Hydrolysis of halogenalkanes
Planning

Aim and background reading

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:

CnHn+1X + OH^{-} à CnHn+1OH + X^{-}

Nucleophilic attacks are a predominant type of chemical attack. It is a type of substitution reaction where a nucleophile breaks the bond between the carbon and in this case the halogen and removes the halogen to get a halide ion. There are 3 main types of nucleophilic reaction; one involves hydrolysis, which is the one being used in this experiment and involves an OH molecule, cyanide ions, which is not being used due to cyanide being extremely dangerous and the final nucleophilic reaction involves ammonia ions. This one is not used because it will just keep substituting the chemicals and you will end up with a huge range of compounds, most, if not all of which will not be needed. These products are called amines and an example of one would be $CH_3CH_2NH_2$, which is ethylamine.

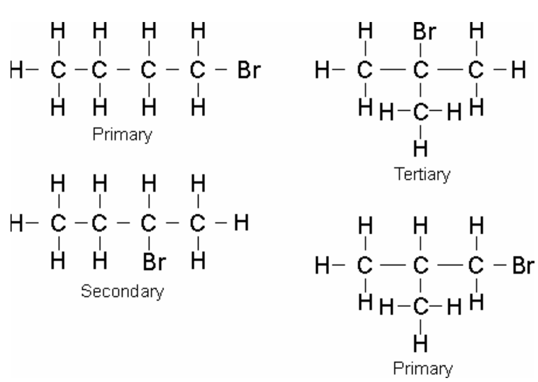
The three elements that will be used for this investigation are chlorine, bromine and iodine. Chlorine is a greenish yellow gas, which combines directly with nearly all elements. Chlorine is a respiratory irritant. The gas irritates the mucous membranes and the liquid burns the skin.
Bromine is the only liquid nonmetallic element. It is a member of the halogen group. It is a heavy, volatile, mobile, dangerous reddish-brown liquid. The red vapour has a strong disagreeable odour, resembling chlorine, and is irritating effect to the eyes and throat. It has a bleaching action. When spilled on the skin it produces painful sores. It is a serious health hazard, and maximum safety precautions should be taken when handling it.

Iodine is a bluish-black, lustrous solid. It volatilises at ambient temperatures into a pretty blue-violet gas with an irritating odour.

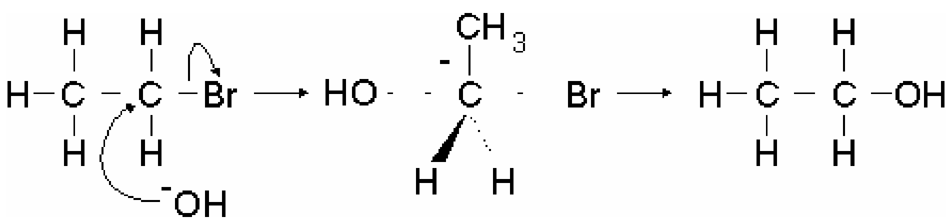
The bond enthalpies of the 4 most reactive halogens is as follows

Bond	Bond enthalpy (Kj mol $^{-1}$)
C-F	467
C-Cl	340
C-Br	280
C-I	240

From the above table you can see that bond enthalpy decreases going down the group. This means that the weaker bonds will be more reactive with a nucleophile, and the C-Cl bond will be the hardest to break out of the bonds being tested as it has a higher value compared to the others. Halogenalkanes are classified as tertiary, secondary and primary. This depends upon the number of carbon atoms bonded to the carbon atom to which the halogen is shown below:



Their reactions are characterised by **nucleophilic substitution** of the halogen atom, owing to polarity of the carbon—halogen bond in which the electron-deficient carbon is susceptible to attack by an electron-rich species, namely a **nucleophile**.
With primary and secondary halogenoalkanes, the reaction is very slow at ordinary temperatures, but rapid with tertiary halogenoalkanes. Alkaline hydrolysis is much faster.
A one-step mechanism is proposed, in which both reactants are involved in the rate-determining step. (The curly arrows show the direction of movement of a pair of electrons.) As the OH^- ion approaches the electron-deficient carbon atom donating a pair of electrons, the halide ion moves away taking with it a pair of electrons. A *transition state* is involved, in which the hydroxide and halide ions are both partially bonded to the same carbon.



Prediction

My prediction for which bond will react most vigorously with the nucleophile is C-I. This is because it has the lowest bond enthalpy and is also very polar because of the large difference of sizes between the carbon and iodine thus allowing the nucleophile to attack the bond much easier. C-Br will not be as easy to break as C-I because the molecule is not as polar and also has a higher bond enthalpy. C-Cl will therefore be the hardest bond to break because it is the least polar and has the highest bond enthalpy of all the bonds being tested.

Procedure

Before carrying out this experiment a hazard analysis will need to be done. The equipment needed to ensure safety would be; goggles, lab coat, gloves and long hair tied back. Halogenalkanes are highly flammable. Alcohol's are corrosive and can cause irritation to the skin.

Equipment

- 3x Test tubes
- Test tube rack
- 2 x10 cm Measuring cylinder
- Bunsen burner
- Stop Watch
- Ethanol
- Halogenalkanes, including 1-chlorobutane, 1-bromobutane, 1-iodobutane
- 0.02 M Silver Nitrate
- Test tube holder and pipette

Method

1. Arrange three test tubes, into a test tube rack, in a row.

2. Using the pipette, add 3 drops of the Halogenalkanes in the following sequence:

   1-chlorobutane 1-bromobutane 1-iodobutane

3. Using the measuring cylinder, measure out 2 cm^3 of ethanol and add to each test tube (this acts as a solvent).

3. Measure out another 2 cm^3 of 0.02 M of Silver nitrate and pour into each test tube.

4. Measure out 2 cm^3 of 1-chlorobutane.

5. Using the test tube holder, hold the test tube containing 1-chlorobutane, ethanol and silver nitrate to the Bunsen burner (with blue flame). Make sure that the solution boils then as quickly as possible add the 1-chlorobutane and time with the stopwatch provided and note the colour change of the precipitate formed.

6. Repeat the steps 4 to 5 using the other two Halogenalkanes and note the colour change of the precipitate formed.

The results should be recorded in the below table.

Halogenalkane	Colour change of precipitate	Time taken
1-chlorobutane	Clear	1.22
1-bromobutane	White/cloudy	0.97
1-iodobutane	Yellow	0.73

Evaluation

The level of accuracy of these results was fairly high. It was possible to gain a high level of accuracy, as the procedure was fairly simple to set up and carry out. There was little chance of the data getting mixed up as the results collected contained minute information. However, there could have been some sources of error that could have occurred during the investigation, that might have disrupted the accuracy of the results. One error could have been due to the way the drops were measured and inserted into the test tubes. The pipette used did not have a measurement scale, this would have caused the error as the amount poured into each test tube was not accurate. This may have altered the time limit either making the reaction occur faster than usual or slower. Another source of error would have been when the Halogenalkane were inserted into the test tube. The possibility of the solution hitting the side of the test tube and not running all the way down is high. This happening would have made the silver nitrate reaction occur faster than it should have been. Measurements taken from the cylinder may not have been 100 % accurate as there could have been a possibility that when the solution was poured into the test tubes droplets of the solution may have remained within the cylinder. The timing of the Halogenalkanes may not be accurate as the time taken for the colour change to occur could have happened at the start of the experiment but had taken time to develop into a stronger denser colour. There may have been spillages when transferring the chemicals into the test tubes, which would result in a lower amount of Halogenalkanes being reacted. All these errors would have been caused by human error, as the equipment used was reliable. The experiment was only carried out once. This may suggest that the result obtained may not be reliable as errors may have occurred whilst recording the result.

To minimise errors and increase reliability I would have to revise the method and improve it to minimise the errors. The changes that would be made to make the method would be to make what should be done more specific, such as to say that the measurements taken from the cylinder should be poured into each test tube carefully (avoiding spillage's) including the last drop. It would also help if the experiment were repeated at least five times to see whether three timings out of five are the same. It is it only then that the time should be noted as a result. This wo uld not just make the experiment seem more complex it should hopefully increase levels of accuracy and reliabilty.