Core practical 4: Investigate the hydrolysis of halogenoalkanes

Objective

- To investigate the relative rates of hydrolysis of primary, secondary and tertiary halogenoalkanes and of chloro-, bromo-, and iodoalkanes

Safety

- Wear eye protection.
- Halogenoalkanes are flammable and harmful.
- Ethanol is flammable.
- Silver nitrate is corrosive.
- Obtain hot water from a kettle rather than using a naked flame in the laboratory.

Specification links

- Practical techniques 1, 2, 4, 5, 6, 11
- CPAC 1a, 2a, 2b, 3a, 3b, 3c

Procedure

Part 1

1. Set up a water bath. Fill the 250 ml beaker up to the three quarters mark with water, at around 50 °C.
2. Fill three test tubes each with 5 cm^3 of ethanol. Now add four drops of 1-iodobutane to the first tube, four drops of 1-bromobutane to the second tube and four drops of 1-chlorobutane to the third tube. Label the tubes.
3. Loosely place a bung in each test tube and place the test tubes in the water bath.
4. Pour 5 cm^3 of silver nitrate solution into three clean test tubes. Now place the test tubes in the water bath.
5. When the halogenoalkane–ethanol solutions have reached the temperature of the water bath, add the silver nitrate solution to one of the halogenoalkane–ethanol solutions and replace the bung. Start the stop clock as you do so.
6. Measure the time taken for the precipitate to appear. As soon as the solution becomes cloudy stop the stop clock.
7. Repeat steps 5 and 6 for the other two halogenoalkanes.

Part 2

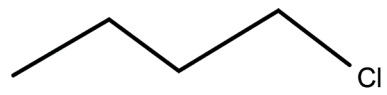
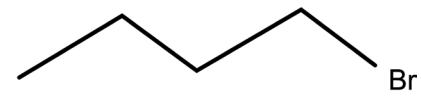
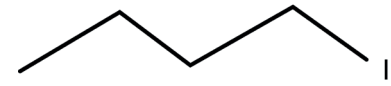
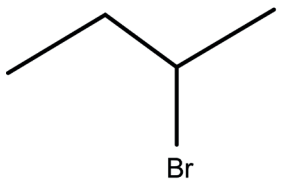
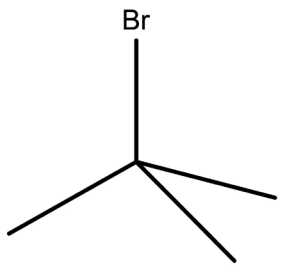
8. Repeat Part 1 using 1-bromobutane, 2-bromobutane and 2-bromo-2-methylpropane instead of the other halogenoalkanes.

Notes on procedure

- The reaction of the 1-chlorobutane can be very slow. It is possible that a precipitate will not form in a reasonable time period. Instruct the students to stop timing after 10 minutes.
- The test tubes containing the mixture of halogenoalkane–ethanol solution and silver nitrate solution should be kept in the water bath.

Answers to questions

1. $CH_3CH_2CH_2CH_2Br + H_2O \rightarrow CH_3CH_2CH_2CH_2OH + H^+ + Br^-$
2. silver iodide
3. The halogenoalkanes are insoluble in water. Using ethanol ensures that the halogenoalkane dissolves so it can react with the water molecules.
4. Water has lone pair(s) of electrons on the oxygen atom.
5. If hydroxide ions were used, a precipitate of silver hydroxide would form instantly.
6.

	primary
	primary
	primary
	secondary
	tertiary

Sample data

Part 1

Halogenoalkane	Time taken for a precipitate to form/s
1-iodobutane	52
1-bromobutane	87
1-chlorobutane	606

Part 2

Halogenoalkane	Time taken for a precipitate to form/s
1-bromobutane	59
2-bromobutane	34
2-bromo-2-methylpropane	3

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All the maths you need

- Use ratios to construct and balance equations.

Equipment

- 250 cm^3 beaker
- 12 test tubes with bungs
- 1-chlorobutane
- 1-bromobutane
- 1-iodobutane
- 2-bromobutane
- 2-bromo-2-methylpropane
- silver nitrate solution
- 15 cm^3 ethanol
- dropping pipettes
- two 10 cm^3 measuring cylinder
- stop clock
- labels for test tubes
- kettle

Procedure

Part 1

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7. Repeat steps 5 and 6 for the other two halogenoalkanes.

Part 2

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Analysis of results

1. Record your results for Part 1 and Part 2 in a suitable way.
2. What is the pattern shown in Part 1?
3. What is the pattern shown in Part 2?

Learning tips

- The hydrolysis of halogenoalkanes is a nucleophilic substitution reaction.
- In this investigation the nucleophile is water.
- If NaOH is used to hydrolyse the halogenoalkanes, then any excess NaOH has to be neutralised by HNO_3 before adding $AgNO_3$.

Questions

1. Write an equation for the reaction of 1-bromobutane with water.
2. In these reactions a precipitate forms. Identify the precipitate formed when the halogenoalkane is 1-iodobutane.
3. Explain why ethanol is used in these reactions.
4. Explain why water is able to act as a nucleophile.
5. Explain why water is used as the nucleophile rather than hydroxide ions?
6. Draw skeletal formulae for each of the halogenoalkanes used in this investigation (there are 5 of them). Classify each halogenoalkane as primary, secondary or tertiary.

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Equipment per student/group	Notes on equipment
250 cm^3 beaker	
12 test tubes	
1-chlorobutane	Students need access to the organic reagents but need not have access to individual bottles.
1-bromobutane	
1-iodobutane	
2-bromobutane	
2-bromo-2-methylpropane	
silver nitrate solution	Of same concentration as used for halide identification tests
dropping pipettes	
15 cm^3 ethanol	
two 10 cm^3 measuring cylinders	
stop clock	
labels for test tubes	
kettle	

Notes