate
- To predict whether an ionic product dissolves or precipitates, you rely on your memorized solubility rules
  - If both ionic products are soluble, then there is really no product produced, so we say there is no reaction that occurred
- If a reaction occurs when two aqueous ionic solutions are mixed, then you can write a net ionic equation

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What basic information do you need to memorize?

- Polyatomic ions, and common ions of elements
  - Names
  - Formulas
  - Charges
- Names and symbols of the first 36 elements
  - you will always get a periodic table to use, but it will only have the symbols, not the element names on it
- Names and symbols of some other common elements, and their typical charges when they form ions
  - silver, strontium, barium, cadmium, gold, mercury, tin, lead, iodine
- Solubility guidelines
  - p. 125 in the 11th edition, or p. 127 in the 10th edition
- You will also need to know the brief list of strong acids

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