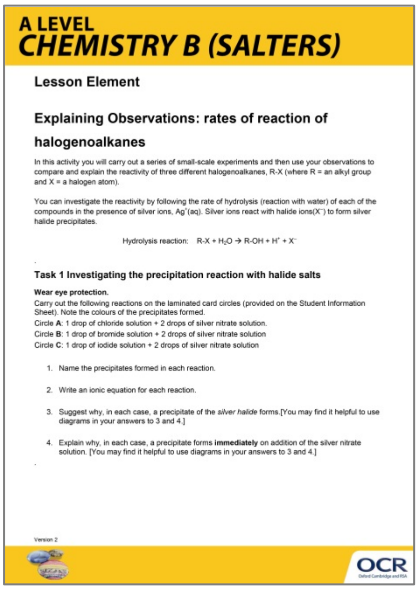
Lesson Element

Explaining Observations: rates of reaction of halogenoalkanes

Instructions and answers for teachers

These instructions should accompany the OCR resource* ‘Explaining Observations: rates of reaction of halogenoalkanes’ *activity *which supports OCR A Level Chemistry OCR A Level Chemistry B (Salters).*


A LEVEL
CHEMISTRY B (SALTERS)

Lesson Element

Explaining Observations: rates of reaction of halogenoalkanes

In this activity you will carry out a series of small-scale experiments and then use your observations to compare and explain the reactivity of three different halogenoalkanes, R-X (where R = an alkyl group and X = a halogen atom).

You can investigate the reactivity by following the rate of hydrolysis (reaction with water) of each of the compounds in the presence of silver ions, $Ag^+(aq)$. Silver ions react with halide ions(X^-) to form silver halide precipitates.

Hydrolysis reaction: $R\text{-}X + H_2O \rightarrow R\text{-}OH + H^+ + X^-$

Task 1 Investigating the precipitation reaction with halide salts

Wear eye protection.
Carry out the following reactions on the laminated card circles (provided on the Student Information Sheet). Note the colours of the precipitates formed.
Circle **A**: 1 drop of chloride solution + 2 drops of silver nitrate solution.
Circle **B**: 1 drop of bromide solution + 2 drops of silver nitrate solution
Circle **C**: 1 drop of iodide solution + 2 drops of silver nitrate solution

1. Name the precipitates formed in each reaction.
2. Write an ionic equation for each reaction.
3. Suggest why, in each case, a precipitate of the *silver halide* forms.[You may find it helpful to use diagrams in your answers to 3 and 4.]
4. Explain why, in each case, a precipitate forms **immediately** on addition of the silver nitrate solution. [You may find it helpful to use diagrams in your answers to 3 and 4.]

Version 2

The Activity:

The simple, small-scale practical activity described here provides students with the opportunity to explore the precipitation reactions between solutions of halide salts and silver nitrate before going on to investigate the rates of hydrolysis of 1-chlorobutane, 1-bromobutane and 1-iodobutane.

This activity offers an opportunity for English skills development.

This activity offers an opportunity for maths skills development.

Associated materials:

‘Explaining Observations: rates of reaction of halogenoalkanes’ activity.

Overview

Understanding the properties and reactions of organic compounds is important if chemists are to develop safe and effective new materials using environmentally-friendly procedures.

The halogenoalkanes (also known as haloalkanes or alkyl halides) are found in many important industrial products as well as being useful (ie reactive) intermediates for conversion into other substances.

The effect of different halogen atoms (X) on the reactivity of some halogenoalkanes, R-X, can be investigated by comparing the rates of hydrolysis of 1-chlorobutane, 1-bromobutane and 1-iodobutane

$$.R\text{-}X + H_2O \rightarrow R\text{-}OH + H^+ + X^-$$

The reaction is carried out in in the presence of silver ions, Ag^+. These react with the halide ions produced, X^-, to form a precipitate, AgX.

$$Ag^+(aq) + X^-(aq) \rightarrow AgX(s)$$

The time taken to form the precipitate gives an indication of how quickly the halogen atom, X, in the halogenoalkane is replaced by an –OH group.

Students' common misconceptions

In order to suggest, develop and evaluate explanations for observed differences in the rates of reaction students need to draw on their understanding of (i) ionic and covalent compounds, (ii) electronegativity and bond polarity and (iii) bond enthalpy (bond strength).
However, even though they may have previously used silver nitrate solution to test for the presence of halide ions, some students do not fully appreciate the significance of the silver halide precipitate and the clues its formation provides about the hydrolysis reactions of halogenoalkanes.

There is evidence that some post-16 students are unable to explain what is happening at the level of particles when precipitation occurs and that this may be related to their lack of understanding of what happens during dissolving and their ideas about the nature of ionic bonding.
[Adapted from: Chemical misconceptions – prevention, diagnosis and cure. Volume II by Keith Taber. Royal Society of Chemistry 2002]

Teachers may like to use the diagnostic probe activities (see links below) with the practical activity described here to explore their students' existing understanding of some of the key ideas involved. Teacher notes and expected answers are included with the probes. Some teachers may also be interested in reading the more in-depth background research findings relating to the use of these probes with groups of pre-16 and post-16 students.

Diagnostic probes (classroom resources)

- Precipitation: http://www.rsc.org/learn-chemistry/resource/res00001096/precipitation
- Ionic bonding: http://www.rsc.org/learn-chemistry/resource/res00001095/ionic-bonding

Theoretical background (research findings)

- Students' ideas about precipitation processes: http://www.rsc.org/learn-chemistry/resource/res00001141/chemical-reactions
- Students' ideas about ionic bonding: http://www.rsc.org/learn-chemistry/resource/res00001140/chemical-bonding

Teacher and Technician notes

Practical requirements

Each student (or pair of students) will require:

- Eye protection
- Beaker, 100 cm^3
- Small test-tubes or combustion tubes, 75 mm x 10 mm (4)
- Student worksheet plus a laminated drop-chemistry/data card (or put inside a plastic pocket)
- Plastic dropper pipettes, 1 cm^3 (2)
- Thermometer, 0-110 ^oC

Students will also require access to:

- Hot water (use a kettle to avoid sources of ignition/naked flames)
- Silver nitrate solution, 0.05 mol dm^{-3} [Solution will stain skin]
- Ethanol or IDA/IMS [Highly flammable, Harmful if swallowed]
- Dropper bottles (or equivalent) containing:
  – Sodium (or potassium) chloride, bromide and iodide solutions, each at 0.1 mol dm^{-3}
  – 1-chlorobutane [Highly flammable]
  – 1-bromobutane [Highly flammable, Irritating to eyes, respiratory system and skin]
  – 1-iodobutane [Flammable, Harmful by inhalation and in contact with skin]

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http://www.rsc.org/learn-chemistry/resource/res00001096/precipitation

The notes accompanying the Precipitation diagnostic probe activities *(see hyperlink)* provide some possible answers that post-16 students could be expected to suggest *(see activities A reaction to form silver chloride and A precipitation reaction).*

Students may offer different explanations depending on which topics they have already studied (eg, explanations in terms of energy changes in solution).

Students could just be provided with the diagrams from the probes to use in their explanations.

Task 2 Investigating the rate of hydrolysis of halogenoalkenes

Students should recognise that this time a precipitate does not immediately occur because the halogen atoms are covalently bonded in the halogenobutane and are not already present in solution as solvated halide ions. As the hydrolysis (a nucleophilic substitution reaction) progresses, halide ions are gradually produced.

In trials at about 40 ^{o}C the iodobutane produced a precipitate within a few seconds - this gradually became thicker. The bromobutane took around 1-2 minutes to produce the first signs of a precipitate and the chlorobutane produced a faint precipitate after about 5-7 minutes.

The order in which precipitates appear is explained by the trend in bond enthalpies rather than bond polarities (ie bond has lowest bond enthalpy, bond breaks most quickly so produces precipitate first).

Drawing the ideas together, students should be able to offer some logical ideas for a possible mechanism for the hydrolysis reaction.

Teachers may like to provide students with an opportunity to model the nucleophilic substitution mechanism. A set of cards and additional information can be found in Activity 55 on the Royal Society of Chemistry's *Assessment for learning chemistry* website, http://www.rsc.org/education/teachers/resources/aflchem/. Some students have produced effective animations of the mechanism using various software tools.

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