EXPERIMENT 5

Reactions of Anions with Cations

This experiment is assigned on page 184 of the textbook.

FOR THE INSTRUCTOR

This experiment can either be done (1) in laboratory or (2) as a demonstration with discussion. As a demonstration this experiment involves a lot of mixing, so ahead of time I set up four racks of eight large test tubes. The first test tube in each rack is 40% filled with the solution of Cs^+, the second rack with the solution of K^+, and so on for the remaining test tubes with the solutions of Ag^+, Mg^{2+}, Sr^{2+}, Hg^{2+}, Zn^{2+}, and Al^{3+}. The night before class I add an equal volume of the sulfate solution to each test tube in the second rack, mix, and let the test tubes sit—some sulfates are slow to precipitate.

During class I add an equal volume of the perchlorate salt to each test tube in the first rack, mix, and hold the rack of test tubes up for the students to observe. Then I hold up the second rack containing the pre-mixed cation and sulfate solutions, for the solutions to see the results. Then I add an equal volume of the phosphate solution to each test tube in the third rack, mix, and hold up the rack of test tubes. Likewise I add an equal volume of the silicate solution to each test tube in the fourth rack (the results will be very similar to those with the phosphate solution).

SOLUTIONS REQUIRED (salts required to make 100 L of each solution): Note that starred (*) solutions were also used in a preceding Experiment.

1 M $AgNO_3$ (8.5g/50 mL)	1 M $NaClO_4$*
0.33 M $AlCl_3$ (8.0 g 6-hydrate)	0.5 M K_2CrO_4* (optional)
1 M CsCl*	<1 M $KMnO_4$* (optional)
0.5 M $Hg(NO_3)_2$ (17.1 f hydrate; add a few drops conc. HNO_3	
1 M KNO_3 (optional)	0.5 M $MgCl_2$ (10.2 g 6-hydrate)
0.33 M K_3PO_4*	0.5 M $SrCl_2$ (13.3 g 6-hydrate)
0.5 M Na_2SO_4*	0.5 M $ZnCl_2$ (6.8 g)
0.25 M Na_4SiO_4*	1 M KCl (7.4 g)

FOR THE STUDENTS

In this experiment, we investigate what happens when cations of varying acidity are combined with oxo anions of varying basicity.

A. PLANNING THE EXPERIMENT. 1. We study the reactions of the following eight cations: Cs^+, K^+, Ag^+, Mg^{2+}, Sr^{2+}, Hg^{2+}, Zn^{2+}, and Al^{3+}. Recalling the principles of Chapter 2, give the category of acidity of each cation. Then try to arrange the ions within each category in order of increasing acidity, so that, when you list all eight ions, they will all be in order of increasing acidity. Finally, check yourself by listing the pK_a values for the ions (Table 2.1). (You probably will not be precisely right, since the rules of thumb in Chapter 2 are not exact, but the ordering you predict should put the pK_a values reasonably close to the correct order.)

2. We now prepare to study the reactions of the above eight cations with the following four oxo anions: SiO_4^{4-}, SO_4^{2-}, PO_4^{3-}, and ClO_4^-. List these four anions in order of increasing basicity, and give the category of basicity and the approximate pK_b for each.

B. EXPERIMENTAL. Test the reactions of each of the eight cations with each of the four anions. For each test, mix equal volumes (say, one eyedropperful) of the two solutions, mix well, and allow a minute (if necessary) for the reaction to occur. Note whether the test tubes get hot or cold. Describe the reactions and list your observations in tabular form, listing the eight cations down one side of the table in a logical order, and listing the four anions across the top of the table in a logical order.

C. ANALYSIS OF THE RESULTS 1. What do we call the kind of reaction that occurs in some of the test tubes? Write the formulas of some of the products.

2. How does the tendency for this kind of reaction appear to relate to the acidity and basicity of the cations and anions involved?

3. Predict which categories of metal cations would give insoluble salts with each of the following anions: selenate, permanganate, chromate, carbonate, and nitrate. If a solution of one of these ions is available, test your predictions using the eight available cations. Check your answers for one of the anions that is not available by looking up the solubilities of the salts of that ion in the Handbook of Chemistry and Physics.