Name _____**Chem 161, Section**: _____**Group Number:** _____

ALE 15. Electrolytes and Precipitation Reactions

(Reference: Sections 4.1 – 4.3 in *Silberberg 5th edition*)

When will two aqueous solutes undergo a double displacement reaction?

The Model: Electrolytes

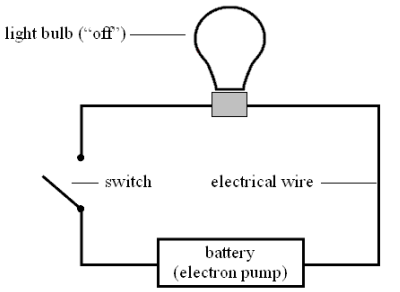

Figure 1A

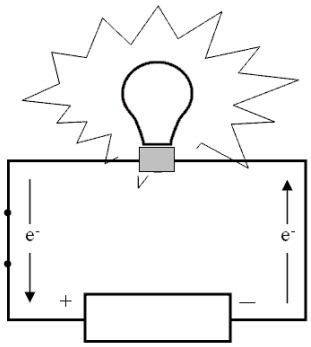

Figure 1B

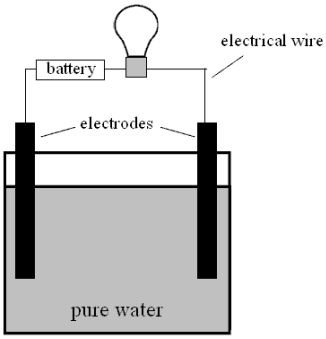

Figure 2A

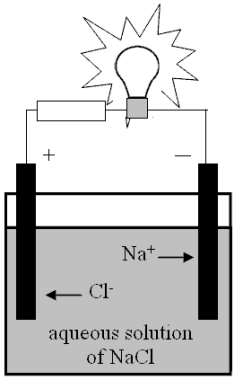

Figure 2B

Key Questions

1. Why is the light bulb in Figure 1A "off" and the one in Figure 1B "on"?

2 a. *Electrons* <u>*cannot*</u> flow from one electrode to the second through the water to "close the circuit" in Figure 2B. Based on the Model, what particles flow through the water, thus "closing the circuit" between the electrodes in Figure 2B?

b. Besides being matter, what do the particles in your answer to Question 2a have in common with the electron? (*Hint*: What do their symbols have in common with the symbol for the electron?)

c. Is water a <u>*molecular*</u> or an <u>*ionic compound*</u>? (Circle your answer.)

d. Why is pure water virtually nonconductive? (*Hint*: According to the Model, what is necessary for electricity to be conducted through a body of water?)

3. Aqueous sodium chloride is an ***electrolyte***. Based on the Model (and Question 2), define what an electrolyte is.

The Model: Solubility Rules

If an amount of a salt is placed in 100 mL of water, the following table describes whether or not the salt will dissolve:

	NO_3^-	$C_2H_3O_2^-$	SO_4^{2-}	Cl^-, Br^-, I^-	S^{2-}	OH^-	CO_3^{2-}, PO_4^{3-}, SO_3^{2-}
NH_4^+	s	s	s	s	s	s	s
Na^+, K^+, Rb^+, Cs^+	s	s	s	s	s	s	s
Ca^{2+}, Sr^{2+}, Ba^{2+}	s	s	ppt[a]	s	s	s[b]	ppt
Ag^+	s	s	ppt[a]	ppt	ppt	ppt	ppt
Hg_2^{2+}, Hg^{2+}	s	s	ppt	ppt[c]	ppt	ppt	ppt
Pb^{2+}	s	s[d]	ppt	ppt[c]	ppt	ppt	ppt
most other metals	s	s	s	s	ppt	ppt	ppt

Legend: **s** ("soluble") = One gram or more of the salt can be dissolved in 100 mL of H_2O.

ppt ("precipitate") = A precipitate forms if as much as 0.1 g of the salt is placed in 100 mL of H_2O.

Footnotes: ***a*** = $CaSO_4$ and Ag_2SO_4 are slightly soluble, so a precipitate is possible. $SrSO_4$ and $BaSO_4$ are insoluble.
b = $Ca(OH)_2$ and $Sr(OH)_2$ are slightly soluble, so a precipitate is possible.
c = $HgCl_2$ is actually a soluble weak electrolyte. $HgBr_2$, $PbCl_2$, and $PbBr_2$ are slightly soluble, so a precipitate is possible.
d = While $Pb(C_2H_3O_2)_2$ is soluble, it is a weak electrolyte.

If MX is a soluble salt, then MX is a ***strong electrolyte*** and "MX(*aq*)" should be written as "M^+(*aq*) + X^-(*aq*)" in an ionic chemical equation. If MX is insoluble, then MX is a ***nonelectrolyte***. The ("molecular") formula of a nonelectrolyte must be written out as a complete neutral formula unit in all chemical equations.

Key Question

4. Why is an insoluble salt a nonelectrolyte? (*Hint*: See Question 2d.)

The Model: Writing Ionic Chemical Equations

The general chemical equation for a double displacement reaction between two salts is

$$AB(aq) + CD(aq) \rightarrow AD + CB$$

where **A** and **C** represent *cations* and **B** and **D** represent *anions*. The double displacement reaction will occur spontaneously **if one of the products is insoluble, either AD or CB in the reaction above**.

Example 1. Reaction between aqueous sodium carbonate and aqueous cobalt (II) chloride:

$$Na_2CO_3(aq) + CoCl_2(aq) \rightarrow ?$$

According to the solubility table, both Na_2CO_3 and $CoCl_2$ are soluble in water. Soluble salts are strong electrolytes, so we can write the reactants as:

$$Na_2CO_3(aq) = 2\ Na^+(aq) + CO_3^{2-}(aq)$$

$$CoCl_2(aq) = Co^{2+}(aq) + 2\ Cl^-(aq)$$

Swapping the ionic partners, we see the products are NaCl and $CoCO_3$. NaCl is soluble in water, but $CoCO_3$ is not. Therefore, the ***total ionic equation*** is:

$$2\ Na^+(aq) + CO_3^{2-}(aq) + Co^{2+}(aq) + 2\ Cl^-(aq) \rightarrow CoCO_3(s) + 2\ Na^+(aq) + 2\ Cl^-(aq)$$

Na^+ and Cl^- aren't doing anything chemically. They're just "spectating" the precipitation going on around them, so we call them **spectator ions**. Eliminating the spectator ions from the total ionic equation, we get the ***net ionic equation***:

$$CO_3^{2-}(aq) + Co^{2+}(aq) \rightarrow CoCO_3(s)$$

Example 2. Mixing of aqueous sodium nitrate and aqueous barium hydroxide:

$$NaNO_3(aq) + Ba(OH)_2(aq) \rightarrow ?$$

Swapping the ionic partners, we see the products are NaOH and $Ba(NO_3)_2$, which are both soluble strong electrolytes. The total ionic equation is:

$$2\ Na^+(aq) + 2\ NO_3^-(aq) + Ba^{2+}(aq) + 2\ OH^-(aq) \rightarrow 2\ Na^+(aq) + 2\ OH^-(aq) + Ba^{2+}(aq) + 2\ NO_3^-(aq)$$

All of the species are spectator ions! So there is ***no reaction***:

$$NaNO_3(aq) + Ba(OH)_2(aq) \rightarrow \text{N.R.}$$

Key Questions

5. Why is the formula of cobalt(II) carbonate *not written* as "$Co^{2+}(aq) + CO_3^{2-}(aq)$" on the product side of the total and net ionic equations in Example 1?

6. Note that "$Na_2CO_3(aq)$" = "2 $Na^+(aq)$ + $CO_3^{2-}(aq)$" in the total ionic equation in Example 1. Why is it wrong to write aqueous sodium carbonate as "$Na_2^{2+}(aq)$ + $CO_3^{2-}(aq)$"?

7. How is the ***net ionic equation*** different from the ***total ionic equation***?

8. In preparation for the following Exercises, determine the solubilities of the following salts from the above solubility table (*Circle your answers*.):

a.	FeI_3	soluble / insoluble	g.	NH_4NO_3	soluble / insoluble
b.	Na_2SO_4	soluble / insoluble	h.	$BaSO_4$	soluble / insoluble
c.	$Fe_2(SO_4)_3$	soluble / insoluble	i.	K_3PO_4	soluble / insoluble
d.	NaI	soluble / insoluble	j.	$Cu(C_2H_3O_2)_2$	soluble / insoluble
e.	$(NH_4)_2SO_4$	soluble / insoluble	k.	$KC_2H_3O_2$	soluble / insoluble
f.	$Ba(NO_3)_2$	soluble / insoluble	l.	$Cu_3(PO_4)_2$	soluble / insoluble

Exercises

Write ***balanced*** total ionic AND net ionic equations for each reaction when the following pairs of aqueous solutions are mixed together. If no reaction occurs, write "N.R." after the reaction arrow. Please, write the phases of all reactants and products. Check that all equations are balanced by both mass and charge!

A. $FeI_3(aq) + Na_2SO_4(aq) \rightarrow$ _____

Total ionic equation:

Net ionic equation:

B. $(NH_4)_2SO_4(aq) + Ba(NO_3)_2(aq) \rightarrow$ _____

Total ionic equation:

Net ionic equation:

C. $K_3PO_4(aq) + Cu(C_2H_3O_2)_2(aq) \rightarrow$ _____

Total ionic equation:

Net ionic equation: