

UCLA Chemistry 144 Organic Synthesis

Professor Michael E. Jung

Experiment 2: Tropolone Synthesis

Heather Graehl

Abstract

The multistep synthesis of tropolone was carried out using cyclopentadiene and dichloroketene to a 7,7-dichlorobicyclo [3.2.0]hept-2-en-6-one which then undergoes an interesting elimination consistent with Grob fragmentation with acetic acid, acetate, and water. The synthetic route starts with readily available starting compounds and produces high yields. Though tropolone was believed to be successfully synthesized, the decomplexing of tropolone from copper proved unsuccessful.

Introduction

Tropolone (6) is an interesting compound that has many resonance structures and characteristics of similar polyenones and polyenes, though it does not have aromatic character as one might infer from its structure.¹ Tropolone can be used in diels alder reactions and is a useful starting compound for complex larger ring systems such as steroids. The synthetic route performed in this experiment employs the use of a ketene (5) to undergo a unique elimination following Grob fragmentation pattern.^{2,3} The reaction scheme is outlined in Figure 1. Other routes to tropolone synthesis include irradiation of benzene in diazomethane to cycloheptatriene and subsequent oxidation with KMnO_4 .⁴ Though this alternative is one step, it requires equipment since as 80-plate column that is not available in this course.

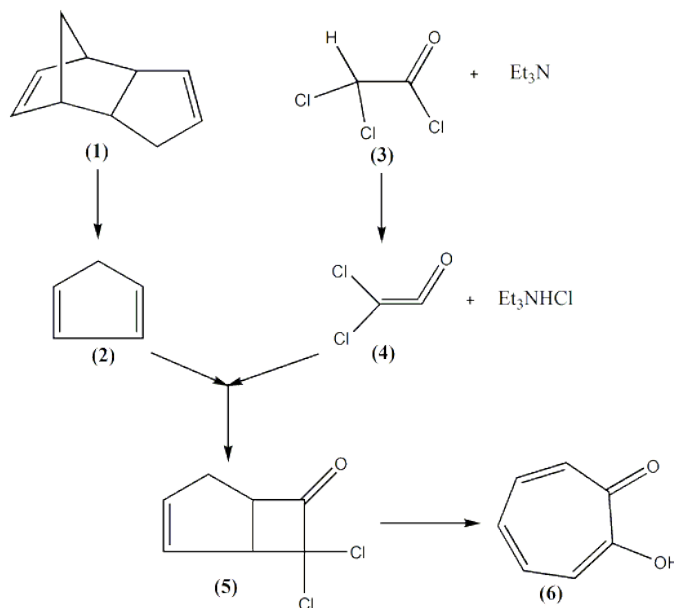


Figure 1: Reaction Scheme

Discussion

Cyclopentadiene (2) – Monomeric cyclopentadiene (2) is a good reagent for diels alder reactions though it must be prepared by cracking its more stable dimer (1) via a retro-diels alder reaction. Though dicyclopentadiene (1) is a liquid at room temperature, the reagent bottle was mostly solid indicating a higher degree of polymerization though this is not believed to have significant effect on obtaining the monomer (2) by distillation. The procedure by Feiser⁵ did not indicate a specific temperature required to crack (1), though an oil bath maintained at 180-240°C gave optimal distillation. The internal temperature

did periodically exceed 42°C as warned against in Feiser⁵ since this is the boiling point of monomer (2), so some dimer was likely collected since the dimer has boiling point of 170°C. Though it is advantageous to minimize collection of the dimer, it is not detrimental since redimerization is unavoidable during storage as well as subsequent steps use monomer in excess. Cyclopentadiene monomer has a dimerization rate of 3.5% mol per hour at 25°C, so precaution was taken to store it at 0°C which reduces the dimerization rate to 0.5% mol per hour.⁶

The proton and carbon NMR peak assignments are shown in table 1. A variable temperature proton NMR would be interesting to better show 1-5 sigmatropic shifts of cyclopentadiene. FTIR has notable sp² C peaks at 1339cm⁻¹, 1360cm⁻¹, 1439 cm⁻¹, 1615cm⁻¹ and C-H peaks at 2844cm⁻¹, 2927cm⁻¹, 2961cm⁻¹, and 3046cm⁻¹.

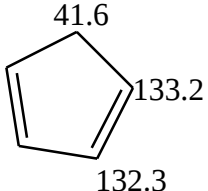
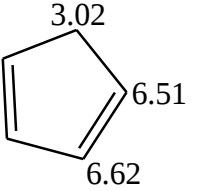
 ¹³C NMR (100 MHz, CDCl₃) δ (ppm) 41.6, 132.3, 133.2	 ¹H NMR (400 MHz, CDCl₃) δ (ppm) 3.02 (2H, dt, J=3.0 Hz, 1.5 Hz), 6.51 (2H, m), 6.62 (2H, m)
--	---

Table 1: NMR Peak Assignment of Cyclopentadiene (2)

7,7-dichlorobicyclo [3.2.0]hept-2-en-6-one (5) – This reaction had to be repeated since the first attempt a broken additional funnel caused an unknown amount of triethylamine to be lost. The reaction was stopped and started over to ensure a proper amount of triethylamine was used. The vacuum distillation was successful, though the process could be improved by using boiling chips and a stronger vacuum. The reaction mechanism occurs by a diels alder process with cyclopentadiene as the diene and the dichloroketone (4) as the dienophile. Since dichloroketene (3) is highly reactive and unstable, it is produced in situ with triethylamine and dichloroacetyl chloride.

Notable FTIR peaks at 1607cm⁻¹ (C=C) and 1802cm⁻¹ (C=O) further suggest successful synthesis of (5) and coincide with published values^{2,7}. NMR Peak assignments are addressed in table 2.

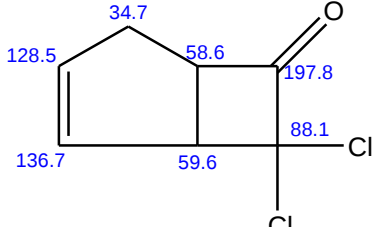
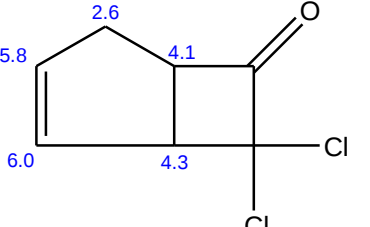
 ¹³C NMR (100 MHz, CDCl₃) δ (ppm) 34.7, 58.6, 59.6, 88.1, 128.5, 136.7, 197.8	 ¹H NMR (400 MHz, CDCl₃) δ (ppm) 2.60 (2H, m), 4.07 (1H, m), 4.26 (1H, m), 5.79 (1H, m), 6.03 (1H, m)
---	--

Table 2: NMR Peak Assignment of (5)

Tropolone (6) – The mechanism of formation of tropolone (6) from ketene (5) occurs by acetate attachment alpha to the ketone and bicyclic opening to a single ring system as chlorine is kicked off.² The mechanism is consistent with Grob fragmentation in which an elimination occurs with an electrofuge and nucleofuge in 1,3 position.³

The literature procedure⁷ called for six hour reflux, though due to time constraints the reaction was refluxed 3 hours and stirred at room temperature for 2 days. The reaction likely proceeded to produce tropolone, though the workup was not successful since copper remained in complex with tropolone. Unfortunately, spectra data on the tropolone copper complex is not available for comparison, so spectra is difficult to analyze. Pure tropolone is a white solid with melting point of 50-51°C⁷, though the product isolated was a green powder with melting point of 310°C. The FTIR contains many sp² carbon peaks at 1342cm⁻¹, 1410cm⁻¹, 1515cm⁻¹ and a C=O peak at 1591cm⁻¹ although it lacks an OH peak. This suggests that copper likely complexes to the hydroxyl group of tropolone which explains the absence of an OH peak in the IR spectrum. Proton NMR has two peak areas of interest at 12.7ppm and 7-7.5ppm. The 12.7ppm peak is suspect from the hydroxyl group, though it is peculiar that this hydrogen would be present in NMR and not FTIR. The remaining 5 protons are assigned to the numerous peaks from 7.0-7.4ppm. Three of the five peaks would be expected to triplets and the other two of five would be expected to be doublets, though these exact splitting patterns are not observed since these unequivalent protons are so similar that the proton NMR does not discern them clearly from each other.

Modification to this step would definitely aim to successfully decomplex tropolone from copper. The literature procedure⁷ called for use of hydrogen sulfide to decomplex copper, but instead an acidified sodium sulfide solution was used as suggested by the course reader⁸. The workup could be repeated by using the hydrogen sulfide solution method as described by Stevens rather than the modified procedure in the course reader.

No final yield was reported in experimental since the structure and molecular weight of the copper tropolone complex is not known. The reported 0.0816g of green powder is notably low though due to the final recrystallization from hexane was performed on the complex, but this step was intended to be performed on decomplexed tropolone. This resulted in a very large loss of complex since it does not recrystallize ideally under these conditions.

Conclusions

This method of tropolone synthesis is straight forward and uses readily available starting compounds. The copper complex used to purify tropolone was never successfully decomplexed, but despite this the successful synthesis of tropolone was believed to have been reached. The route showcases interesting reaction mechanisms, though alternative routes that do not require such high distillation temperatures are worthy of investigation.

Experimental

Cyclopentadiene (2) – Distillation of 41ml of dicyclopentadiene (1) was performed with high temperature oil bath and 10.067g (157.2 mmol) cyclopentadiene (2) was collected over ice as a clear liquid with strong irritating odor. Oil bath and internal distillation temperature were monitored at 180°-240°C and 35°-80°C respectively. Cyclopentadiene (2) was stored under nitrogen at 0°C. FT-IR ν (cm⁻¹) 1023 (w), 1252 (w), 1339 (m), 1360 (w), 1439 (w), 2884 (m), 2867 (m), 2927 (s), 2961 (s), 3046 (m); ¹H

NMR (400 MHz, CDCl₃) δ (ppm) 3.02 (2H, dt, J = 3.0 Hz, 1.5 Hz), 6.51 (2H, m), 6.62 (2H, m); ¹³C NMR (100 MHz, CDCl₃) δ (ppm) 41.6, 132.3, 133.2.

7,7-dichlorobicyclo [3.2.0]hept-2-en-6-one (5) Charged a 250mL round bottom flask with 8.6308g (0.13468 mol) of cyclopentadiene, 3.4ml dichloroacetyl dichloride (44.7mmol), and 50mL of hexane. An addition funnel with 6.23mL of triethylamine in 50ml hexane was added dropwise for 1 hour 5 minutes under nitrogen and stirred for 2 days at room temperature. The resulting white and brown mixture was vacuum filtered and washed with cold hexane. Solvent was removed to an orange liquid. Vacuum distillation was performed with external oil bath temperature ranging from 130°-195°C and internal temperature of 81°-110°C. The collected yellow liquid resulted in 6.62g (37mmol) at 84% yield of (5). FT-IR ν (cm⁻¹) 1207 (m), 1070 (w), 1107 (w), 1125 (w), 1168 (w), 1235 (w), 1257 (w), 1291 (w), 1344(w), 1441(w), 1607 (w), 1802 (s), 2855 (w), 2924 (w), 2966 (w), 3061 (w); ¹H NMR (400 MHz, CDCl₃) δ (ppm) 2.60 (2H, m), 4.07 (1H, m), 4.26 (1H, m), 5.79 (1H, m), 6.03 (1H, m); ¹³C NMR (100 MHz, CDCl₃) δ (ppm) 34.7, 58.6, 59.6, 88.1, 128.5, 136.7, 197.8

Tropolone (6) In a 100mL round bottom flask dissolved 6.625g NaOH in 37mL glacial acetic acid. Added 6.483g (36.5mmol) of (5) and 5mL dH₂O and refluxed under nitrogen for 2 hours and 40 minutes at 100°C. Then the reaction mixture was stirred at room temperature for two days. Poured reaction mixture into 230mL of 20% cupric sulfate solution and vacuum filtered. The filtrate was neutralized with sodium bicarbonate, extracted four times with 150mL chloroform and dried with magnesium sulfate. Removed excess solvent and recrystallized in hexane and chloroform. The resulting green solid was redissolved in chloroform and washed with sodium sulfide solution acidified to pH 5 with 10% HCl. The organic layer was filtered to remove a brown precipitate and the solvent was removed to result in 0.0816g of green powder. FT-IR ν (cm⁻¹) 419 (w), 585 (m), 710(m), 731 (m), 875 (w), 1230 (m), 1342 (s), 1410 (s), 1515(s), 1591 (m); ¹H NMR (400 MHz, CDCl₃) δ (ppm) 7.00-7.44 (5H, m), 12.66 (1H,m); mp 310°C

References

1. Bertelli, D. J.; Andrews, T.G.; Crews, P. O. *J. Am. Chem. Soc.* **1969**, *91*, 5286.
2. Barlett, P.D.; Ando, T. *J. Am. Chem. Soc.* **1970**, *92*, 7518.
3. Grob, C. A.; Baumann, W. *Helv. Chim. Acta* **1955**, *38*, 594.
4. Dauben, W. G.; Eastham, J. F.; *Am. Chem. Soc.* **1950**, *72*, 2305
5. Feiser, L. F.; Fieser, M. "Organic Experiments", 3rd ed., Raytheon Education Co., Lexington Mass., 1975, pp120
6. "Kirk-Othmer Encyclopedia of Chemical Technology", vol. 8, John Wiley & sons Inc., pp 219
7. Stevens, H.C.; Rinehart, J.k.; Lavanish, J.; Trenta, G. *J. Org. Chem.* **1971**, *36*, 2780
8. Chemistry 144 Organic Synthesis Laboratory Experiments Profesor Michael e. Jung Fal 2008
UCLA Department of Chemistry and Biochemistry

Spectra