

Experiment 26

MULTISTEP SYNTHESIS: CARBENE CHEMISTRY

“If I mix CH₂ with NH₄ and boil the atoms in osmotic fog, I should get speckled nitrogen!” Donald Duck, *Walt Disney’s Comics and Stories*, #44, May, 1944.

For cartoon, see:
<http://www.freewebs.com/thebundyprinciple/apps/blog/>



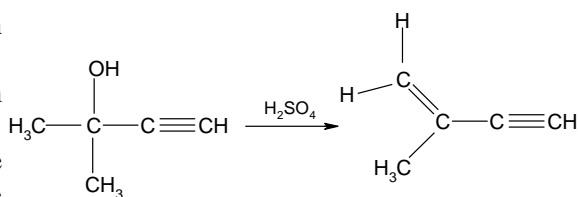
Text Topics, Comments

Carbene reactions. Because of the cost of 2-methyl-3-butyne-2-ol, it is suggested that students work in pairs on this experiment.

Discussion

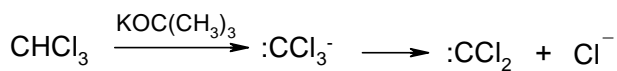
Although Donald Duck’s mention of CH₂ in Issue #44 of *Walt Disney’s Comics and Stories* in 1944 had been preceded by work on CH₂ by John Nef at the end of the 19th century and later by Peter Skell, much of the research that characterized CH₂ (methylene or a carbene) came after the now famous cartoon. While it is doubtful that Donald Duck contributed to this research, his cartoon has often been included in talks and papers on the history of carbene chemistry. Although carbenes, because of their very high reactivity, have been described as one of the most indiscriminate reagents in organic chemistry, they play an extremely important role in organic synthesis. The addition of carbenes and carbenoids to alkenes is one of the best methods for preparing cyclopropanes. From a theoretician’s perspective, the two electrons on the CH₂ provide a playland for calculations. Are the two electrons paired resulting in a singlet state or do they have the same spin resulting in a triplet state? This is an interesting question but the focus of today’s experiment will be on the selectivity of the reaction of dichlorocarbene with a compound containing a double bond and a triple bond. After running the reaction, you should be able to determine the reaction locus using nmr and ir spectroscopy.

The two step synthesis to be run starts with the elimination of water from 2-methyl-3-butyne-2-ol. For the elimination of water from 2-methyl-3-butyne-2-ol, the literature suggests a 30% yield of the product.

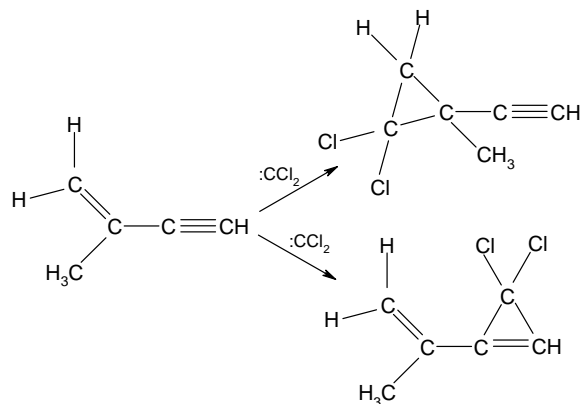


Although we have found this mixture to work, the yield and the substantial amounts of residue after the first distillation do leave considerable room for improvement. It might be interesting to vary the percentage of H₂SO₄ and have students compare yields. As the product boils at 32°C, the heating can and should be provided by a steam bath. Students should determine the infrared and nmr spectra, gas chromatograms and refractive indices on both the starting material and product to verify the course of the reaction.

The dichlorocarbene that will be reacted with the product synthesized from the elimination reaction (2-methyl-1-buten-3-yne) is generated by reacting potassium t-butoxide with chloroform. As the conjugate base of chloroform is inductively stabilized by three chlorines, t-butoxide is a strong enough base to remove the proton from the chloroform. The resulting trichloromethyl carbanion then loses a chloride to form dichlorocarbene.



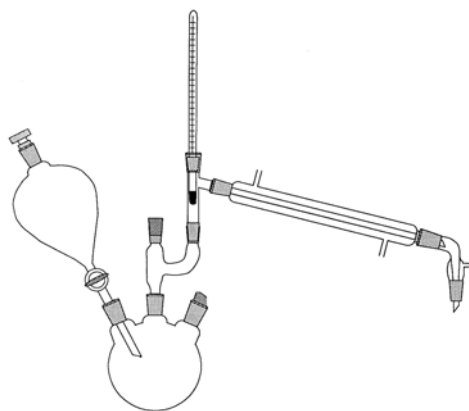
The very reactive dichlorocarbene that results could attack either the double bond or triple bond as illustrated. Both nmr and ir should be able to distinguish between the two possible products. Predict how the spectra of the two products should differ.



Procedure

Preparation of 2-methyl-1-buten-3-yne.

1. Assemble a 250 or 500 mL 3 necked round bottom flask equipped with a dropping funnel and a Claisen adapter connected to a three way adapter with a water cooled condenser. This apparatus should be mounted over a steam bath or heatable water bath. A 50 mL round bottom flask cooled by a salt-ice-water bath should be used as a receiver.
2. **Very cautiously**, slowly add 17 mL of concentrated sulfuric acid to 40 mL of ice cold water in an Erlenmeyer flask. Cool to room temperature and add to the 500 mL flask.
3. Using the dropping funnel, slowly add 26 mL of 2-methyl-3-butyn-2-ol to the acid. Slowly heat the mixture using the steam or water bath. Collect distillate until the vapor temperature reaches about 45°C. Transfer the distillate to a 100 mL Erlenmeyer flask containing a few grams of anhydrous sodium sulfate. Determine the refractive index, ir, nmr and store in a tightly sealed container in a freezer. If you do not get at least 0.06 moles of product, it may be advisable to combine your product with that of another group and work together on the next part.



Addition of dichlorocarbene to 2-methyl-1-buten-3-yne.

1. Assemble a 125 mL three necked flask equipped with a magnetic stirring bar, a thermometer, a dropping funnel and reflux condenser.
2. Introduce into the flask 7.5 g of potassium *t*-butoxide (the potassium *t*-butoxide must be dry and preferably from a freshly opened bottle), 40 mL of pentane and 0.060 moles of 2-methyl-1-buten-3-yne. Cool the mixture to 0°C in an ice bath and with continuous stirring, add 4 mL of chloroform dropwise. Maintain the mixture at 0°C for 1 1/2 hours.
3. Hydrolyze by carefully pouring the mixture onto about 75 grams of ice. Separate the layers using a separatory funnel and extract the aqueous layer with an additional 25 mL of pentane twice and add these to the first extraction.
4. Dry the pentane extracts over sodium sulfate and then carefully rotary evaporate or distill off the pentane and unreacted starting material.
5. Set up a small scale or a microscale vacuum (aspirator) distillation and collect the product which distills at about 52°C at 18 mm. The distillation must be done carefully as commonly only about 1 to 2 mL is collected. This amount should be sufficient for the determination of the desired properties.
6. Determine the ir and H-nmr spectra.

References

W. E. Parham W. E.; Schweizer, E. E. *Organic Reactions*, **1963**, *13*, 55.

Vo-Quang, L. and Simonnin, M-P. *Bull. Soc. Chim. France*, **1965**, *5*, 1534-1537

Vo-Quang, L. and Cadiot, P. *Bull. Soc. Chim. France*, **1965**, *5*, 1518 - 1524.

Vo-Quang, L. and Cadiot, P. *Acad. Sci, Paris*, **1961**, *252*, 3827 -3829.

For cartoons, see:

<http://www.freewebs.com/thebundyprinciple/apps/blog/>

<http://answers.yahoo.com/question/index?qid=20100916104312AAR86Kt>

<http://bressanini-lescienze.blogautore.espresso.repubblica.it/2011/04/11/paperino-eroe-per-caso-della-chimica-a-fumetti/>

Prelaboratory Preparation - *Experiment 26*

First, be sure to list all the goals of the experiment. Prepare a table for insertion of useful and observed data such as molecular mass, mass, moles, boiling points and percent yields and recoveries. Predict how the nmr and ir spectra will differ for the two possible products and how you should be able to determine which product is formed. Predict which product should predominate. Locate the reactions involved in this experiment on the *Reaction-Map of Organic Chemistry* in **Appendix C** and include the reaction numbers in your report.

Observations

Report all relevant observations including, masses, spectra and boiling points.

Conclusions

This section should include the following:

1. Were the goals of the experiment achieved? Explain your answer.
2. Assign as many absorptions in the ir and H-nmr as possible.
3. What was the identity of your product and did it agree with your prediction? Explain your answer.
4. Explain why the reaction occurred at the double or triple bond.
5. How could the percent yield and recoveries have been improved? Especially comment on how the elimination could be improved.
6. In the ir, where does the cyclopropyl C-H stretching occur and why does it occur at higher frequency than the CH₃ stretching?
7. In the nmr, where does the cyclopropyl C-H resonate? Suggest a reason for this chemical shift.
8. Has the product been reported previously in the literature? If so, give the citation.