**The Effect of Solvent on an Elimination Reaction**

This experiment is designed to achieve the following major objectives: 1) to use 1H NMR spectroscopy and TLC to determine the mechanism involved in an elimination reaction performed in two different solvents; 2) to use 1H NMR spectroscopy to identify and quantify the relative amounts of products in a product mixture; 3) to determine the overall yield for a multi-step synthesis.

**Using 1H NMR spectroscopy to determine identities and relative amounts of *cis*/*trans*-isomers.**

NMR spectroscopy is a powerful tool used for the identification of production. The integration and spin-spin splitting together gives information on the connectivity within a molecule. Used less often, but also useful in product identification is the coupling constant (*J*, the energy in Hz between adjacent peaks in a grouping). The Karplus equation (eq 1) relates the dihedral angle (*φ*) with coupling constant.

J(\phi) = A \cos^2 \phi + B \cos\,\phi + C (eq 1)

One of the simplest examples of this relationship is examining the difference between *cis*- and *trans*-double bonds. Protons with a *cis*-orientation (*φ* = 0°) typically have coupling constants between 6 - 12 Hz, while those on a *trans*-double bond (*φ* = 180°) have coupling constants ranging from 12 - 18 Hz. You will be provided you with 1H NMR spectra weeks for both weeks 1 and 2 of the experiment. Each spectrum will contain a mixture of both possible stereoisomeric products. The coupling constant for the protons of the products, found between 6.4 - 7.0 ppm, can be used to determine the identities of the two stereoisomers. The integration the peaks will be used to determine the relative amount of each isomer. Since the integration of a peak in a 1H NMR spectrum is proportional to the number of hydrogens in resonance, if one knows the number of protons represented by a particular integral value for more than one compound, one can use those values to determine the relative amounts of those compounds in the sample. For example, a 1H NMR spectrum is run on a sample containing two different methyl ester compounds. Ester **A** gives a peak for the methyl group at 3.9 ppm with an integration of 30, while ester **B** gives a peak for the methyl group at 3.8 ppm whose integral value is 10. Therefore, the ratio of **A**:**B** must be 30:10 (3:1) or 75% **A** and 25% **B**.

**Multi-step synthesis:**

The simplest example of a multi-step synthesis is to examine virtually any commercial medicine. Almost without exception that medicine was prepared by a series of reactions rather than in a single step. A multi-step synthesis generally requires a chemist to perform a chemical reaction, isolate, purify and characterize the product, then use some (or all) of the product as the starting material for the next reaction. What reasons can you think of for why someone would not want to use all of one’s product in the next reaction? In this experiment, you will be using the product of last week’s experiment as your starting material both elimination reactions that are part of this experiment. It will be important for you to have last week’s product properly identified so you can correctly predict the product of the these experiments. So how does one calculate the overall % yield for the two reactions when one does not use all of the product from the previous reaction? Actually, it is simple; one multiplies the % yields for the two reactions together. You will be asked to prove this in a postlab question.

**WEEK 1: AN ELIMINATION REACTION WITH 2,3-DIBROMO-3-PHENYLPROPANOIC ACID TO  
-BROMOSTYRENE IN ACETONE**



Required prelab readings: McMurry Sections 11.7 – 11.12

Previous techniques you must understand and be able to perform: Reflux; TLC; rotary evaporation

**Introduction:**

In the reaction above, there is no stereochemistry implied for either the reactant or the product. You will need to re-write the equation ***showing the absolute configuration*** of both the starting material and product based on your results from last week and this week. Carbonate is a base and the first step in the reaction is formation of the conjugate base of the starting material. This intermediate can proceed through either an E1- or E2-type mechanism where CO2 is lost in place of a proton. By identifying the major product and comparing it with the two mechanistic possibilities you will be able to determine the dominant mechanism involved in the elimination. ***Predict which mechanism results in which -bromostyrene stereoisomer before you come to lab****.*

**Experimental Procedure:**

Place 300 mg of 2,3-dibromo-3-phenylpropanoic acid (save a few mg for a later TLC analysis) and 300 mg of potassium carbonate in a 50 mL round bottom flask with a magnetic stir bar. Add 7‑10 mL acetone (pre-dried over sodium sulfate) to the flask. Attach a reflux condenser and assemble the apparatus on a heating mantle with a stirrer motor. Reflux the mixture with stirring for one hour. After reflux, cool the solution to room temperature and then remove the acetone using the rotary evaporator. Add RO water (5 mL) to dissolve any remaining solids. Using a Pasteur pipet, transfer the solution to a 12 mL centrifuge tube. Rinse the round bottom flask with 2 mL methylene chloride (why?) and add the solution to the centrifuge tube. In the centrifuge tube, you should see two layers-an aqueous layer on top and an organic layer on the bottom. The organic layer contains your product and may be pale yellow. Using a clean pastuer pipet transfer the organic layer to a 50 mL Erlenmeyer flask. You will have to insert the pipet through the aqueous layer to get to the bottom of the tube to collect the organic layer. Extract the aqueous layer twice more with 2 mL portions of methylene chloride (*i.e.* add 2 mL of methylene chloride to the aqueous layer in the centrifuge tube, mix well and remove the organic layer with a Pasteur pipet. Repeat.) Combine all the organic extracts and dry them with anhydrous sodium sulfate for at least 10 minutes. Run a TLC plate of both your product and starting material side-by-side using 1:1 hexane/methylene chloride as the eluant. Transfer the dried solution to a tared (analytical balances) 50 mL round bottom. Rinse the sodium sulfate with an approximately 1 mL of methylene chloride and add this to the flask. Concentrate the solution on the rotary evaporator being careful not to overheat (*overheating or leaving the solution on a rotary evaporator for too long a period can greatly reduce your yield)*. You should isolate β-bromostyrene as a colorless to yellow oil. Weigh to constant weight and record the final weight of your product. Save your product for TLC in week 3.

**WEEK 2: AN ELIMINATION REACTION WITH 2,3-DIBROMO-3-PHENYLPROPANOIC ACID TO  
-BROMOSTYRENE IN WATER**



**Experimental Procedure:**

Place 300 mg of 2,3-dibromo-3-phenylpropanoic acid (save a few mg for a later TLC analysis) in a 50 mL round bottom flask with a magnetic stir bar. Add 5 mL 1 M aqueous sodium carbonate to the flask. Attach a reflux condenser and assemble the apparatus on a heating mantle with a stirrer motor. Reflux the mixture with stirring for 20 minutes. After reflux, cool the solution to room temperature. Using a Pasteur pipet, transfer the solution to a 12 mL centrifuge tube. Rinse the round bottom flask with 2 mL methylene chloride and add the solution to the centrifuge tube. In the centrifuge tube, you should see two layers-an aqueous layer on the top and an organic layer on bottom. The organic layer contains your product and may be pale yellow. Using a clean pastuer pipet transfer the organic layer to a 50 mL Erlenmeyer flask. Extract the aqueous layer twice more with 2 mL portions of methylene chloride (*i.e.* add 2 mL of methylene chloride to the aqueous layer in the centrifuge tube, mix well and remove the organic layer with a Pasteur pipet. Repeat.) Combine all the organic extracts and dry them with anhydrous sodium sulfate for at least 10 minutes. Run a single TLC plate of the starting material as well as your products from week 2 and week 3 using 3:1 hexane/methylene chloride as the eluant. Transfer the dried solution to a tared (analytical balances) 50 mL round bottom. Rinse the sodium sulfate with an approximately 1 mL of methylene chloride and add this to the flask. Concentrate the solution on the rotary evaporator being careful not to overheat (*overheating or leaving the solution on a rotary evaporator for too long a period can greatly reduce your yield)*. You should isolate β-bromostyrene as a yellowish oil. Weigh to constant weight and record the final weight of your product.

**DATA SHEET**

**Week 1: Elimination in Acetone**

|  |  |  |  |
| --- | --- | --- | --- |
| **Name:** |  | **Section:** |  |

Overall Reaction (including stereochemistry, in perspective [not Fischer]; major product only; use chemical drawing software):

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Mass of dibromide: |  |  | Theo mmol product: | | |  | | | |
|  |  |  |  | | | |  | | |
| mmol of dibromide: |  |  | Theo mass product: | |  | | | | |
|  |  |  |  | | | | |  | |
| Mass of K2CO3: |  |  | Mass recovered product: | | | | |  | |
|  |  |  |  | | | | |  | |
| mmol of K2CO3: |  |  | mmol recovered product: | | | | | |  |
|  |  |  |  | | | | |  | |
|  |  |  | % yield of product: |  | | | | | |
|  |  |  |  |  | | | | | |
|  |  | % yield for starting material (last expt): | |  | | | | | |
|  |  |  |  |  | | | | | |
|  |  | Overall yield (two steps): | |  | | | | | |
|  |  |  |  |  | | | | | |
|  |  | *cis* : *trans* ratio | |  | | | | | |

(Note: all product calculations in the table are for the total amount of product (both isomers)).

Calculations: (notebook)

Tape your TLC plate (properly labeled) to your data sheet.

**WEEK 2: Elimination in Water**

Overall Reaction (including stereochemistry, in perspective [not Fischer]; major product only; use chemical drawing software):

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Mass of dibromide: |  |  | Theo mmol product: | | |  | | | |
|  |  |  |  | | | |  | | |
| mmol of dibromide: |  |  | Theo mass product: | |  | | | | |
|  |  |  |  | | | | |  | |
| volume of Na2CO3: |  |  | Mass recovered product: | | | | |  | |
|  |  |  |  | | | | |  | |
| mmol of Na2CO3: |  |  | mmol recovered product: | | | | | |  |
|  |  |  |  | | | | |  | |
|  |  |  | % yield of product: |  | | | | | |
|  |  |  |  |  | | | | | |
|  |  | % yield for starting material (last expt): | |  | | | | | |
|  |  |  |  |  | | | | | |
|  |  | Overall yield (two steps): | |  | | | | | |
|  |  |  |  |  | | | | | |
|  |  | *cis* : *trans* ratio | |  | | | | | |

(Note: all product calculations in the table are for the total amount of product (both isomers)).

Calculations: (notebook)

Tape your TLC plate (properly labeled) to your data sheet.

**Conclusion** (The first two post-lab question will help you with your conclusion. It is recommended that you do them first)

In addition to the items normally found in your conclusion, your conclusion must:

a. Use the NMR and TLC data to support that a chemical reaction took place.

b. Contrast the identity and ratio of products produced as a function of solvent.

c. Describe the mechanism for the reaction in each solvent and explain how they are supported by the NMR data.

d. Explain how the effect of solvent on the reactions you performed is consistent with theory.

**Post lab Questions**

1. Using the 1H NMR spectra provided, fill out the tables below for only the -hydrogen of each isomer for the reaction in acetone and in water. Briefly explain how you decided which isomer to associate with each -hydrogen. Include sample calculations separately.

**Reaction in acetone**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  (ppm) | Multiplicity | J, Hz | Isomer (E/Z) | % of isomer |
|  |  |  |  |  |
|  |  |  |  |  |

**Reaction in water**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  (ppm) | Multiplicity | J, Hz | Isomer (E/Z) | % of isomer |
|  |  |  |  |  |
|  |  |  |  |  |

2. Provide a step-by-step electron pushing mechanism that accounts for the major products you identified in Question 1. Use perspective drawings throughout and be sure your drawings support your stereochemical conclusions. Clearly show and name (E/Z) the stereochemistry of the products.

**Mechanism in acetone**

**Mechanism in water**

3. A multi-step synthesis is performed to convert the starting material (SM) into product C.

a. Calculate the theoretical mass of product C starting from SM (show your work).

b. Calculate the % yield from SM using the mass of product C (show your work).

c. Calculate the overall % yield by multiplying the % of each individual step together (show your work).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **SM** |  | **A** |  | **B** |  | **C** |
| **4.26 g** |  | **2.68 g** |  | **0.86 g** |  | **1.22 g** |
| **MW: 226.4639** |  | **MW: 269.7727** |  | **MW: 169.5562** |  | **MW: 298.2564** |
|  |  | **52.83%** |  | **50.93%** |  | **80.78%** |

4. Show the major elimination product(s) of the following reactions:

|  |  |  |  |
| --- | --- | --- | --- |
| a. |  |  |  |
|  |  |  |  |
| b. |  |  |  |
|  |  |  |  |
| c. |  |  |  |
|  |  |  |  |
| d. |  |  |  |