ORGANIC LETTERS
2008
Vol. 10, No. 9
1843−1845

The General Synthesis and Trapping of 3-Substituted 1-Chlorocyclopropenes

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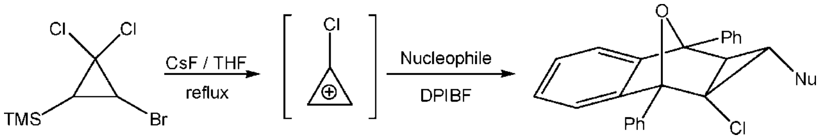
Received March 3, 2008

ABSTRACT



Treatment of 1-bromo-2,2-dichloro-3-trimethylsilylcyclopropane with CsF in THF refluxing temperature gave chlorocyclopropenyl cation (1), which reacted with various nucleophiles to generate 3-monosubstituted 1-chlorocyclopropenes. The Diels−Alder reactions of 3-monosubstituted 1-chlorocyclopropenes with 1,3-diphenylisobenzofuran (DPIBF) yielded only the *exo-anti* adducts in excellent yield. When cation 1 was treated with water and trapped with DPIBF, an aldehyde, 12, was isolated.

Although the first derivative of cyclopropane was obtained as early as 1881, and cyclopropane itself was obtained the following year,[1] the first authenticated synthesis of cyclopropene was not obtained until four decades later.[2] Cyclopropenes continue to fascinate both theoretical and experimental chemists because of their unique structure, high degree of ring strain, and difficult synthesis.[3] Consequently, the chemistry of cyclopropenes is very rich, containing many unusual processes such as ene dimerizations, [2 + 2] cycloadditions, and ring-opening reactions to release strain energy.[3] Cyclopropenes containing 3-hydrogen usually undergo ene dimerizations to form 3-cyclopropylcyclopropenes, and such asymmetric compounds undergo ene reactions to generate several regio- and stereodimers.[4] To understand the chemical properties of 3-monosubsituted cyclopropenes, it is very important to identify systematic methods and an easier route for synthesizing such compounds. Several synthesis methods for cyclopropenes have been developed.[1,4i,5] There are two easy methods to synthesize cylopropenes: one uses cyclopropenyl anions at carbon-1 with electrophiles to give 1-substituted cyclopropenes;[6] the other uses cyclopropenyl cations, the smallest Hückel aromatic system compounds,[7] with nucleophiles to generate 3-substituted cyclopropenes.

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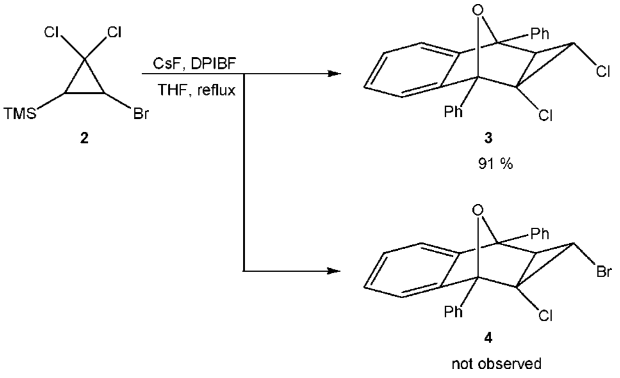
10.1021/ol8004479 CCC: $40.75

Cyclopropenyl anions can be generated by treatment with 1-halocyclopropenes with alkyllithium,[8] 1-trimethylsilylcyclopropenes with fluoride salt,[9] or cyclopropenes containing 1-hydrogen with alkyllithium.[10] Cyclopropenyl cations can be formed by treatment of cyclopropenes containing 3-hydrogen with triphenylmethyl perchlorate, $NO^+BF_4^-$,[11] or trialkyloxonium salts.[12] 3-Chlorocyclopropenes with strong Lewis acids also form cyclopropenyl cations.[13] In the literature, polysubstituted cyclopropenyl cations such as 1,2,3-trichloro, 1,2,3-triphenyl,[14] 3-methyl-1,2-diphenyl,[14a] tri-*tert*-butylcyclopropenyl,[15] and diphenyl[16] reacted with nucleophiles to give various types of 3-substituted cyclopropenes. To the best of our knowledge, there is only one report using chlorocyclopropenyl cation. Breslow and coworkers reported that treatment of a mixture of 1,3- and 3,3-dichlorocyclopropenes with $SbCl_5$ afforded chlorocyclopropenyl cation (**1**), allowing hydrolyzation to cyclopropenone.[17]

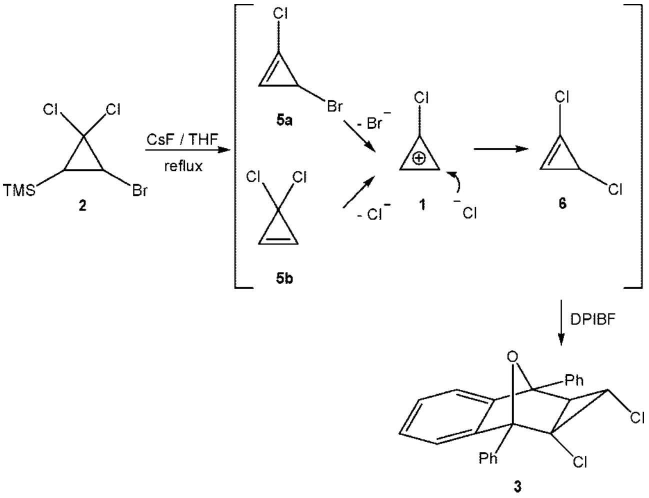
We now report a simpler preparation of cation **1**, which followed treatment with nucleophiles to form various 3-monosubstituted 1-chlorocyclopropenes. In addition, the stereochemistry of these cyclopropenes with DPIBF was studied.

1-Bromo-2,2-dichloro-3-trimethylsilylcyclopropane (**2**)[4h] was treated with 1.2 equiv of CsF and 1.2 equiv of DPIBF at refluxing temperature, and the mixture was then stirred for 8 h. The mixture was purified by chromatography and a sole product **3**[17] was obtained. According to the ^{1}H NMR spectrum and single-crystal X-ray analysis, the structure of product **3** was confirmed to be an *exo-anti* adduct of 1,3-dichlorocyclopropene with DPIBF (Scheme 1).

Scheme 1



Scheme 2



A plausible reaction mechanism is depicted in Scheme 2. 1-Chloro-3-bromocyclopropene (**5a**) or 3,3-dichlorocyclopropene (**5b**) was generated by the fluoride-induced elimination of 1-bromo-2,2-dichloro-3-trimethylsilylcyclopropane (**2**). Neither of the intermediates **5a** or **5b** expelled a halide ion autonomously to yield a chlorocyclopropenyl cation (**1**). According to the literature, the order of nucleophilicity was $Cl^- > Br^-$ in an aprotic solvent (THF).[18] A chloride ion attacked the intermediate **1** at the C-2 position to afford 1,3-dichlorocyclopropene, which was further trapped by DPIBF to yield an *exo-anti* adduct **3** (Scheme 2).

To prove the mechanism, compound **2** was treated with 1.2 equiv of CsF, 1.2 equiv of DPIBF, and 10 equiv of MeOH at a gently refluxing temperature. Compound **7** was the only isolated product of this reaction, and its structure was confirmed by single-crystal X-ray analysis (Figure 1).

Intermediate 1-chloro-3-methoxycyclopropene was synthesized by the reaction of methanol as it attacked the

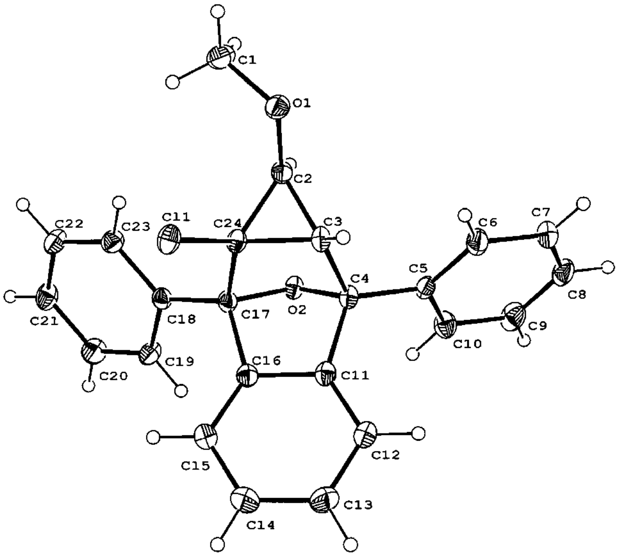


Figure 1. X-ray structure of compound **7**.

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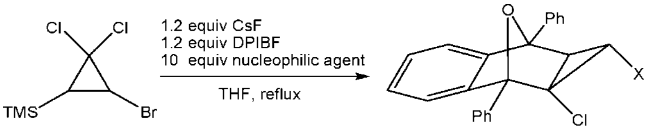
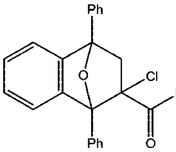
chlorocyclopropenyl cation (**1**) at the C-2 position. 1-Chloro-3-methoxycyclopropene formed a DPIBF adduct (*exo-anti*) in 85% yield.

In the literature, 3-substituted 1-chlorocyclopropenes are rare because they are difficult to synthesize.[17,19] Based on these reports, we plan to synthesize a series of 3-substituted 1-chlorocyclopropenes using this methodology. The results of the reaction of chlorocyclopropenyl cation (**1**) with various nucleophilic agents are shown in Table 1.

Table 1. Various Nucleophilic Agents Reacted with Monochlorocyclopropenyl Cation (**1**)



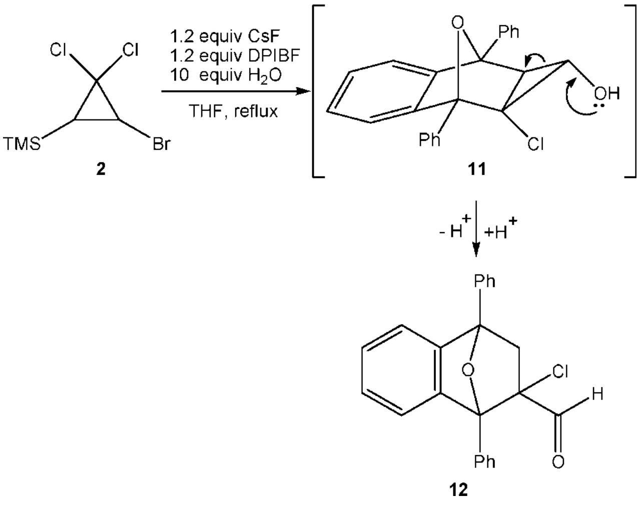
2

entry	10 equiv nucleophilic agent	X	yield
1		Cl, **3**	91%
2	Benzyltrimethylammonium chloride	Cl, **3**	92%
3	Methanol	OMe, **7**	85%
4	Thiophenol	SPh, **8**	91%
5	Sodium borohydride	H, **9**	56%
6	2-Propanol	OCH(CH$_3$)$_2$, **10**	9%
		Cl, **2**	75%
7	2-Propanol (excess)	OCH(CH$_3$)$_2$, **10**	68%
8	Water	OH	not observed
		 ,**12**	84%

Reaction of DPIBF with 3-substituted 1-chlorocyclopropenes yielded only the *exo-anti* adducts. Compounds **3** and **10** were isolated by chromatography in 75% and 9% using 10 equiv of 2-propanol, but compound **10** was the only product isolated using 2-propanol as a solvent (yield = 68%).

Chlorocyclopropenyl cation (**1**) reacted with water and was further trapped by DPIBF. The mixture was then concentrated and chromatographed to give aldehyde **12** (yield = 84%). A possible explanation for its production of compound **12** could be an intermediate **11** via a ring-opening reaction to release the strain energy (Scheme 3).

Scheme 3



In summary, we have prepared, in high regioselectivity, a very good yield of the chlorocyclopropene family by the reaction of chlorocyclopropenyl cation (**1**) with various nucleophiles. Diels−Alder cycloaddition of chlorocyclopropenes with 1,3-diphenylisobenzofuran (DPIBF) yielded only an *exo-anti* adduct. The structures of these compounds were determined by single-crystal X-ray analysis, and the chemistry of all 3-substituted 1-chlorocyclopropenes is being investigated.

Acknowledgment. Financial support from the National Science Council of the Republic of China (NSC 96-2113-M-030-003-MY2) and the National Center for High-performance Computing for computer time and facilities is gratefully acknowledged. We thank Professor M. Shieh and Mr. T.-S. Kuo at NTNU for the X-ray structure determination.

Supporting Information Available: Experimental procedures and full spectroscopic data for all new compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

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