

Nucleophilic Substitution

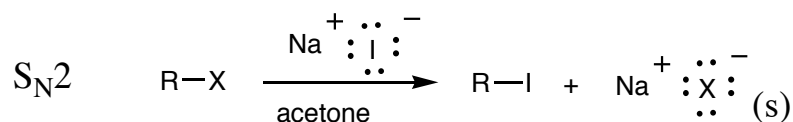
Introduction

Nucleophilic substitution of alkyl halides can proceed by two different mechanisms – the S_N2 and the S_N1 . In an S_N2 reaction, a strong nucleophile attacks the carbon attached to the halide and pushes it off in one step. In an S_N1 reaction, the halide falls off first, resulting in a highly reactive carbocation which is quickly attacked by a weaker nucleophile.

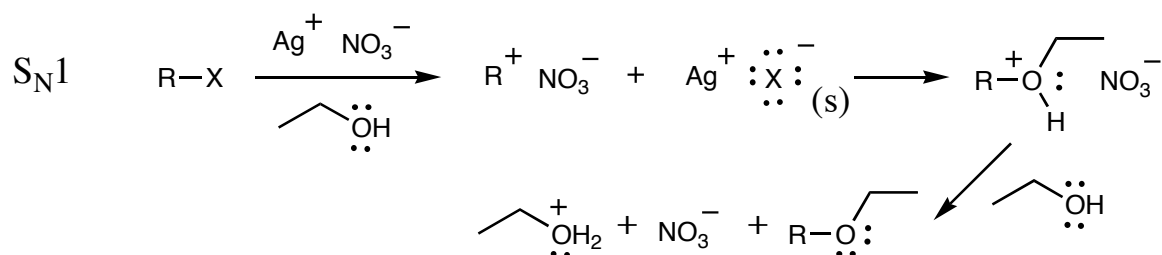
Different alkyl halides will undergo these two reactions at different rates. Alkyl halides which are easily attacked by a nucleophile will undergo S_N2 more quickly, whereas alkyl halides which can form a more stable carbocation will undergo S_N1 more quickly.

In this experiment, you will compare the reactivity of a series of alkyl halides under S_N2 and S_N1 conditions. In order to determine how rapidly the reaction is proceeding, we will run the reactions under conditions which provide a visible precipitate which we can observe.

In the first set of reactions, S_N2 conditions will be observed. A solution of sodium iodide dissolved in acetone will provide the strong nucleophile – the I^- ions. Since I^- is an unusually large nucleophile, the steric effects of S_N2 reactions should be easily observed. A few drops of alkyl halide will be added. If an S_N2 reaction occurs, the iodide will displace the bromide or chloride of the alkyl halide. The resulting sodium chloride or sodium bromide will precipitate from the reaction, since neither compound is soluble in acetone. Observation of a precipitate will tell you that a reaction has occurred. The fact that the bromide and chloride are removed from the solution will prevent them from turning around and acting as nucleophiles themselves.



In the second set of reactions, S_N1 will be observed. A solution of ethanol with some silver nitrate added will provide the weak nucleophile – the alcohol itself. A few drops of alkyl halide will be added. If an S_N1 reaction occurs, the alkyl halide will dissociate to form a carbocation, which will then react with the ethanol to form an ether. The halide ion will combine with a silver ion from the silver nitrate to form a silver halide precipitate, which will tell us that a reaction occurred.



Procedure

Analyzing the organic halides:

- Write the names and draw the structures of each of the alkyl halides below. Beside each structure, note whether it is 1°, 2°, 3°, allyl, benzyl, or aryl, and also note any that are cyclic. Then predict whether each will react under S_N2 and S_N1 conditions.
 - A. 1-bromo-2-methylpropane
 - B. 1-bromopentane
 - C. 2-bromobutane
 - D. 2-chloro-2-methylpropane
 - E. 2-chlorobutane
 - F. 2-iodobutane
 - G. 3-bromopropene
 - H. 3-chloropropene
 - I. benzyl bromide
 - J. benzyl chloride
 - K. bromobenzene
 - L. bromocyclohexane
 - M. bromocyclopentane
 - N. chlorobenzene
 - O. chlorocyclohexane
 - P. chlorocyclopentane

S_N2 reactions:

- Label 16 test tubes A-P.
- Add about 2 ml of 15% NaI in acetone to each test tube (measure one, then add the same height to the rest).
- Using the plastic pipet in the test tube on the bottle, add about 5 drops of the first alkyl halide to the first test tube. Observe how fast a precipitate forms, using relative terms like "instantaneous," "within a few seconds," "within a few minutes," "never," etc.. Make sure to check back with ones that don't react quickly to see if they react within 5 minutes. Compare your results with what you predicted.
- Do the same with all of the rest of the alkyl halides (please take only two at a time to your hood).
- Add water to a beaker and heat it to about 60°C. Dip the test tubes in which no reaction occurred in the bath just long enough to start the solvent boiling without letting the solvent boil off. Note any which formed a precipitate under these conditions.

S_N1 reactions:

- Label 16 new test tubes A-P.
- Add about 2 ml of 1% AgNO₃ in ethanol to each test tube.
- Add about 5 drops of each alkyl halide to the appropriate test tube, as before, and observe and record the results. Compare them with your predictions.
- Dip the test tubes that didn't react into the heated water bath to see if any react under these conditions. Record any new observations.
- Dispose of all solutions in the organic waste container. Then rinse out the test tubes with tap water into the inorganic waste container to remove most of the precipitates, and place the rinsed test tubes in the glass waste.
- In your conclusion, discuss which compounds reacted fastest under each set of conditions, which were slower, which didn't react, and why. Make sure to mention any compounds which did not react as you would expect them to.

Questions

- 1) Why is acetone used as the solvent in the first set of reactions? Why is ethanol used in the second set?
- 2) What would happen if no AgNO₃ were used the S_N1 experiments - just ethanol? Would the reaction still occur? Would the product be visible?
- 3) Could the insolubility of silver chloride and silver bromide affect the ability of alkyl halides to form carbocations? What affect would you see if this were the case?
- 4) Could an E2 reaction have taken place instead of an S_N2 reaction under our experimental conditions? Why or why not? How would this affect the results?
- 5) Could an E1 reaction take place instead of an S_N1 reaction under our experimental conditions? How would this affect the results?
- 6) Is there any difference between 2° alkyl halide chains and rings in the S_N2 reactions? What do you think could cause this?
- 7) Your results should show that the presence of a benzene ring affects the reactivity of halide compounds. How does chlorobenzene react differently from benzyl chloride under S_N1 and S_N2 conditions, and why?
- 8) Which was the better leaving group, bromine or chlorine? Give a reason for your answer. Are the results different in S_N1 and S_N2 reactions?