# The Seven Solution Problem

(Adapted from *Chemistry in Microscale* by Eherenkranz and Mauch, Kendall/Hunt, 1992)

## Background

Before beginning this experiment, re–read the sections in your textbook concerning ionic reactions and net ionic equations.

When ionic compounds are dissolved in water their ions are freed from the solid crystal lattice and distributed homogeneously throughout the solution. If two aqueous ionic solutions are mixed, the cation from one solution may react with the anion from the other to form a precipitate, a gas, a molecular compound, or a complex ion. There is also the possibility that no reaction will occur.

When aqueous lead (II) nitrate reacts with aqueous sodium phosphate, the possible reaction is:

$$3Pb(NO_3)_{2\,(aq)} + 2Na_3PO_{4\,(aq)} \longrightarrow 6NaNO_{3\,(?)} + Pb_3(PO_4)_{2\,(?)}$$

By checking the solubility rules following the procedure it can be seen that one of the products, $NaNO_3$, is soluble while the other, $Pb_3(PO_4)_2$, is not. The total ionic equations is:

$$3Pb^{2+}{}_{(aq)} + 6NO_3^-{}_{(aq)} + 6Na^+{}_{(aq)} + 2(PO_4)^{3-} \longrightarrow 6Na^+{}_{(aq)} + 6NO_3^-{}_{(aq)} + Pb_3(PO_4)_{2\,(s)}$$

Elimination of the "spectator ions" leaves the net ionic equation:

$$3Pb^{2+}{}_{(aq)} + 2(PO_4)^{3-}{}_{(aq)} \longrightarrow Pb_3(PO_4)_2$$

When the solutions are mixed, the formation of insoluble $Pb_3(PO_4)_2$ would be observed as a precipitate.

When HCl(aq) which is colorless is added to $CuSO_4$(aq) which is blue, the resultant solution is green. This is due to the formation of the $CuCl_4^{2-}$ complex ion.

$$Cu^{2+}{}_{(aq)} + 4Cl^-{}_{(aq)} \longrightarrow CuCl_4^{2-}{}_{(aq)}$$

When HCl(aq) is added to $Na_2S$(aq), the formation of the molecular gas, $H_2S$, can be detected by the gas bubbles which form and by the distinctive "rotten egg" odor of the gas.

$$2H^+ + S^{2-} \longrightarrow H_2S_{(g)}$$

The above examples demonstrate that there are several ways in which the occurrence of ionic reactions can be observed. Sometimes there is no odor or visible change, but there is a temperature change, and of course, there may be no reaction.

In this experiment, you will react each of the following solutions with each of the others.

| | | |
|---|---|---|
| 0.1 M $AgNO_3$ | 0.1 M $FeCl_3$ | 0.1 M NaCl |
| 0.1 M $Pb(NO_3)_2$ | 0.1 M $Ba(NO_3)_2$ | 0.1 M $Na_2SO_4$ |
| 0.1 M KSCN | | |

When you have recorded all your observations in the table provided, you will receive an unknown consisting of seven numbered vials. Each vial will contain one of the solutions listed above. By reacting each solution with each of the others, you will identify and report the identity of the solution in each vial.

## Equipment

From the stockroom:
6 micro test tubes

From your drawer:
2 beakers

## Procedure

Obtain six micro test tubes from the stockroom. Clean them using a cotton swab as a test tube brush and rinse them with deionized water. Use a beaker to hold the test tubes. Put five to ten drops of silver nitrate solution in each test tube. Add to each of these about the same amount of one of the other solutions. Mix well. Wait for at least a minute and report your observations in the table provided. Empty the test tubes into your waste beaker and rinse them with deionized water. Clean the test tubes. Put five to ten drops of lead nitrate solution into five of the test tubes and mix it with equal amounts of the others, except silver nitrate, which it has already been mixed with. Mix well. Wait for at least a minute and report your observations. Continue this process until each solution has been mixed with each of the others. Empty your waste beaker into the **aqueous metal waste container**.

Write a net ionic equation for each reaction. There are twenty–one possibilities. If there is no reaction write NR.

Obtain a set of unknown solutions from your instructor. ***Record the unknown letters.*** Repeat the above procedure with each of the numbered unknown solutions. Report your results in the table provided. Empty your waste beaker into the **aqueous metal waste container**.

Report the identity of each of the unknown solutions.

## SOLUBILITY RULES

1. All ionic compounds containing $Na^+$, $K^+$, and $NH_4^+$ are soluble.
2. All ionic compounds containing $NO_3^-$ are soluble.
3. All ionic compounds containing $C_2H_3O_2^-$ are soluble except $AgC_2H_3O_2$.
4. All ionic compounds containing $Cl^-$, $Br^-$, and $I^-$ are soluble except AgCl, AgBr, AgI, $PbCl_2$*, $PbBr_2$, $PbI_2$, $Hg_2Cl_2$, $Hg_2Br_2$, and $Hg_2I_2$. (*$PbCl_2$'s solubility is very dependent on concentration and temperature.)
5. All ionic compounds containing $F^-$ are soluble except $MgF_2$, $CaF_2$, $SrF_2$, $BaF_2$, and $PbF_2$.
6. All ionic compounds containing $SO_4^{2-}$ are soluble except $BaSO_4$, $SrSO_4$, and $PbSO_4$. ($Ag_2SO_4$ and $CaSO_4$ are slightly soluble)
7. All ionic compounds containing $OH^-$ are insoluble except NaOH, KOH, and $Ba(OH)_2$.
8. All ionic compounds containing $S^{2-}$ are insoluble except $Na_2S$, $K_2S$, $(NH_4)_2S$, MgS, CaS, SrS, and BaS.
9. All ionic compounds containing $CO_3^{2-}$, $PO_4^{3-}$, and $CrO_4^{2-}$ are insoluble except $Na_2CO_3$, $Na_3PO_4$, $Na_2CrO_4$, $K_2CO_3$, $K_3PO_4$, $K_2CrO_4$, $(NH_4)_2CO_3$, $(NH_4)_3PO_4$, and $(NH_4)_2CrO_4$.
10. All common acids are soluble.

**Acids:** HCl, HBr, HI, $HNO_3$, $HClO_4$, and $H_2SO_4$ are strong. Other common acids are weak.

**Bases:** $NH_3$ is the only weak base usually considered in Chem 108.