Investigating the Rates of Reaction for Halogenoalkanes

Aim

The aim of this experiment is to show how the rate of reaction of the halogenoalkanes changes in respect to the C-X bond, where the C is the carbon and the X is the halogen. This will occur through a nucleophilic attack.

The halogenoalkanes undergo hydrolysis according to the following equation:

$$C_nH_{2n+1}X + OH^- \longrightarrow C_nH_{2n+1}OH + X^-$$

Plan

The plan for this experiment is to take three different halogenoalkanes and add a nucleophile to each of the halogenoalkanes record and compare my observations for each halogenoalkane experiment. In the experiment, the number of carbons in the halogenoalkene will not vary.
The carbon compound I am going to use will be halogen butane. The nucleophile I am going to use is hydroxide ion (OH^-). In this experiment I will not use the halogen fluorine because of the strong bond it forms with carbon. According to bond enthalpy the C-F bond is the less reactive of the halogenoalkanes because of how strong the bond energy is between them. The bond energy in the C-F bond is 467 kJ mol-1. So the C-F bond will be too strong to be affect by nucleophiles.

Equations for nucleophilic substitution reactions are:

$$C_4H_9Br + OH^- \longrightarrow C_4H_9OH + Br^-$$

$$C_4H_9Cl + OH^- \longrightarrow C_4H_9OH + Cl^-$$

$$C_4H_9I + OH^- \longrightarrow C_4H_9OH + I^-$$

Prediction

My prediction for which bond will react most vigorously with the nucleophile will be the C-I halogenoalkane. This is because it has the lowest bond enthalpy of all the halogenoalkanes. The C-Cl halogenoalkane will be the leased reactive because it has one of the highest bond enthalpy of the entire bond being tested. The C-Br will be in the middle because it bond enthalpy show that it is more reactive than the C-Cl bond but less reactive than the C-I bond.

In the reaction of halogenoalkanes, bond polarity show us that C-F would be the most reactive then C-Cl, C-Br and C-I would be the lest reactive. This is due to the electronegativity of the halogen atoms. Electronegativity is the measure of how strongly an atom in a compound attaches electron in a bond. The greater the difference in the electronegativity of two atoms, the more polar is the covalent bond between the two atoms. So in a carbon halogen bond the halogen is more electronegative than carbon. Consequently the bond between them is polarized so the halogen atom is slightly negative.

According to bond enthalpy the reverse is true. Bond enthalpy shows us that C-I bond is the most reactive and the C-F bond is lest reactive. This is due to the bond energy between the atoms. Bond energy is the average standard molar enthalpy changes for the breaking of a mole of bonds in a gaseous molecule to from gaseous atoms. Bond energies indicate the strength of the forces holding together atoms in a covalent molecule. Bond energy is increased with the number of shared electron pairs. So C-I bond has bond energy of 228 kJ mol-1, which is more reactive because the bond is weak. Compared to C-F, which has bond energy of 467 KJ mol-1, which is a strong bond.

C-H – 413 KJ mol-1

C-F – 485 KJ mol-1

C-Cl – 328 KJ mol-1

C-Br – 276 KJ mol-1

C-I – 240 KJ mol-1

On the basis of bond enthalpies I would predict C-I to be the fastest reaction followed by C-Br, then C-Cl.

<u>Healthy and Safety Precautions</u>

- Every chemical is a potential hazard to health, the degree of risk depending on its physical and chemical properties and the kind of exposure. It should be taken into careful consideration that we know how to dispose of waste and how to deal with spillages immediate clearing of spillages of any kind, wet or dry in an appropriate manner.

- Any splashes into the eye must be washed out continuously for 10-15 minutes
- Before starting the experiment we must make sure to wear safety goggles and an apron in the lab at all times. Do not ingest chemicals.
- Laboratory coats should be worn during the investigation to prevent chemicals from spoiling clothes. Care should also be taken whilst handling the chemicals as halogenoalkanes and ethanol are harmful and flammable.

Apparatus

- ✓ Google
- ✓ Lab coat
- ✓ Test Tubes
- ✓ Test tube rack
- ✓ 250cm3 beaker
- ✓ 10cm Measuring cylinder
- ✓ Silver nitrate solution (0.01 mol dm-3)
- ✓ Bunsen burner
- ✓ Heat proof mat
- ✓ Tripod
- ✓ Stop watch
- ✓ Ethanol
- ✓ Thermometer
- ✓ Halogenoalkanes, which are 1-chlorobutane, 1-bromobutane, 1-iodobutane
- ✓ Test tube holder and pipette

Method

1. Arrange three test tubes into a test tube rack, in a row. Label them as A, B and C.
2. Using 250cm3 beaker, heat water to about 60 °C

3. Using a measuring cylinder, measure out 2 cm3 of ethanol and add to each test tube. (Ethanol is highly flammable; keep it away from naked flames.)

4. Add 3 drops of halogenoalkanes in the following sequence:
3 drops of 1-chlorobutane in test tube A, 3 drops of 1-bromobutane in test tube B and 3 drops of 1-iodobutane in test tube C. (avoid inhaling halogenoalkanes vapour as it is harmful and irritating)

5. Place test tube A, B and C in the same hot water beaker.

6. Measure 2 cm3 of silver nitrate solution (0.01 mol dm-3) and pour it into 3 different test tubes.

7. Place them all in the same hot water beaker

8. Leave all the six test tubes in the beaker for 15 minutes to maintain the same temperature as the beaker

9. Extract the test tubes out of the beaker and add the 2 cm3 of silver nitrate solution to each test tube (A, B and C) quickly and in the same time.

10. Shake the test tube with their content, and leave the test tubes for 10 minutes, then detect how long silver halides precipitate takes to form.

My method would work because of the equipment I used for the experiment. Like the measuring cylinder, which will ensure that, the equal and right amounts are being used in the experiment.

Bibliography

- http://itl.chem.ufl.edu/2045_s00/lectures/lec_9be.html : I have used this website to obtain the average bond enthalpies of halogenoalkanes.
- Revise AS&A2 Chemistry (Letts) by Rob Ritchie page 132&133: I have used this book to understand and wide my knowledge of nucleophilic substitution mechanism.