Experiment 1: Reactions Of Anions With Cations[1]

1. In this experiment we will investigate what happens when cations of varying acidity are combined with oxo anions of varying basicity. We will study the reactions of the following eight cations: Cs^+, K^+, Ag^+, Mg^{2+}, Sr^{2+}, Hg^{2+}, Zn^{2+}, Al^{3+}. Arrange the ions in order of increasing acidity. The pK_a values for the ions are as follows:

Cs^+	14.7	Sr^{2+}	13.3
K^+	14.5	Hg^{2+}	3.4
Ag^+	12.0	Zn^{2+}	9.0
Mg^{2+}	11.4	Al^{3+}	5.0

2. We will study the reactions of the above eight cations with the following four oxo anions: SiO_4^{4-}, SO_4^{2-}, PO_4^{3-}, ClO_4^-. List these four in order of increasing basicity. The pK_b values for the ions are as follows:

SiO_4^{4-}	-8.0	PO_4^{3-}	2.0
SO_4^{2-}	12.1	ClO_4^-	22.6

3. Test the reactions of each of the eight cations in part 1 with each of the four anions in part 2. 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 logical order, and listing the four anions across the top of the table in a logical order.

4. Write the formulas of some of the products.

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

6. Predict which metal cations would give insoluble salts with each of the following anions: selenate (pK_b=12.0), permanganate (pK_b=22.6), chromate (pK_b=7.5), carbonate (pK_b=6.7), nitrate (pK_b=16.9). Test your predictions using the eight available cations with one of the oxoanions. Check your answers for one of the anions that is not available by looking up the solubilities of the salts of the ion in the *Handbook of Chemistry and Physics.*

7. The perbromate ion was first synthesized in the 1960s in minute quantities by the radioactive decay of $*SeO_4^{2-}$. How would you go about separating the BrO_4^- ion from the selenate ion?

8. According to solubility tables, they state that all hydroxides are insoluble except for the strong bases (Li^+, Na^+, K^+, Rb^+, Cs^+, Ca^{2+}(I don't agree with this one!), Sr^{2+}, and Ba^{2+}). Consider the hydroxide anion as a type of oxo anion. Is this rule consistent with the principles learned in part 5?

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[1] Adapted from *Inorganic Chemistry,* G. Wulfsberg, University Science Books, Sausolito, CA, 2000.