Testing for Ions

What kinds of substances are present in a glass of water? We know that there are molecules of water (H₂O) present, but are there other substances as well? People often say that water from a different area has a different taste. Could there be small amounts of substances dissolved in a water sample from one area that gives it a different composition from another sample of water?

In fact, drinking water does contain many different substances (Figure 1). Some are added deliberately during the process of water purification. But many substances in water occur naturally. As rainwater passes through the ground, minerals dissolve into the water. These minerals are ionic compounds that may contain ions such as calcium (Ca²⁺), magnesium (Mg²⁺), iron (Fe³⁺), chloride (Cl⁻), nitrate (NO₃⁻), or sulfate (SO₄²⁻).

One method of detecting these ions is to use chemical tests. Such tests can also be used to identify unknown ions. A positive test for a substance is one that clearly indicates the substance is present. A positive test for a dissolved ion may produce an insoluble precipitate or it may produce a coloured product. In this investigation, you will use chemical tests to investigate the ions that are dissolved in water.

Question

How can samples of water be tested for the presence of chloride ions (Cl⁻), sulfate ions (SO₄²⁻), and iron ions (Fe³⁺)?

Design

In this investigation you will test solutions containing three known ions with various testing solutions. You will then test some unknown solutions with the same testing solutions and compare your observations to determine which ions are present in the unknown solutions.

(a) Plan a table to record your observations. Write the names of the testing solutions along the top and the names of the known solutions and the codes for the unknown ones on the side.

Materials

- apron
- safety goggles
- testing solutions:
  - silver nitrate solution (0.5% or 0.03 mol/L)
  - barium chloride solution (2% or 0.1 mol/L)
  - potassium thiocyanate solution (1% or 0.1 mol/L)
- sample solutions:
  - potassium chloride solution (3% or 0.4 mol/L)
  - sodium sulfate solution (3% or 0.2 mol/L)
  - iron(III) nitrate solution (3% or 0.1 mol/L)
- unknown solutions:
  - teacher-provided solutions containing one or more ions
  - samples of water from various sources (tap water, bottled waters, etc.)
- labelled microdroppers
- microtrays

Silver nitrate solution is toxic and can stain skin and clothing. Barium chloride and potassium thiocyanate are toxic. Iron (III) nitrate is an irritant. Any spills on the skin, in the eyes, or on clothing should be washed immediately with cold water.
Part 1: Testing Known Solutions

Procedure

1. Put on your apron and safety goggles.

2. Obtain a microdropper containing potassium chloride solution (source of chloride ion) and a second microdropper containing silver nitrate solution.

3. Add one or two drops of the first solution to one of the wells on the microtray. Add one or two drops of the second solution to the same well (Figure 2). Record your observations, particularly noting the appearance and colour of both starting materials and any product.

4. Obtain a microdropper containing sodium sulfate solution (source of sulfate ion) and a microdropper containing barium chloride solution. Repeat step 3 in another well on the microtray. Record your observations.

Avoid cross-contamination of microdroppers and solutions; let solutions “free-fall” into the microtray wells rather than touching the dropper to the microtray.

5. Obtain a microdropper containing iron(III) nitrate solution (a source of iron(III) ions) and a microdropper containing potassium thiocyanate solution. Repeat step 3 in another well on the microtray. Record your observations.

Part 2: Testing Unknown Solutions

6. Obtain a microdropper containing one of the unknown solutions provided by your teacher. Use the testing solutions in separate microtray cells to determine whether chloride, sulfate, or iron(III) ions are present in the solution. Record your observations.

7. Repeat step 6 for other unknown solutions.

8. Dispose of the mixtures and put away your materials as directed by your teacher. Clean up your workstation. Wash your hands.

Analysis

(b) Make a table to summarize the observations that indicate a positive test for chloride, sulfate, and iron(III) ions. Possible headings could be: Type of ion, Reagent solution added, and Observation for positive test.

(c) Make a table to summarize your analyses of the unknown solutions.

Understanding Concepts

1. (a) Explain what is meant by a positive test for an ion.

(b) Describe two types of changes that demonstrate a positive test.

2. Write chemical formulas for the following substances:
   (a) silver nitrate
   (b) barium chloride
   (c) sodium sulfate
   (d) iron(III) nitrate

3. Why do you think chemical tests, similar to the tests used in this investigation, are called qualitative analyses?

4. If a silver nitrate solution is added to a potassium chloride solution and a precipitate forms, what are the names and formulas of the possible products?

Exploring

5. Suppose that you were asked to determine whether an ion was present in a solution and how much ion was present.

(a) Compare the amounts of precipitate that you would expect if you added barium chloride to two solutions that contained different amounts of sulfate ion.

(b) Compare the colour intensity that you would expect if you added potassium thiocyanate to two solutions that contained different amounts of iron(III) ion.

(c) Design an experiment to compare the amount of chloride, sulfate, or iron(III) ion present in a solution.