Solubility Rules

Whether or not a reaction forms a precipitate is dictated by the solubility rules. These rules provide guidelines that tell which ions form solids and which remain in their ionic form in aqueous solution. The rules are to be followed from the top down, meaning that if something is insoluble (or soluble) due to rule 1, it has precedence over a higher-numbered rule.

1. Salts formed with group 1 cations and NH_4^+ cations are **soluble**. There are some exceptions for certain Li^+ salts.
2. Acetates ($C_2H_3O_2^-$), nitrates (NO_3^-), and perchlorates (ClO_4^-) are **soluble.**
3. Bromides, chlorides, and iodides are **soluble.**
4. Sulfates (SO_4^{2-}) are **soluble** with the exception of sulfates formed with Ca^{2+}, Sr^{2+}, and Ba^{2+}.
5. Salts containing silver, lead, and mercury (I) are **insoluble.**
6. Carbonates (CO_3^{2-}), phosphates (PO_4^{3-}), sulfides, oxides, and hydroxides (OH^-) are **insoluble**. Sulfides formed with group 2 cations and hydroxides formed with calcium, strontium, and barium are exceptions.

If the rules state that an ion is soluble, then it remains in its aqueous ion form. If an ion is insoluble based on the solubility rules, then it forms a solid with an ion from the other reactant. If all the ions in a reaction are shown to be soluble, then no precipitation reaction occurs.

Name: _____ Regents Chemistry

Predicting Precipitation Reactions

Directions: To predict whether a precipitation reaction will take place between two aqueous solutions and if the answer is yes, to write the complete equation for the reaction.

Ex. $Li_2CO_3(aq) + Al(NO_3)_3(aq) \rightarrow ?$

Remember: Double replacement reactions follow the general equation:

AB + CD → AD + CB

Here is an example:

STEP 1: Write the formulas for the products
Caution: Forgetting to check the charges and criss-cross if necessary will result in an incorrect answer!

Ex: $Li_2CO_3(aq) + Al(NO_3)_3(aq) \rightarrow LiNO_3 + Al_2(CO_3)_3$

STEP 2: Use the SOLUBILITY GUIDLELINES on your Reference Tables (Table F!) to determine whether either of the possible products is water **insoluble**. If either possible product is insoluble, a precipitation reaction takes place, and continue to Step 3. If neither is insoluble, write "no reaction".

Ex. $LiNO_3$ = soluble (all nitrates soluble)
$Al_2(CO_3)_3$ = insoluble (carbonates insoluble; aluminum not an exception)

STEP 3: Put an (s) for solid next to the **insoluble** product. This is the precipitate formed in the reaction. It does not dissolve. Put (aq) next to the compound that is water-soluble.

Ex: $Li_2CO_3(aq) + Al(NO_3)_3(aq) \rightarrow LiNO_3$**(aq)** $+ Al_2(CO_3)_3$**(s)**

STEP 4: Balance the equation.

Ex: $3\ Li_2CO_3(aq) + 2\ Al(NO_3)_3(aq) \rightarrow 6\ LiNO_3(aq) + \_\ Al_2(CO_3)_3(s)$

Practice:

1. $Pb(NO_3)_2(aq) + LiBr(aq) \rightarrow$

2. $MgCl_2(aq) + NaOH(aq) \rightarrow$

3. $AgNO_3(aq) + NaCl(aq) \rightarrow$

4. $KNO_3(aq) + MgI_2(aq) \rightarrow$

Over →

Circle the precipitate in the following reactions.

1. $3KOH(aq) + Fe(NO3)_3(aq) \rightarrow Fe(OH)_3 + 3KNO_3$

2. $K_2SO_4(aq) + Pb(NO_3)_2(aq) \rightarrow 2KNO_3 + PbSO_4$

3. $3CaCl_2(aq) + 2Na_3PO_4(aq) \rightarrow Ca_3(PO_4)_2 + 6NaCl$

4. $Cu_2SO_4(aq) + BaCl_2(aq) \rightarrow 2CuCl + BaSO_4$

Precipitation Reactions Worksheet

Write chemical, complete ionic, and net ionic equations for the following reactions that may produce precipitates. Use NR to indicate that no reaction occurs.

1. Aqueous solutions of potassium iodide and silver nitrate are mixed.

2. Aqueous solutions of ammonium phosphate and sodium sulfate are mixed.

3. Aqueous solutions of aluminum chloride and sodium hydroxide are mixed.

4. Aqueous solutions of lithium sulfate and calcium nitrate are mixed.

5. Aqueous solutions of iron (II) sulfate and barium hydroxide are mixed.

6. $NH_3SO_4(aq) + BaCl_2(aq) \rightarrow$

7. $Na_2S(aq) + NiSO_4(aq) \rightarrow$

8. $Al(NO_3)_3(aq) + Na_3PO_4(aq) \rightarrow$

9. $(NH_4)_2CO_3(aq) + MgSO_4(aq) \rightarrow$

10. $Ca(OH)_2(aq) + Na_2SO_4(aq) \rightarrow$

Precipitate Lab

Procedure

1. Use masking tape and a pen to label 2 plastic cups Baking Soda Solution and Calcium Chloride Solution.

2. Use a graduated cylinder to add 20 mL of water to each cup.

3. Add 2 g (about ½ teaspoon) of calcium chloride to the water in its labeled cup. Swirl until as much of the calcium chloride dissolves as possible.

4. Add 2 g (about ½ teaspoon) of baking soda to the water in its labeled cup. Swirl until as much of the baking soda dissolves as possible. Some undissolved baking soda may remain in the bottom of the cup.

5. Carefully pour the baking soda solution into the calcium chloride solution. Try not to pour in any undissolved baking soda. Observe.

1. What do you observe when you combine baking soda solution and calcium chloride solution?

2. How do you know that a chemical reaction occurs when you combine baking soda solution and calcium chloride solution?

5. Take a look at the chemical equation for the reaction between calcium chloride and sodium bicarbonate. **Balance it.** Then answer the following questions.

$$\underset{\text{calcium chloride}}{CaCl_2} + \underset{\text{sodium bicarbonate}}{NaHCO_3} \rightarrow \underset{\text{calcium carbonate}}{CaCO_3} + \underset{\text{sodium chloride}}{NaCl} + \underset{\text{water}}{H_2O} + \underset{\text{carbon dioxide}}{CO_2}$$

What gas is produced in the chemical reaction?

What do you think is the precipitate?

Question to Investigate

Can you separate the calcium carbonate from the rest of the products?

Materials for Each Group

- Coffee filter or paper towel
- Tall clear plastic cup

Procedure

1. Use a large enough coffee filter (or paper towel) so that you can push it about ⅓ of the way into the cup and still have enough left to hold it around the outside of the cup.

2. While holding the coffee filter in place, pour the products into the center of the coffee filter.

3. Allow the liquid to drip through the filter. This may take a while.

4. Set the precipitate aside and allow the water to evaporate.

Is filtering the calcium carbonate and allowing the water to evaporate a chemical change or a physical change? Why?