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ADDITION REACTION OF CYCLIC ETHERS TO 1,1-ETHYLENE-1*H*-AZULENIUM ION

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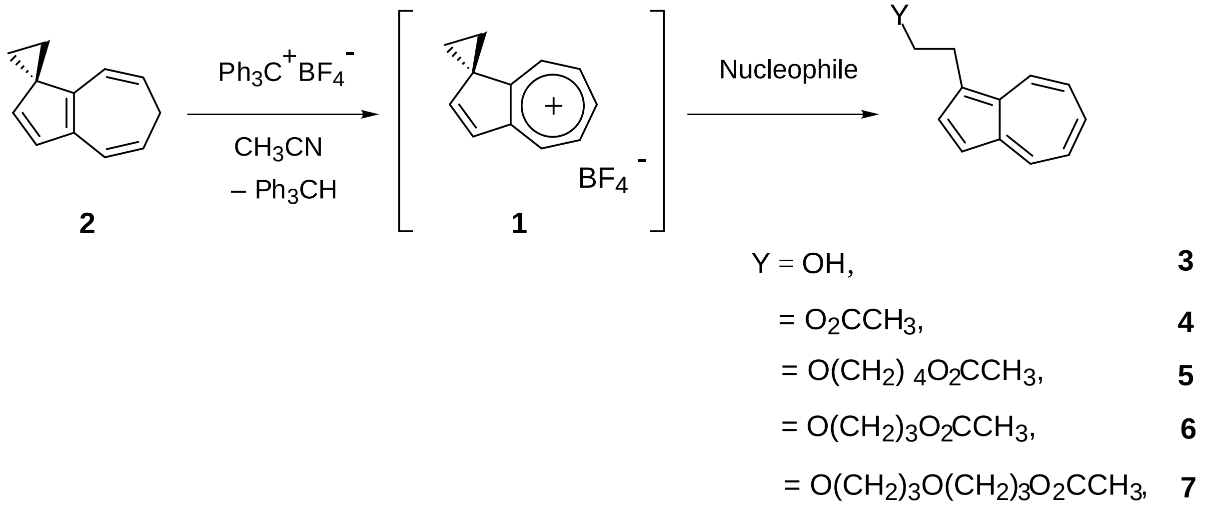
Abstract – The title cation (**1**) was found to react with some cyclic ethers in the presence of sodium acetate and acetic acid to give the products derived from nucleophilic addition of the ether oxygen atom at the three-membered ring methylene carbon of **1**.

We have recently reported the generation, characterization and some reactions of the 1,1-ethylene-1*H*-azulenium ion (**1**),[1,2] which had been postulated as an intermediate in β-azulylethyl *p*-toluenesulfonate solvolysis.[3] This cation was found to undergo expansion of the three-membered ring at 0˚C or to react readily with various nucleophiles to give thermodynamically controlled, stable adducts at its cyclopropane methylene carbon.[1,4] In the course of our investigation of the chemical behavior of **1** we have found high electrophilic reactivity of this cation, particularly against reagents which are known to show poor nucleophilicity and to be used commonly as a solvent, such as cyclic ethers, etc.[5] Herein we describe the addition reaction of the ethers with **1** in the presence of sodium acetate and acetic acid.

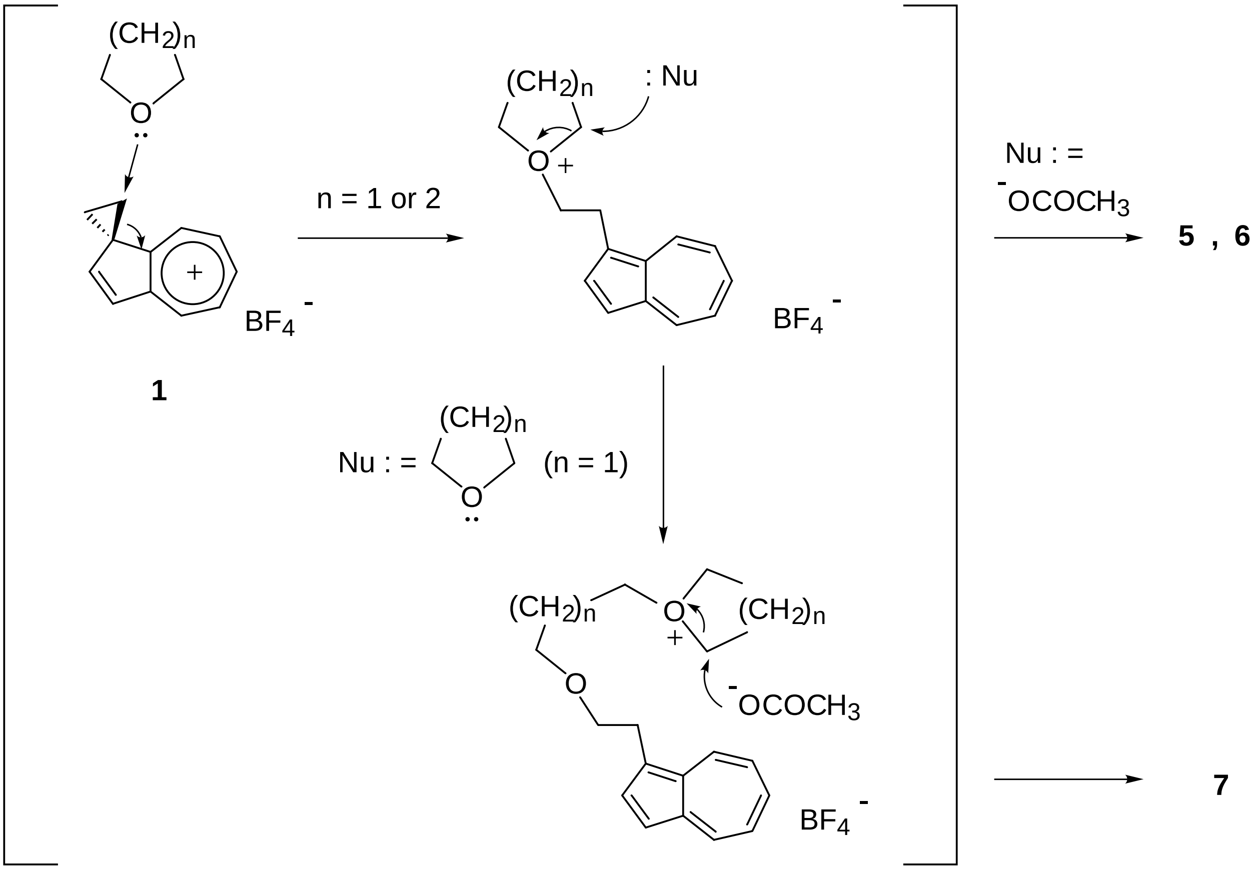
As previouly reported,[1] the greenish solution of cation (**1**) can be easily obtained *via* hydride abstraction of 1,1-ethylene-1,6-dihydroazulene (**2**) with trityl tetrafluoroborate[6] in acetonitrile at –20 ˚C. Addition of a large excess of sodium acetate and a mixture of acetic acid and tetrahydrofuran (THF) to this solution resulted in a slightly blue reaction solution. Quenching the reaction mixture with water at this stage or after a period of 30 min at the same temperature mainly afforded 2-(1-azulyl)ethanol (**3**),[3] indicating clearly that a nucleophilic

Scheme 1.



attack of either an acetate ion or THF at least to the cyclopropane methylene carbon is slow under the conditions. Warming the reaction mixture to room temperature caused darkening of the blue color. After being stirred at room temperature for 30 min, aqueous work-up and chromatographic purification gave 2-(1-azulyl)ethyl acetate (**4**)[1,3] in 38% yield, along with a 28% yield of 4-{2-(1-azulyl)ethoxy}butyl acetate (**5**).[7,8] Formation of the latter product probably involves addition of the THF oxygen atom at the cyclopropane methylene carbon of **1**, followed by an ether ring cleavage of an intermediary oxonium ion by attack of the acetate ion. Although alkylation of ether and carbonyl oxygens with carbocations has been well documented,[9] the alkylation reaction competed with nucleophilic addition of an acetate ion is a first example as far as we know. Using trimethylene oxide (TMO) instead of THF in the reaction gave **4** in 12% yield, along with a 9% yield of 3-{2-(1-azulyl)ethoxy}propyl acetate (**6**) and an 8% yield of 3-[3-{2-(1-azulyl)-ethoxy}propoxy]propyl acetate (**7**). Formation of **7**, which has two trimethyleneoxy units, evidenced higher nucleophilic character of the TMO oxygen atom than that of the THF one. In this reaction many blue products which were thought to have more than two trimethyleneoxy units were observed by TLC and NMR analyses, though they could not be isolated and characterized because of their low yields. Therefore, addition of the TMO oxygen atom at the cyclopropane methylene carbon may successively occur in the oxonium intermediates. Since the azulene skeleton carbons of **1** have greater net atomic charges than the cyclopropane methylene carbons based on semiempirical molecular orbital calculations (the PM3 method),[10,11] a hard acetate ion tends to attack the seven- and five-membered ring carbons as kinetically controlled reactions.

Scheme 2.



However, this process should be reversible under the reaction conditions so that such addition products may regenerate the cation (**1**). On the other hand, an ether oxygen atom with slightly soft nature compared with an acetate ion rather combines with the cyclopropane methylene carbon, resulting in the formation of **5**, **6**, and **7**. Using either tetrahydropyran (THP) or ether under the similar reaction conditions gave **4** as the sole product. Thus, nucleophilicity of the ethers to the cation (**1**) is in the order of TMO > THF >> THP, Et_2O, which is in accordance with their reported basicity.[5,12]

EXPERIMENTAL

IR spectra were recorded on a JASCO IR-810 spectrophotometer. UV spectra were measured on a Shimadzu UV-256FS spectrophotometer. ^{1}H-NMR (400 MHz) and ^{13}C-NMR (100 MHz) were recorded with tetramethylsilane as an internal standard in choloform-d_1 on a JEOL α400 spectrometer. MS spectra were measured on a JEOL JMS-D-300 mass spectrometer. Column chromatography was done with Merck

Kieselgel 60 Art 7734. The precursor for **1**, 1,1-ethylene-1,6-dihydrozulene (**2**), was prepared by the reported method.[1] Trityl tetrafluoroborate was prepared by the reported method.[6] THF and ether were purified just before use by distillation from sodium diphenylketyl under nitrogen atmosphere. THP, TMO, and acetonitrile were purified by distillation from calcium hydride.

*Reactions of 1,1-Ethylene-1H-azulenium Ion (**1**) with Cyclic Ethers.*

General Procedure : Trityl tetrafluoroborate (396 mg, 1.2 mmol) was added in one portion to a solution of 1,1-ethylene-1,6-dihydroazulene (**2**, 187 mg, 1.2 mmol) in 15 mL of acetonitrile at –20 ˚C. After the mixture was stirred at the same temperature for 10 min, a solution of 1.50 g (20.0 mmol) of sodium acetate in a mixture of acetic acid (1.0 mL) and a cyclic ether (20.0 mmol) was added. After the addition the bath was removed, and the reaction mixture was gradually warmed to rt and then stirred for 30 min. The resulted mixture was poured into water (50 mL) and extracted with dichloromethane (3 x 30 mL). The combined organic layer was washed with brine and dried with anhydrous $MgSO_4$. After evaporation of the solvent, the residual oil was purified by chromatography to give triphenylmethane (95~99%) as colorless crystals and the addition products.

4-{2-(1-Azulyl)ethoxy}butyl Acetate (**5**): a blue oil. ^{1}H NMR δ = 1.66 (m, 4 H), 2.03 (s, 3 H), 3.35 (t, *J* = 7.4 Hz, 2 H), 3.47 (t, *J* = 6.0 Hz, 2 H), 3.72 (t, *J* = 7.4 Hz, 2 H), 4.06 (t, *J* = 6.0 Hz, 2 H), 7.06 (t, *J* = 9.8 Hz, 1 H), 7.10 (t, *J* = 9.8 Hz, 1 H), 7.33 (d, *J* = 3.9 Hz, 1 H), 7.53 (t, *J* = 9.8 Hz, 1 H), 7.80 (d, *J* = 3.9 Hz, 1 H), 8.24 (d, *J* = 9.8 Hz, 1 H), 8.30 (d, *J* = 9.8 Hz, 1 H); ^{13}C NMR δ = 20.9, 25.4, 26.2, 28.1, 64.2, 70.3, 71.9, 116.7, 121.5, 122.2, 127.1, 133.4, 136.2, 136.3, 137.3, 137.4, 140.6, 171.1; IR (film) 2940 (m), 2850 (m), 1740 (s), 1575 (m), 1440 (m), 1390 (w), 1390 (m), 1360 (m), 1240 (s), 1110 (s), 1060 (w), 1040 (w), 770 (w), 740 (w) cm^{-1}. UV/Vis λmax (CH_3OH) 238 nm (log ε = 4.18), 261^{sh} (4.32), 266^{sh} (4.50), 271^{sh} (4.62), 277 (4.68), 281^{sh} (4.63), 286^{sh} (4.44), 296^{sh} (3.69), 318^{sh} (3.24), 327^{sh} (3.44), 334 (3.45), 343 (3.62), 359 (3.31), 549^{sh} (2.33), 574^{sh} (2.42), 598 (2.48), 622^{sh} (2.42), 651

(2.40), 686^{sh} (2.08), 720 (1.95). EIMS (70 eV) *m/z* (rel intensity): 286 (M^+, 9), 133 (12), 132 (100), 209 (16), 107 (8). Found: *m/z* 286.1568. Calcd for $C_{18}H_{22}O_3$: M, 286.1568. A tricyanovinyl derivative, 4-{2-(3-tricyanovinylazulen-1-yl)ethoxy}butyl acetate, of **5**[13]: dark voilet needles, mp 105-106 °C. *Anal.* Calcd for $C_{23}H_{21}N_3O_3 \cdot 0.2H_2O$: C, 70.65; H, 5.52; N, 10.75. Found: C, 70.39; H, 5.57; N, 10.53.

3-{2-(1-Azulyl)ethoxy}propyl Acetate (**6**): a blue oil. ^{1}H NMR δ = 1.90 (quin, *J* = 6.4 Hz, 2 H), 2.03 (s, 3 H), 3.52 (t, *J* = 7.4 Hz, 2 H), 3.53 (t, *J* = 6.4 Hz, 2 H), 3.73 (t, *J* = 7.4 Hz, 2 H), 4.16 (t, *J* = 6.4 Hz, 2 H), 7.08 (t, *J* = 9.8 Hz, 1 H), 7.11 (t, *J* = 9.8 Hz, 1 H), 7.33 (d, *J* = 3.8 Hz, 1 H), 7.54 (t, *J* = 10.0 Hz, 1 H), 7.80 (d, *J* = 3.8 Hz, 1 H), 8.25 (d, *J* = 9.8, 1 H), 8.31 (d, *J* = 9.8 Hz, 1 H); ^{13}C NMR δ = 21.0, 28.0, 29.0, 61.8, 67.3, 72.0, 116.7, 121.6, 122.2, 127.0, 133.4, 136.2, 136.7, 137.3, 137.4, 140.5, 171.1; IR (film) 2920 (m), 2850 (m), 1740 (s), 1580 (m), 1560 (w), 1510 (w), 1480 (m), 1460 (m), 1440 (m), 1420 (m), 1395 (m), 1365 (m), 1300 (w), 1240 (s), 1110 (s), 1050 (m), 940 (w), 770 (m), 740 (m) cm^{-1}. UV/Vis λmax (CH_3OH) 238 nm (log ε = 4.19), 268^{sh} (4.48), 273^{sh} (4.63), 278 (4.68), 277 (4.68), 283^{sh} (4.64), 288^{sh} (4.47), 297^{sh} (3.77), 328^{sh} (3.274), 334^{sh} (3.46), 344 (3.62), 359 (3.33), 534^{sh} (2.23), 574^{sh} (2.42), 576^{sh}(2.42), 599 (2.48), 620^{sh} (2.42), 651 (2.41), 683^{sh} (2.13), 720 (1.98). EIMS (70 eV) *m/z* (rel intensity): 272 (M^+, 12), 142 (12), 141 (100), 115 (6), 43 (8), 28 (37). Found: *m/z* 272.1405. Calcd for $C_{17}H_{20}O_3$: M, 272.1410.

3-[3-{2-(1-Azulyl)ethoxy}propoxy]propyl Acetate (**7**): a blue oil. ^{1}H NMR δ = 1.84 (quin, *J* = 6.4 Hz, 2 H), 1.86 (quin, *J* = 6.4 Hz, 2 H), 2.03 (s, 3 H), 3.35 (t, *J* = 7.4 Hz, 2H), 3.44 (t, *J* = 6.4 Hz, 2 H), 3.46 (t, *J* = 6.4 Hz, 2H), 3.54 (t, *J* = 6.4 Hz, 2 H), 3.74 (t, *J* = 7.4 Hz, 2 H), 4.13 (t, *J* = 6.4 Hz, 2 H), 7.08 (t, *J* = 9.8 Hz, 1 H), 7.11 (t, *J* = 9.8, 1 H), 7.33 (d, *J* = 3.8 Hz, 1H), 7.54 (t, *J* = 9.8 Hz, 1 H), 7.81 (d, *J* = 3.8 Hz, 1 H), 8.26 (d, *J* = 9.8, 1 H), 8.32 (d, *J* = 9.8 Hz, 1 H); ^{13}C NMR δ = 21.0, 28.1, 29.0, 30.1, 61.7, 67.2, 67.76, 67.84, 71.9, 116.7, 121.6, 122.2, 127.2, 133.5, 136.2, 136.4, 137.3, 137.4, 140.6, 171.1; IR (film) 2970 (w), 2940 (m), 2870 (m), 1740 (s), 1580 (m), 1440 (m), 1460 (m), 1400 (s), 1370 (m), 1300 (w), 1250 (s), 1120 (s), 1045 (m), 1060 (m), 950 (w), 780 (m), 740 (m) cm^{-1}. UV/Vis λmax (CH_3OH) 238 nm (log ε = 4.16), 268^{sh} (4.48), 273^{sh} (4.60), 278 (4.60), 278 (4.67), 283^{sh} (4.63), 288^{sh} (4.44), 298^{sh} (3.66), 320^{sh} (3.23), 334^{sh} (3.45), 344 (3.61), 359 (3.31), 555^{sh} (2.34), 577^{sh} (2.41), 599 (2.47), 621^{sh} (2.42), 652 (2.39), 683^{sh} (2.12), 721 (1.95). EIMS (70 eV) *m/z* (rel intensity): 330 (M^+, 10), 222 (16), 180 (8), 179 (11), 178 (9), 155 (100), 128 (19), 118 (100), 115 (17), 90 (19), 89 (9). Found: *m/z* 330.1827. Calcd for $C_{20}H_{26}O_4$: M, 330.1828.

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