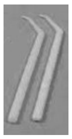
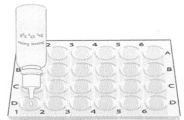
Metathesis Precipitate Reactions

Lab Equipment

 Safety goggles	Regular paper
 toothpick	 24-well reaction plate

Reagents in dropping bottles
0.1 *M* calcium nitrate, $Ca(NO_3)_2$
0.1 *M* copper(II) nitrate, $Cu(NO_3)_2$
0.1 *M* nickel(II) nitrate, $Ni(NO_3)_2$
0.1 *M* zinc nitrate, $Zn(NO_3)_2$
0.1 *M* potassium hydroxide, KOH
0.1 *M* sodium sulfate, Na_2SO_4
0.1 *M* hydrochloric acid, HCl

Background Information

Chemical reactions occur when there is a rearrangement of atoms.
A double replacement reaction occurs when two substances are exchanged. The reaction is

$$AX + BY \rightarrow AY + BX$$

Precipitation often occurs in double replacement reactions. An example is

Molecular equation: $Ba(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow 2\ NaNO_3(aq) + BaSO_4(s)$

Barium sulfate is insoluble in water. It forms a precipitate which can be seen as the reaction occurs. The Na^+ and NO_3^- ions are left in solution. Since there are ionic substances in solution the reaction can be written in its ionic form.

Ionic Equation: $Ba^{2+}(aq) + 2\ NO_3^-(aq) + 2\ Na^+(aq) + SO_4^{2-}(aq) \rightarrow 2Na^+(aq) + 2\ NO_3^-(aq) + BaSO_4(s)$

The sodium and nitrate ions do not undergo a chemical change, so the net reaction is:

Net Ionic Equation: $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

The formation of a precipitate of a new chemical combination is usually considered to be a chemical change. There are general rules for the formation of precipitates that can be used to predict a precipitate reaction. These rules that you are to use for this experiment are more complete than the simple rule that "*All potassium, sodium, ammonium and nitrate compounds are soluble*" which is sufficient for the AP Chemistry Exam

Soluble Compounds

1. All Soluble: **Cations: alkali metal ions and NH_4^+** **Anions: NO_3^-**, $C_2H_3O_2^-$	**No exceptions**
2. Mostly Soluble: Cl^-, Br^-, I^-	Insoluble Exceptions: Ag^+, Pb^{2+}
3. Mostly Soluble: SO_4^{2-}	Insoluble Exceptions: Ag^+, Pb^{2+} Ca^{2+}, Sr^{2+}, Ba^{2+}

Mostly Insoluble Compounds (Carbonates, Phosphates, Sulfides)

1. Mostly Insoluble: CO_3^{2-} (but soluble in acidic solutions)	Soluble Exceptions: alkali metal ions and NH_4^+
2. Mostly Insoluble: OH^- (but soluble in acidic solutions)	
3. Mostly Insoluble: S^{2-}	

There are 6 solutions that you will be mixing to test for double replacement reactions. Combining 6 different solutions 2 at a time would require $\left(\frac{6!}{(6-2)!2!}\right)$, 15 tests:

	$Zn(NO_3)_2$	$Ni(NO_3)_2$	Na_2SO_4	KOH	$Cu(NO_3)_2$	$Ca(NO_3)_2$
$Ca(NO_3)_2$						
$Cu(NO_3)_2$						
KOH						
Na_2SO_4						
$Ni(NO_3)_2$						
$Zn(NO_3)_2$						

However, for a double replacement reaction to occur there must be four unique ions. Some of the possible combinations would not have four unique ions. For example, mixing $Ca(NO_3)_2$ and $Cu(NO_3)_2$ need not be done since the there is no possibility of a new anion combination (both compounds have nitrate ions). After selecting only mixtures with four unique ions, you will only need to perform 8 tests

		1	2
		KOH	Na_2SO_4
A	$Ca(NO_3)_2$		
B	$Cu(NO_3)_2$		
C	$Ni(NO_3)_2$		
D	$Zn(NO_3)_2$		

Procedure

Caveat: In order to avoid problems in shipping, the solutions are dilute and when mixed the individual ions are diluted even more. Because of this the results for this experiment are not always ideal. I've tried and only get precipitates that should have formed about the half the time. Ideally the solutions would be 2 *M* so that on mixing they would be 1 *M*. Then the results would be very reliable. So don't worry if your results are not the expected ones. I would not normally use an experiment that is this unreliable, but I wanted you so see how this type of experiment runs and you will get some precipitates. Also this will give you practice in writing net ionic equations so that makes the experiment worth doing.

Record your results as you get them in the lab notebook and if your results don't match the expected results, just note that the solutions were quite dilute. The WebAssignment for this lab has videos with solutions that are 2 *M* and greater.

Wear safety goggles.

1. Put three drops of $Ca(NO_3)_2$ in wells A1 and A2, three drops of $Cu(NO_3)_2$ in wells B1and B2, three drops of $Ni(NO_3)_2$ in wells C1 and C2, and three drops of $Zn(NO_3)_2$ in wells D1 and D2.

	1	2
A	$Ca(NO_3)_2$	$Ca(NO_3)_2$
B	$Cu(NO_3)_2$	$Cu(NO_3)_2$
C	$Ni(NO_3)_2$	$Ni(NO_3)_2$
D	$Zn(NO_3)_2$	$Zn(NO_3)_2$

2. Put three drops of KOH in wells A1 through D1 (the first column) and three drops of Na_2SO_4 is wells A2-D2.

	1	2
A	$Ca(NO_3)_2$ + KOH	$Ca(NO_3)_2$ + Na_2SO_4
B	$Cu(NO_3)_2$ + KOH	$Cu(NO_3)_2$ + Na_2SO_4
C	$Ni(NO_3)_2$ + KOH	$Ni(NO_3)_2$ + Na_2SO_4
D	$Zn(NO_3)_2$ + KOH	$Zn(NO_3)_2$ + Na_2SO_4

3. Since you know from the solubility rules that sodium, potassium and nitrate ions are all soluble you can view the mixture in terms of ions that could possibly react.

	1	2
A	Ca^{2+} + OH^-	Ca^{2+} + SO^{2-}
B	Cu^{2+} + OH^-	Cu^{2+} + SO_4^{2-}
C	Ni^{2+} + OH^-	Ni^{2+} + SO_4^{2-}
D	Zn^{2+} + OH^-	Zn^{2+} + SO_4^{2-}

A chemical reaction is indicated if there is a change in color or a precipitate (a fine solid) is formed. Use both a light background and a dark background to observe the formation of any precipitates. Describe any changes in the reaction wells and record NR for the cells where there was no noticeable change.

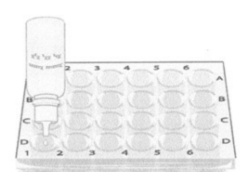
4. Add 3 drops of 0.1 *M* HCl to the most visible hydroxide precipitate, mix, and record the observations along with the reaction that occurred.

5. After recording your observations immerse the reaction plate in a bucket of water to dilute the solutions to harmless levels and the rinse your reaction plate with water. The precipitates are very hard to wash off if they are left standing for a time.

APLab.35	*Metathesis Precipitate Reactions*	DATE

Purpose:
1. To examine the transitions that occur with chemical changes
2. To use empirical evidence to determine the metathesis reactions
3. To examine ways of writing chemical changes as balanced reactions

Apparatus:
24 well spot plate and solutions of ions.
The instructions for this lab can be found in my lab binder.



On mixing the solutions that could possibly make precipitates. Here are my results.

		1	*2*
		KOH	*Na_2SO_4*
A	*$Ca(NO_3)_2$*	*(ppt-weak)*	*ppt*
B	*$Cu(NO_3)_2$*	*ppt*	*NR*
C	*$Ni(NO_3)_2$*	*ppt*	*NR*
D	*$Zn(NO_3)_2$*	*ppt*	*NR*

All the precipitates were white.
Here are the precipitate reactions written in molecular, ionic, and net ionic reactions.
The species are all (aq) unless indicated otherwise:

My zinc hydroxide precipitate was the most opaque precipitate so I added 3 drops of 0.1 M HCl to the well D1 and the precipitate dissolved completely.

Here are the reactions for each of the precipitates and the acid reaction.

A1

This is a weak white ppt and you may or may not see it.

Molecular: $Ca(NO_3)_2 + 2\ KOH \rightarrow Ca(OH)_2(s) + 2\ KNO_3$
Ionic: $Ca^{2+} + 2\ NO_3^- + 2\ K^+ + 2OH^- \rightarrow Ca(OH)_2(s) + 2\ K^+ + 2\ NO_3^-$
Net Ionic: $Ca^{2+} + 2\ OH^- \rightarrow Ca(OH)_2(s)$

A2

Molecular: $Ca(NO_3)_2 + Na_2SO_4 \rightarrow CaSO_4(s) + 2NaNO_3$
Ionic: $Ca^{2+} + 2\ NO_3^- + 2\ Na^+ + SO_4^{2-} \rightarrow CaSO_4(s) + 2\ Na^+ + 2\ NO_3^-$
Net Ionic: $Ca^{2+} + SO_4^{2-} \rightarrow CaSO_4(s)$

B1

Molecular: $Cu(NO_3)_2 + 2\ KOH \rightarrow Cu(OH)_2(s) + 2\ KNO_3$
Ionic: $Cu^{2+} + 2\ NO_3^- + 2K^+ + 2OH^- \rightarrow Cu(OH)_2(s) + 2\ K^+ + 2\ NO_3^-$
Net Ionic: $Cu^{2+} + 2\ OH^- \rightarrow Cu(OH)_2(s)$

C1

Molecular: $Ni(NO_3)_2 + 2\ KOH \rightarrow Ni(OH)_2(s) + 2\ KNO_3$
Ionic: $Ni^{2+} + 2\ NO_3^- + 2\ K^+ + 2\ OH^- \rightarrow Ni(OH)_2(s) + 2\ K^+ + 2\ NO_3^-$
Net Ionic: $Ni^{2+} + 2\ OH^- \rightarrow Ni(OH)_2(s)$

D1

Molecular: $Zn(NO_3)_2 + 2\ KOH \rightarrow Zn\ (OH)_2(s) + 2\ KNO_3$
Ionic: $Zn^{2+} + 2\ NO_3^- + 2\ K^+ + 2\ OH^- \rightarrow Zn(OH)_2(s) + 2\ K^+ + 2\ NO_3^-$
Net Ionic: $Zn^{2+} + 2\ OH^- \rightarrow Zn(OH)_2(s)$

D1 + HCl acid reaction

Molecular: $Zn(OH)_2(s) + 2\ HCl \rightarrow H_2O(l) + ZnCl_2$
Ionic: $Zn(OH)_2(s) + 2\ H^+ + 2\ Cl^- \rightarrow 2\ H_2O(l) + Zn^{2+} + 2\ Cl^-$
Net Ionic: $Zn(OH)_2(s) + 2\ H^+ \rightarrow 2\ H_2O(l) + Zn^{2+}$
