

Reactions of halogens (as aqueous solutions)

Class practical or Demonstration

This activity compares the colours of three **halogens** in aqueous solution and in a **non-polar solvent**. These halogens also react to a small extent with water, forming acidic solutions with **bleaching** properties.

Halogens undergo **redox** reactions with **metal halides** in solution, displacing less reactive halogens from their compounds. These **displacement** reactions are used to establish an order of **reactivity** down **Group 17** of the periodic table.

Lesson organisation

This series of simple experiments illustrates some of the chemical properties of the halogens following an introduction to the physical properties of the Group 17 elements. It can be done as a demonstration or as a class experiment.

Investigating the solubility of the halogens in a non-polar solvent can be left out, or only shown as a demonstration.

If the activity is done as a demonstration it should take around 15 minutes. If it is done as a class experiment you should allow 30 minutes.

Apparatus	Chemicals
Eye protection One demonstration or one group of students requires: Test-tube rack, to hold 10 test-tubes Test-tubes, 10 Cork or rubber bungs to fit, 4 Plastic dropping pipettes, 6 White spotting tile White tile Glass rod Paper towel or tissue	About 10 cm ³ of each of the following halogen solutions in stoppered test-tubes (Notes 1 and 2): Chlorine water, 0.1% (w/v) (HARMFUL) Bromine water, 0.1% (w/v) (HARMFUL) Iodine solution, 0.1 M Half a test-tube of 0.1 M solutions of each of the following: Potassium chloride Potassium bromide Potassium iodide Universal Indicator paper (about 2 cm strips), 3 <i>Optional:</i> Cyclohexane (HIGHLY FLAMMABLE, HARMFUL, DANGEROUS FOR THE ENVIRONMENT) or other suitable non-polar solvent, about 10 cm ³ (Note 1) Refer to Health & Safety and Technical notes section below for additional information.

Health & Safety and Technical notes

[Read our standard health & safety guidance](#)

Wear eye protection.

Chlorine water, Cl₂ (aq). The solution itself is LOW HAZARD but chlorine gas (TOXIC, DANGEROUS FOR THE ENVIRONMENT) escapes, so a HARMFUL label would be sensible. See CLEAPSS Hazcard and CLEAPSS Recipe Book.

Bromine water, Br₂ (aq), (HARMFUL) - see CLEAPSS Hazcard and CLEAPSS Recipe Book.

Iodine solution, I₂ (aq) - iodine solution is actually iodine dissolved in aqueous potassium iodide - see CLEAPSS Hazcard and CLEAPSS Recipe Book.

Potassium chloride, KCl (aq), potassium bromide, KBr (aq) and potassium iodide, KI (aq) solutions are all LOW HAZARD - see CLEAPSS Hazcard and CLEAPSS Recipe Book. The sodium salts can be used if the potassium salts are not available. The concentration of the potassium iodide solution should be adjusted so that it gives a light brown solution on addition of chlorine water. If the reagents are too concentrated, a black precipitate of iodine often results instead of a brown solution.

Cyclohexane, C₆H₁₂ (l), (HIGHLY FLAMMABLE, HARMFUL, DANGEROUS FOR THE ENVIRONMENT) - see CLEAPSS Hazcard.

1 Each group of students should be supplied with stoppered test-tubes containing about 10 cm³ of each of the aqueous solutions of the halogens and one of cyclohexane (optional).

2 The halogen solutions can be diluted further to minimise the amount of chlorine or bromine fumes given off but should not be so dilute that their distinctive colours are not clearly visible in the test-tubes (a white background may be needed for chlorine water).

3 At the end of the experiments all mixtures and solutions should be returned to a suitable waste container in a fume cupboard for safe disposal.

Procedure

The halogens in water and a hydrocarbon solvent (optional)

a Pour about 2 cm³ of each of the aqueous halogen solutions into separate test-tubes. Add equal volumes of hydrocarbon solvent to each tube, stopper the tube and, holding your thumb over the bung, shake the mixture by inverting the test-tube a few times.

b Allow the two layers to settle. Observe and record the colour of each layer. It may be necessary to shake the test-tubes again to transfer more of the halogen from the water to the hydrocarbon layer.

Acidic and bleaching properties of halogen solutions

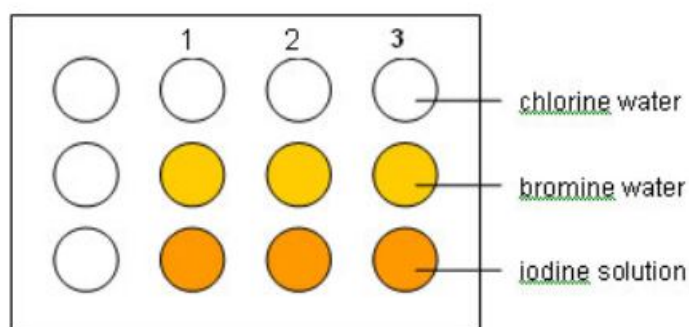
a Place a piece of Universal Indicator paper on a white tile. Transfer a drop of chlorine water onto the paper using a glass rod. Observe and record the colour of the paper.

b Wipe the glass rod and the tile clean with a paper towel or tissue. Place a fresh piece of indicator paper on the tile and transfer a drop of bromine water onto it using the glass rod. Observe the colour of the paper.

c Repeat **b**, using the iodine solution.

Displacement reactions

a Using a plastic pipette put two drops of chlorine solution in each of three dimples in the spotting tile, as shown below. In the same way and using a clean plastic pipette for each solution, add bromine water, and iodine solution to the spotting tile.



b Add two drops of potassium chloride solution to each of the three dimples in column 1 of the tile. Observe and record any colour changes that take place.

c Add two drops of potassium bromide solution to each of the three dimples in column 2 of the tile. Observe and record any colour changes that take place.

d Add two drops of potassium iodide solution to each of the three dimples in column 3 of the tile. Observe and record any colour changes that take place.

e (Optional) For reactions in which bromine or iodine are suspected to have formed, the reaction could be repeated with 2 cm³ of each solution in a test tube, and hexane could then be added to confirm the presence of bromine or iodine.

Teaching notes

A results table similar to the one below could be used for the recording of results. It has been completed with expected observations.

	Colour after shaking with hydrocarbon solvent	Effect on indicator paper	Reaction with potassium chloride solution	Reaction with potassium bromide solution	Reaction with potassium iodide solution
Chlorine water	Aqueous layer: pale yellow-green to colourless Hydrocarbon layer: colourless to pale yellow-green	Turns red then rapidly bleaches white	No reaction	The yellow-orange colour of bromine appears	The brown colour of iodine appears
Bromine water	Aqueous layer: yellow-orange to colourless Hydrocarbon layer: colourless to pale yellow-orange	Turns red then slowly bleaches white	No reaction	No reaction	The colour darkens from yellow-orange to brown
Iodine solution	Aqueous layer: brown to colourless Hydrocarbon layer: colourless to purple	The paper is stained brown	No reaction	No reaction	No reaction

The halogens are more soluble in the hydrocarbon and move to this top layer, when shaken with a hydrocarbon solvent. For chlorine and bromine the colour does not change. You might need a white background to see the colour of the chlorine solution. However, for iodine there is a colour change, from brown in water to purple in the hydrocarbon layer.

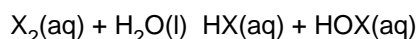
Where no displacement reaction takes place between a halogen solution and a halide solution, it may be that some lightening in the colour of the solution is observed and this can be explained by the effect of dilution.

Take care to limit students' exposure to chlorine and bromine water fumes. Some students with respiratory problems can show an allergic reaction to chlorine, the onset of which may be delayed.

Iodine is the least soluble of the halogens in water. It is more soluble in potassium iodide solution, so the 'iodine solution' here is actually iodine in potassium iodide solution.

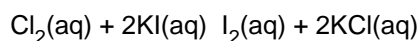
Draw the students' attention to the similarity between the colour of iodine vapour and its colour in a non-polar solvent. Polar water molecules interact with iodine molecules, altering the wavelengths of light they absorb.

All three halogens react with water to produce a strong acid (HX), and a weak acid (HOX), which has bleaching properties and is an oxidising agent.

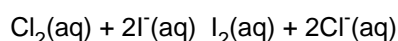


The extent of reaction decreases down the Group. With iodine it is so small that the acidic and bleaching properties of the solution are not seen in this experiment.

In the displacement reactions chlorine displaces both bromine and iodine from their compounds and bromine displaces iodine – for example:



The order of reactivity is therefore chlorine > bromine > iodine. A more advanced treatment identifies the halogens as oxidising agents, accepting an electron to form halide ions:



Contrary to belief among many students, the reaction has nothing to do with the reactivity of potassium 'grabbing' the chlorine. Potassium is only present here as very unreactive potassium ions (spectator ion) in solution.

Health & Safety checked, 2016

Credits

This Practical Chemistry resource was developed by the Nuffield Foundation and the Royal Society of Chemistry.

© Nuffield Foundation and the Royal Society of Chemistry

Page last updated October 2015