CHEM 205 section 03

LECTURE #12 Tues. Feb.12, 2008

ASSIGNED READINGS:

TODAY'S CLASS: continue Ch.5

NEXT CLASS: **more Ch.5**

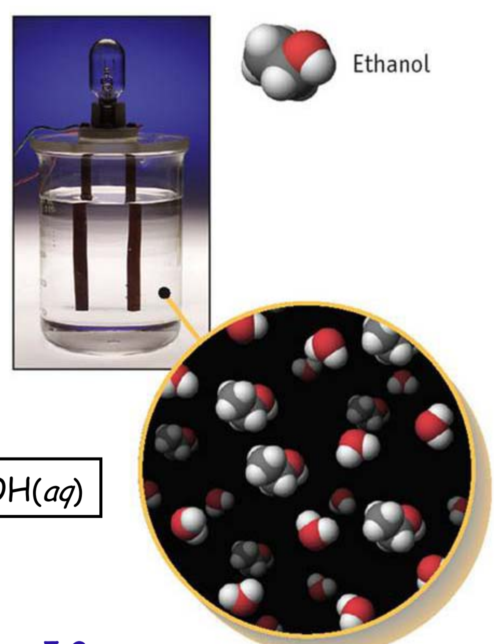
(1)

A nonelectrolyte
= any compound that does NOT dissociate into ions at all

→ solution will NOT conduct electricity

→ most molecular compounds, such as ethanol:

$$CH_3CH_2OH(l) \rightarrow CH_3CH_2OH(aq)$$



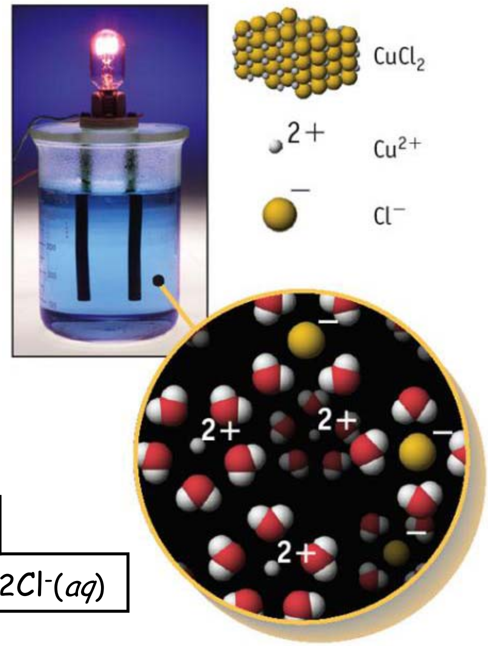
(2) Active Figure 5.2

A strong electrolyte

= any compound that fully ionizes in solution

e.g., any **soluble** ionic compound

When solid $CuCl_2$ dissolves, it fully "dissociates", and Cu^{2+} and Cl^- ions are randomly dispersed in the water.



$CuCl_2(s) \rightarrow CuCl_2(aq)$
$CuCl_2(s) \rightarrow Cu^{2+}(aq) + 2Cl^-(aq)$

(3)

Active Figure 5.2

Solubilities of IONIC compounds

Not all ionic compounds will dissolve much in water:

Highly soluble	Slightly soluble	Insoluble
Strong electrolyte	Weak electrolyte	Nonelectrolyte
High [ions]	Low [ions]	[ions]≈ 0

Reasons for differences in solubility:

- Complex balance between ion-ion & ion-solvent interactions…
- Often: ions with high charge do not get sufficient charge "compensation" by being surrounded by water molecules (compared to in ionic crystal), so have low solubility
- Difficult to predict solubility using theory alone
- Instead: observed solubilities have been measured/tabulated

Trends for water solubilities: determined by experiment summarized in Figure 5.3

must memorize

Water Solubility of Ionic Compounds: IMPORTANT

To predict solubility:
If one ion from the "Soluble Cmpd." list is present in a compound, the compound will be water soluble.

SOLUBLE COMPOUNDS	EXCEPTIONS
Almost all salts of Na^+, K^+, NH_4^+	
Salts of nitrate, NO_3^-; chlorate, ClO_3^-; perchlorate, ClO_4^-; acetate, $CH_3CO_2^-$	
Almost all salts of Cl^-, Br^-, I^-	Halides of Ag^+, Hg_2^{2+}, Pb^{2+}
Compounds containing F^-	Fluorides of Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}
Salts of sulfate, SO_4^{2-}	Sulfates of ~~Mg^{2+}~~, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+} — Is correct in textbook…

INSOLUBLE COMPOUNDS	EXCEPTIONS
All salts of carbonate, CO_3^{2-}; phosphate, PO_4^{3-}; oxalate, $C_2O_4^{2-}$; chromate, CrO_4^{2-}	Salts of NH_4^+ and the alkali metal cations
Most metal sulfides, S^{2-}	
Most metal hydroxides and oxides	

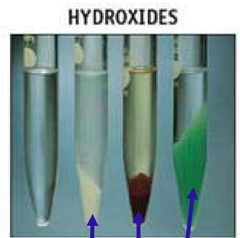
Active Figure 5.3

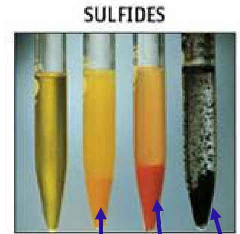
Summary: *"electrolytes"* …solutions *vs.* substances

- **If a solution contains ions**: current can pass through it
  - measure *electrical conductivity* to test for presence of ions
- **"Electrolyte"** : describes ability of solution/substance to conduct
  - solutions: …if contain ions
  - substances: …if yield ions when dissolved in water

Electrolyte type	Solution	Substance
Strong	▪ high concentration of ions ▪ conducts current efficiently NaCl(aq), *HCl(aq)*	▪ quantitatively yield dissociated ions when dissolved NaCl, *HNO_3*
Weak	▪ low concentration of ions ▪ conducts current poorly tap water, *vinegar*	▪ yield ions, but not much dissolves AgCl ▪ *ionize partially when dissolved* *NH_3 , CH_3COOH*
Non-electrolyte	▪ ~ no ions present ▪ no current flows sugar solution	▪ does not ionize appreciably pure water, O_2

Some ionic compounds: soluble *vs.* insoluble





Typically soluble:
- salts of ammonium & alkali metals
- halides, nitrates, sulfates
- acetates
- chlorates, perchlorates

} then learn the major exceptions…

Typically insoluble: Everything else you'll see in Chem 205…
- carbonates, phosphates, oxalates, chromates, sulfides, hydroxides

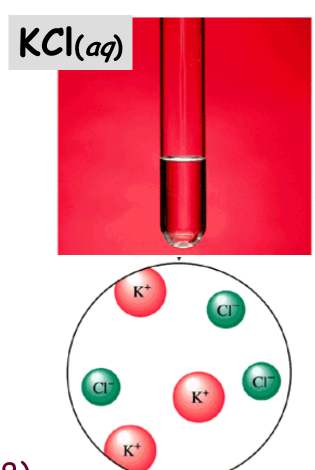
(Note: many of these salts contain ions with high charge!)

(7) Fig. 5.3

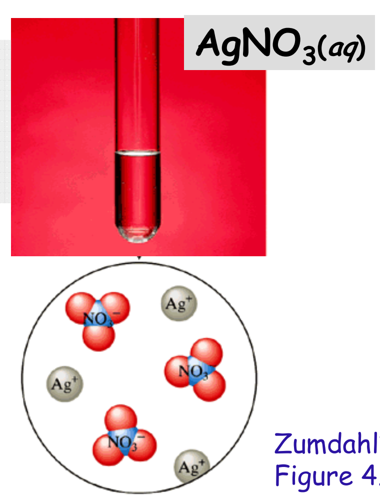
What happens if we mix two salt solutions?

KCl(*aq*) undergoes **counterion ion-exchange** $AgNO_3$(*aq*) to form INSOLUBLE AgCl(*s*)

The reactants:



BOTH ARE clear, colourless solutions



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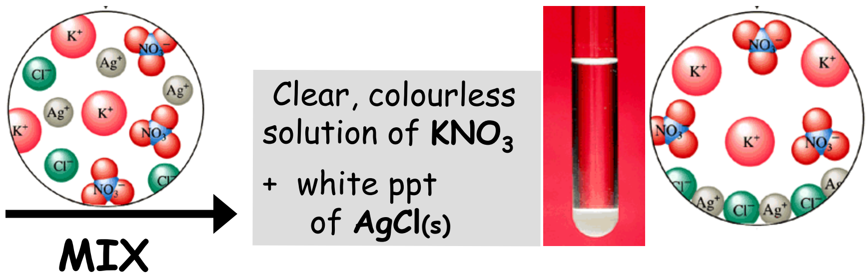
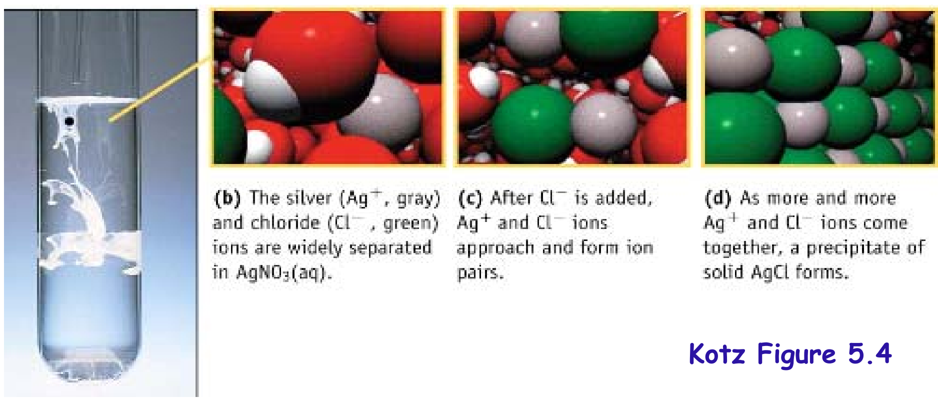
Zumdahl's Figure 4.17





(b) The silver (Ag^+, gray) and chloride (Cl^-, green) ions are widely separated in $AgNO_3(aq)$.

(c) After Cl^- is added, Ag^+ and Cl^- ions approach and form ion pairs.

(d) As more and more Ag^+ and Cl^- ions come together, a precipitate of solid AgCl forms.

Kotz Figure 5.4

5.2 Precipitation Reactions

= when an insoluble solid product (a "precipitate") is formed upon mixing of water-soluble ionic reactants

IMPORTANT THINGS TO CONSIDER:

1.) WHAT IS IN THE REACTANT SOLUTIONS?

- Separated, hydrated ions (cations AND anions)

$$AgNO_3(aq) \rightarrow Ag^+(aq) + NO_3^-(aq)$$
$$KCl(aq) \rightarrow K^+(aq) + Cl^-(aq)$$

2.) WHAT HAPPENS WHEN WE MIX THEM?

- Ions encounter "new" counter-ions via collisions
- If "new" ion pair separates: SOLUBLE SALT
- If "new" ion pair sticks together: INSOLUBLE

Describing Reactions in Solution: 3 types of equation (balanced of course…)

1. Complete ionic equation: strong electrolytes shown as ions.
Provides conceptual view of process.

$$Ag^+(aq) + NO_3^-(aq) + K^+(aq) + Cl^-(aq) \rightarrow AgCl(s) + \underbrace{K^+(aq) + NO_3^-(aq)}$$

Did not change phase
∴ did not actually react
⇨ called *spectator ions*

After the reaction is complete:

- have a precipitated SOLID ionic compound & a SUPERNATANT solution containing spectator ions

Liquid phase "lying above" the solid

- can filter off the solid to separate it from any unreacted (excess) reactants *AND* the spectator ions

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Describing Rxns in Solution: continued…

2. Net ionic equation: only show species that change phase.
Spectator ions are not included.
Must balance (atoms AND charge).
Summarizes overall rxn that occurred.

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

3. Molecular equation: reactants & products as compounds.
Reveals which reagents were involved.

$$AgNO_3(aq) + KCl(aq) \rightarrow AgCl(s) + KNO_3(aq)$$

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Describing the solution reaction of $Pb(NO_3)_2$ & K_2CrO_4

1. Complete ionic equation (how to figure out what happens!)
strong electrolytes shown as ions; solubility trends ⇨ product phases

2. Net ionic equation (summary of what actually changes)
only include components that react, not spectator ions

3. Molecular equation (the big picture)
all reactants and products shown as compounds

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5.10 Stoichiometry of reactions in aqueous sol'n

Before rxn has occurred

1 Identify the species present in the combined solution, and determine what reaction occurs

- Identify types of species present in reactants
- Start with complete ionic equation
- Use solubility trends to predict insoluble products

2 Write the balanced ______ equation for the reaction.

THEN USE SAME APPROACH AS EARLIER (Ch.4)...

3 Calculate the moles of reactants.

4 Determine which reactant is limiting.

5 Calculate the moles of product or products, as required.

6 Convert to grams or other units, as required.

Precipitation: recovering silver ions from solution

What will be the yield of insoluble product when we mix:
150.0 mL of 0.200 M $BaCl_2(aq)$ &
250.0 mL of 0.050 M $AgNO_3(aq)$?
And, what will be present in the supernatant solution?

WHICH EQ'N SHOULD WE USE? *(whichever you like, but...)*

- Conc'ns given for COMPOUNDS ⇨ molecular eqn helpful
- To focus only on product yield ⇨ net ionic eqn helpful
- To focus on **fate of each ion** ⇨ **full ionic eqn** helpful
  limiting *vs.* excess *vs.* completely unreacted...

$$2Ag^{+}(aq) + 2NO_3^{-}(aq) + Ba^{2+}(aq) + 2Cl^{-}(aq) \rightarrow 2AgCl(s) + Ba^{2+}(aq) + 2NO_3^{-}(aq)$$

Ag^+ from $AgNO_3(aq)$ ❶

Cl^- from $BaCl_2(aq)$ ❷

Insoluble product ❸

❶	❷	❸
▪ C = 0.050 M (mol/L...) ▪ V = 0.2500 L n=(0.050M)(0.2500L) = 1.25×10^{-2} mol *compound...* Every 1 mol $AgNO_3$ yields 1 mol Ag^+ $\therefore n_{Ag+} = 1.25\times10^{-2}$ mol *To make AgCl: need same #mol Cl^- to use up all Ag^+...* *...do we have a 1:1 ratio?*	▪ C = 0.200 M ▪ V = 0.1500 L n=(0.200M)(0.1500L) = 3.00×10^{-2} mol *compound...* Every 1 mol $BaCl_2$ yields 2 mol Cl^- $\therefore n_{Cl-} = (2)3.00\times10^{-2}$ mol = 6.00×10^{-2} mol *Now: compare Cl^- to Ag^+*	Require: 1 Ag^+ : 1 Cl^- have: 1.00 : 4.80 $\therefore$ Ag^+ is limiting... $\therefore$ theoretical yield = 1.25×10^{-2} mol AgCl In practical units: = (1.25×10^{-2} mol) x (144.95 g/mol) **= 1.8 g AgCl(s)**

After rxn:
what is the concentration of each ion in the supernatant?

After rxn, what is the concentration of each ion in the supernatant?

$2Ag^+(aq) + 2NO_3^-(aq) + Ba^{2+}(aq) + 2Cl^-(aq) \rightarrow 2AgCl(s) + Ba^{2+}(aq) + 2NO_3^-(aq)$

Ion	Ag^+	Cl^-	Ba^{2+}	NO_3^-
Comments	Limiting reactant	In excess	Spectator	Spectator
Initial quantity	$\#n_{AgNO3}$ = 0.0125 mol	2x $\#n_{BaCl2}$ = 0.0600 mol	$\#n_{BaCl2}$ = 0.0300 mol	$\#n_{AgNO3}$ = 0.0125 mol
Quantity reacted	ALL… 0.0125 mol	Same as Ag^+ 0.0125 mol	None	None
Quantity left in solution	None…	0.0600-0.0125 = 0.0475 mol	0.0300 mol	0.0125 mol
Conc.(M) in final solution	≈ 0 M	= $\frac{0.0475 \text{ mol}}{0.4000 \text{ L}}$ = **0.179 M**	= $\frac{0.0300 \text{ mol}}{0.4000 \text{ L}}$ = **0.0750 M**	= $\frac{0.0125 \text{ mol}}{0.4000 \text{ L}}$ = **0.0313 M**

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Total solution volume ≈ 250.0 + 150.0 mL = 400.0 mL…

Does not require a huge table
(but: table helps ensure you think about EACH ion)…

After rxn, what is the concentration of each ion in the supernatant?

- Ag^+ = limiting reactant ⇨ $[Ag^+] \approx 0$ *(a very tiny amount of AgCl dissolves)*

- Cl^- = excess in solution ⇨ $[Cl^-] = \frac{(0.0600 - 0.0125 \text{ mol})}{(0.2500 + 0.1500 \text{ L})}$ = 0.179 M Cl^-

- NO_3^- & Ba^{2+} = spectator ions, simply diluted now…

  ⇨ $[NO_3^-]$ = (0.0125 mol)/(0.2500 + 0.1500 L) = 0.0313 M NO_3^-

  ⇨ $[Ba^{2+}]$ = (0.0300 mol)/(0.2500 + 0.1500 L) = 0.0750 M Ba^{2+}

(18)

Predicting the products of a precipitation rxn

LEARN THE SALT SOLUBILITY TRENDS: likely soluble if contains…
CATION: ammonium, alkali metals …OR… (but learn key exceptions too)
ANION: halides, nitrate, sulfate, acetate, chlorate, perchlorate

What will happen when the following solutions are mixed?
i.e., if "ion-exchange" takes place…

$Pb(NO_3)_{2(aq)} + CsI_{(aq)} \rightarrow$

$(NH_4)_2SO_{4(aq)} + BaCl_{2(aq)} \rightarrow$

$Ag_2SO_{4(aq)} + NaCl_{(aq)} \rightarrow$

If no precipitation rxn will occur: write NR (no reaction!)

ASSIGNED READINGS

- BEFORE NEXT CLASS:

  Read Ch.5 up to 5.3…

  Master Ch.4 material & exercises

- Practice: identifying precipitation reactions
  writing equations for pptn reactions

- **Practice:** solution stoichiometry problems
  Kotz section 5.10 – don't wait until assigned as homework in tutorials!