Testing for negative ions

This activity is in two parts – in the first, students make observations while carrying out the tests for various negative ions. In the second, they use their observations to help them identify the negative ions present in a number of unknown solutions. To make the second part of the exercise more challenging, tests for positive ions could be introduced and students could be asked to identify both the positive and negative ions present in a solution.

Equipment required

The exact concentrations of the test solutions are not important. Use approximately 0.1–0.5 mol dm^{-3} for salt solutions and 0.5–1.0 mol dm^{-3} for acid solutions, except for nitric acid, which is corrosive at such concentrations (use 0.4 mol dm^{-3} instead).

- Test-tubes
- Dropping pipettes (these can be used just for the carbon dioxide testing or also for dispensing solutions; if the latter, far more pipettes will be required)
- Nitric acid 0.4 mol dm^{-3} (Irritant)
- Silver nitrate solution 0.1 mol dm^{-3}
- Barium chloride solution 0.1 mol dm^{-3} (Harmful)
- Hydrochloric acid
- Aluminium powder (Highly flammable)
- Sodium hydroxide solution less than 0.5 mol dm^{-3} (Irritant)
- Limewater
- Red litmus paper
- Ammonia solution 0.4 mol dm^{-3}.

For the initial observations

- Sodium or potassium chloride solution
- Sodium or potassium bromide solution
- Sodium or potassium iodide solution
- Sulfate solution, eg sodium sulfate
- Carbonate solution, eg potassium carbonate
- Nitrate solution, eg potassium nitrate.

For testing unknowns

The number of unknowns required depends on the time available. It is a good idea to use at least four solutions to ensure students are challenged. Label the solutions A, B, C etc and make sure you know which is which.

Health and safety

Wear eye protection.

Barium chloride solid is toxic; the 0.1 mol dm^{-3} solution is harmful. Wash your hands after use and warn students to do the same.

Ammonia solution is an irritant when concentrated but not at the concentrations used by students in this activity. However, it can give off ammonia vapour, which can irritate the eyes and lungs. Keep the lid on the bottle when not in use.

Nitric acid is an irritant.

Silver nitrate solution can stain skin and clothes.

Further problem solving ideas

There are several suggestions in C. Wood, Creative Problem Solving in Chemistry, London: Royal Society of Chemistry, 1993

Tests for negative ions – expected observations

Negative ion	Test	Observations
Cl^- chloride	Add a few drops of dilute nitric acid followed by a few drops of silver nitrate solution. Let the mixture stand for a few minutes and then add some ammonia solution.	A white precipitate forms which discolours on standing. The precipitate is soluble in ammonia solution.
Br^- bromide	"	A cream precipitate forms which discolours a little on standing. The precipitate is slightly soluble in ammonia solution.
I^- iodide	"	A yellow precipitate forms which does not discolour on standing. The precipitate is insoluble in ammonia solution.
SO_4^{2-} sulfate	Add a few drops of barium chloride solution and then a few drops of hydrochloric acid.	A white precipitate forms.
CO_3^{2-} carbonate	Put a small amount of limewater into a test-tube (no more than 1 cm^3). Put your sample in a separate test-tube and add a few drops of hydrochloric acid. Using a pipette, collect the gas given off and bubble it through the limewater. (Note: you can also do this test on a solid sample.)	Bubbles of gas form. The gas turns the limewater milky, which shows that it is carbon dioxide.
NO_3^- nitrate	Add a few drops of sodium hydroxide solution and a little aluminium powder. Warm the solution in a Bunsen flame and test any gas given off using red litmus paper.	A gas is given off which turns the litmus blue. This shows that the gas is ammonia.

Equations

$NaCl(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + AgCl(s)$

$Cl^-(aq) + Ag^+(aq) \rightarrow AgCl(s)$ (and similarly for Br^- and I^-)

$Na_2SO_4(aq) + BaCl_2(aq) \rightarrow 2\,NaCl(aq) + BaSO_4(s)$

$SO_4^{2-}(aq) + Ba^{2+}(aq) \rightarrow BaSO_4(s)$

$2\,HCl(aq) + Na_2CO_3(aq) \rightarrow 2\,NaCl(aq) + H_2O(l) + CO_2(g)$

$CO_3^{2-}(aq) + 2H^+(aq) \rightarrow CO_2(g) + H_2O(l)$

For completeness, the reaction with the nitrate ion is shown below. It is unlikely that students will be able to construct this for themselves and the student sheet does not ask them to do so.

$8Al(s) + 3NO_3^-(aq) + 5OH^-(aq) + 18H_2O(l) \rightarrow 8[Al(OH)_4]^-(aq) + 3NH_3(g)$

Testing for negative ions – making observations

This activity is in two parts. In the first part you observe the reactions of various negative ions and in the second you use those observations to identify unknown solutions.

Use the table **Tests for negative ions** to record your observations during each test. Use a clean test-tube each time or wash up thoroughly between tests using distilled or deionised water to avoid contamination. Use a small portion of the test solution each time (no more than 1 cm^3).

Write balanced symbol equations for the reaction that occurs in each of the tests (except the test for a nitrate).

Health and safety

Wear eye protection.
Take extra care when dealing with unknown solutions.
At the concentrations used in this experiment:

- Barium chloride solution is harmful; wash your hands after use.
- Sodium hydroxide is an irritant.
- Ammonia solution can give off ammonia vapour, which can irritate the eyes and lungs. Keep the lid on the bottle when not in use.
- Nitric acid is an irritant.
- Silver nitrate can stain skin and clothes.

Tests for negative ions

Negative ion	Test	Observation
Cl^- Chloride	Add a few drops of dilute nitric acid followed by a few drops of silver nitrate solution. Let the mixture stand for a few minutes and then add some ammonia solution.	
Br^- Bromide	Add a few drops of dilute nitric acid followed by a few drops of silver nitrate solution. Let the mixture stand for a few minutes and then add some ammonia solution.	
I^- Iodide	Add a few drops of dilute nitric acid followed by a few drops of silver nitrate solution. Let the mixture stand for a few minutes and then add some ammonia solution.	
$SO_4\ 2^-$ Sulfate	Add a few drops of barium chloride solution and then a few drops of hydrochloric acid.	
$CO_3\ 2^-$ Carbonate	Put a small amount of limewater into a test-tube	

	(no more than 1 cm3). Put your sample in a separate test tube and add a few drops of hydrochloric acid. Using a pipette, collect the gas given off and bubble it through the limewater. (Note: you can also do this test on a solid sample.)	
NO_3^- Nitrate	Add a few drops of sodium hydroxide solution and a little aluminium powder. Warm the solution in a Bunsen flame and test any gas given off using red litmus paper.	

Testing for negative ions – identifying unknowns

Using the observations chart you made in Testing for negative ions – making observations, test the unknown solutions provided and identify the negative ions present. Make careful observations, including any negative results. You may need to try a number of tests before you get a positive result.

Design a table to record your observations.

You may wish to use the headings: Unknown sample; Test tried; Observations; and Conclusion.

Health and safety

Wear eye protection.
Take extra care when dealing with unknown solutions. At the concentration used in this experiment:

- Barium chloride solution is harmful; wash your hands after use.
- Sodium hydroxide is an irritant.
- Ammonia solution can give off ammonia vapour, which can irritate the eyes and lungs. Keep the lid on the bottle when not in use.
- Nitric acid is an irritant.
- Silver nitrate can stain skin and clothes.