

## Chemistry BC2001x: General Chemistry I



Lecture 11: Thursday October 15, 2009

Topics: Equilibrium and  $K_{eq}$ . Solubility and  $K_{sp}$ .

Hand in set 5

Pick up

- 1) Set 6
- 2) Solubility rules
- 3) Solubility examples, for practice answers on course web page.
- 4)  $K_{sp}$  table.

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## Strong and Weak Electrolytes

Definitions are important!

**Strong electrolytes** form ions in solution (never molecules), but they need not be very soluble.

**Insoluble** often means that only a little dissolves in water.

A solution of an insoluble strong electrolyte may not conduct electricity all that well, since there are few ions present.

The acids you will encounter in this course are generally soluble.

	strong electrolyte	weak electrolyte	non-electrolyte
soluble	NaCl	CH <sub>3</sub> COOH acetic acid	sugar, alcohol
insoluble	PbI <sub>2</sub>	C <sub>8</sub> H <sub>17</sub> COOH nonanoic acid	sand

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## Strong and Weak Electrolytes

RULE	EXCEPTIONS
Most acids are weak electrolytes.	The only common strong acids are HCl, HBr, HI, HNO <sub>3</sub> , HClO <sub>4</sub> , and H <sub>2</sub> SO <sub>4</sub> . Note: H <sub>2</sub> SO <sub>4</sub> loses only one H <sup>+</sup> completely; the resulting acidic anion, HSO <sub>4</sub> <sup>-</sup> , dissociates only slightly.
Most bases are weak electrolytes.	Soluble hydroxides (e.g. NaOH, KOH) are strong bases. Note: Slightly soluble Ca(OH) <sub>2</sub> , Sr(OH) <sub>2</sub> , and Ba(OH) <sub>2</sub>
Most salts are strong electrolytes.	Weak electrolytes: HgCl <sub>2</sub> , Hg(CN) <sub>2</sub> . [There are several only moderately strong electrolytes; these include CdCl <sub>2</sub> , CdBr <sub>2</sub> , CdI <sub>2</sub> , and Pb(OAc) <sub>2</sub> .]

The weak bases you will encounter in this course (other than anions conjugate to weak acids, like CH<sub>3</sub>COO<sup>-</sup>) are mostly related to ammonia, NH<sub>3</sub>(aq). They are soluble.

one related weak base is CH<sub>3</sub>NH<sub>2</sub>(aq), methylamine.

Solubility rules: memorize them now!

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## Solubility Product Equilibrium Constants; $K_{sp}$ do not memorize: such data will be provided as needed.

Salt	formula	$K_{sp}$	p $K_{sp}$
Aluminum hydroxide	Al(OH) <sub>3</sub>	$1.9 \times 10^{-33}$	32.74
Aluminum phosphate	AlPO <sub>4</sub>	$1.3 \times 10^{-20}$	10.89
Barium carbonate	BaCO <sub>3</sub>	$8.1 \times 10^{-9}$	8.09
Barium fluoride	BaF <sub>2</sub>	$1.7 \times 10^{-6}$	5.77
Barium sulfate	BaSO <sub>4</sub>	$1.1 \times 10^{-10}$	9.96
Barium sulfite	BaSO <sub>3</sub>	$8.0 \times 10^{-7}$	6.10
Cadmium hydroxide	Cd(OH) <sub>2</sub>	$1.2 \times 10^{-14}$	13.92
Calcium carbonate	CaCO <sub>3</sub>	$4.8 \times 10^{-9}$	8.32
Calcium fluoride	CaF <sub>2</sub>	$3.9 \times 10^{-11}$	10.41
Calcium hydroxide	Ca(OH) <sub>2</sub>	$7.9 \times 10^{-6}$	5.10
Chromium (III) hydroxide	Cr(OH) <sub>3</sub>	$7 \times 10^{-31}$	30.2
Cobalt (III) hydroxide	Co(OH) <sub>3</sub>	$4 \times 10^{-45}$	44.4
Copper (I) chloride	CuCl	$2 \times 10^{-7}$	6.7
Copper (II) hydroxide	Cu(OH) <sub>2</sub>	$2 \times 10^{-19}$	18.7
Copper (II) sulfide	CuS	$8.7 \times 10^{-36}$	35.06

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## Solubility Rules

**MEMORIZE!**

RULE	EXCEPTIONS
1. Salts of the alkali metals ( $\text{Li}^+$ , $\text{Na}^+$ , $\text{K}^+$ , $\text{Rb}^+$ , $\text{Cs}^+$ ) and of the ammonium ion ( $\text{NH}_4^+$ ) are generally <i>soluble</i> .	No common exceptions. [ $\text{KClO}_4$ is only <i>slightly</i> soluble.]
2. Nitrate ( $\text{NO}_3^-$ ), chlorate ( $\text{ClO}_3^-$ ), perchlorate ( $\text{ClO}_4^-$ ), and acetate ( $\text{CH}_3\text{COO}^-$ , or $\text{C}_2\text{H}_3\text{O}_2^-$ , or $\text{OAc}^-$ ) salts are generally <i>soluble</i> .	No common exceptions. [ $\text{KClO}_4$ is only <i>slightly</i> soluble.] [ $\text{AgOAc}$ is only <i>slightly</i> soluble.]
3. Chloride ( $\text{Cl}^-$ ), bromide ( $\text{Br}^-$ ), and iodide ( $\text{I}^-$ ) salts are generally <i>soluble</i> .	$\text{Cu}^+$ (note: <i>not</i> $\text{Cu}^{2+}$ ), $\text{Ag}^+$ , $\text{Pb}^{2+}$ , and $\text{Hg}_2^{2+}$ (note: <i>not</i> $\text{Hg}^{2+}$ ) form <b>insoluble</b> $\text{Cl}^-$ , $\text{Br}^-$ , and $\text{I}^-$ salts, except for <i>slightly</i> soluble $\text{PbCl}_2$ . $\text{Hg}_2$ is <b>insoluble</b> .
4. Sulfate ( $\text{SO}_4^{2-}$ ) salts are generally <i>soluble</i> .	$\text{SrSO}_4$ , $\text{BaSO}_4$ , and $\text{PbSO}_4$ are <b>insoluble</b> . $\text{CaSO}_4$ , $\text{Ag}_2\text{SO}_4$ , and $\text{Hg}_2\text{SO}_4$ are <i>slightly</i> soluble.
5. Carbonate ( $\text{CO}_3^{2-}$ ), phosphate ( $\text{PO}_4^{3-}$ ), sulfite ( $\text{SO}_3^{2-}$ ), and chromate ( $\text{CrO}_4^{2-}$ ) salts are generally <b>insoluble</b> .	The alkali metal and ammonium salts of these anions are soluble (Rule 1). [ $\text{Li}_3\text{PO}_4$ is only <i>slightly</i> soluble.]
6. Sulfide ( $\text{S}^{2-}$ ) salts are generally <b>insoluble</b> .	The alkali metal sulfides $\text{M}_2\text{S}$ and $(\text{NH}_4)_2\text{S}$ are soluble (Rule 1). [The alkaline earth metal sulfides $\text{MS}$ , $\text{Cr}_2\text{S}_3$ , and $\text{Al}_2\text{S}_3$ are <i>decomposed</i> by reaction with $\text{H}_2\text{O}$ .]
7. Hydroxide ( $\text{OH}^-$ ) salts are generally <b>insoluble</b> .	The alkali metal hydroxides $\text{MOH}$ are soluble (Rule 1). (Note: no substance $\text{NH}_4\text{OH}$ exists.) $\text{Ca}^{2+}$ , $\text{Sr}^{2+}$ , and $\text{Ba}^{2+}$ hydroxides are <i>slightly</i> soluble.