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LETTERS TO THE EDITOR

Reactions of 3-Nitro- and 3-Bromo-3-nitroacrylates with 1,3-Cyclohexadiene

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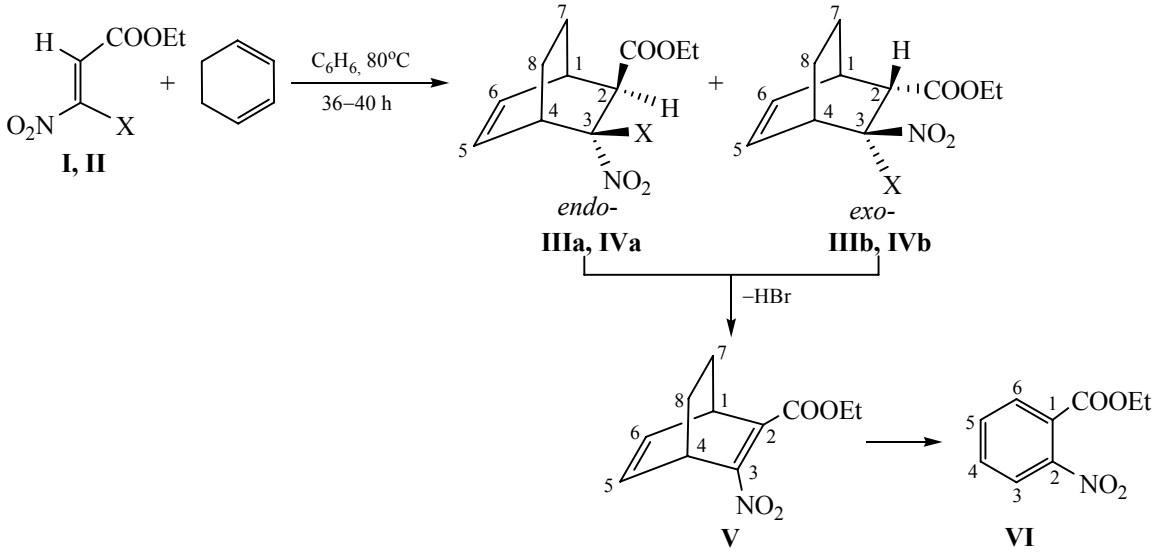
Nitroacrylates and their derivatives are known to be active dienophiles in the Diels–Alder reaction with acyclic [1, 2] and cyclic {cyclopentadiene [3, 4], furan [5, 6], β-furylnitroethene [7], β-(2-nitrovinyl)indole [8]} 1,3-dienes. In this work we investigate the reaction of the nitro- and *gem*-bromonitroacrylates **I**, **II** with 1,3-cyclohexadiene. The study of these reactions is of interest for the development of convenient methods of the synthesis of functionalized bicycleoctenes, which are important intermediates in the synthesis of fragments of the natural compounds (hormones, vitamin D_3, etc.) [1, 9].

Cyclopentadiene is known to react with nitroacrylate **I** at 0°C to give a mixture of *endo*- and *exo*-diastereomers of the corresponding nitronorbornene in a quantitative yield [3, 4]. In contrast to cyclopentadiene the reaction of 1,3-cyclohexadiene occurs in more rigid conditions (boiling the reaction mixture in benzene for 36 h) and results in a mixture of *endo*- and *exo*-isomers of ethyl 3-nitrobicyclo[2.2.2]-5-octen-2-ylcarboxylate **IIIa**, **IIIb** in 87% yield. The *endo*-isomer **IIIa** was isolated in pure form by the repeated chromatography of the bicyclooctene isomers mixture.

Bromonitroacrylate **II** reacts with cyclohexadiene under similar conditions (benzene, 80°C, 40 h) to afford a mixture of the difficultly separable products, from which by the column chromatography the *endo*-**IVa** and *exo*-**IVb** isomers of ethyl 3-bromo-3-nitrobicyclo[2.2.2]-5-octen-2-ylcarboxylate in the ratio of 6:1 with an overall yield of 45%, and the products of



X = H (**I, IIIa, IIIb**), Br (**II, IVa, IVb**).

their intramolecular transformations: ethyl 3-nitrobicyclo[2.2.2]-2 ,5-octadien-2-ylcarboxylate **V** and ethyl 2-nitrophenylcarboxylate **VI** were isolated.

The lower yield of bicyclooctene **IV** (45%) compared to bicyclooctene **III** (87%) seems to originate from a greater steric strain of the unsaturated bicyclic system with three electron-withdrawing groups (COOR, NO_2, Br) and from a greater susceptibility of **IV** to intramolecular transformations under the rigid conditions. The presence of a good leaving nucleofuge halogen atom *gem*-positioned relative to the nitro group and the labile hydrogen atom at the COOR function obviously contributes to the dehydrohalogenation process and to the formation of the corresponding bicyclooctadiene **V**. The possibility of producing the substituted bicyclooctadienes from the diene synthesis adducts have been discussed by us [10] and other authors [11, 12] for the condensation of 1,3-cyclohexadiene with various dienophiles. The instability of **V** is, probably, due to a forced *cis* location of the ester and nitro groups at the C=C bond (steric factor) [13]. As a result, the ethane bridge destruction and the formation of aromatic structure **VI** occurs. The presence of compound **VI** in the reaction mixture is confirmed by the presence of the characteristic signals of aromatic protons at 7.70–8.80 ppm in the ^{1}H NMR spectrum.

The formation of aromatic products in a significant yield (80–92%) in the Diels–Alder reaction involving 1,3-cyclohexadiene was also observed by other authors [12, 14, 15], for example, in the case of the reaction of cyclohexadiene with acetylenic dienophiles or β-halonitroalkenes [10]. The formation of the benzene ring Petrzilka et al. [11] and Wolinsky et al. [12] associated with the bridge destruction in the intermediate bicyclooctadiene by removing ethylene.

Bicyclooctadiene **V** we detected only spectrally. In the ^{1}H NMR spectra there are multiplets of the C^1H and C^4H protons at 3.40 and 3.55 ppm, respectively. They are regularly observed in a weaker field compared with those of the original bicyclooctene **IV**.

The structure of nitrobicyclooctenes **IIIa**, **IVa**, **IVb**, and arene **VI** was established by the NMR spectra analysis and their comparison with the corresponding parameters of the structuraly similar compounds described in the literature [10, 16]. In the ^{1}H NMR spectra of bicyclooctenes **III**, **IV** there are a doubling of the signals of all the ring protons, which indicates the existence of a mixture of two diastereomers *endo*-(NO_2)-**IIIa**, **IVa** and *exo*-(NO_2)-**IIIb**, **IVb**.

In accordance with [17, 18], the criteria used to determine the stereochemical nature of the bicyclic systems (norbornenes) were applied to bicyclooctenes. One of the criteria for the substituted bicyclooctenes can be a difference between the chemical shifts of the ring C^5H and C^6H protons. In the *endo*-isomer a difference between the chemical shifts of these protons is greater due to the steric closeness with the substituent on the rear part of the molecule (in this case, NO_2-group). In the *exo*-isomer the effect of a nitro group is weakened, and the chemical shifts of the olefinic protons differ less that can be seen by comparing the corresponding parameters of the *endo*- and *exo*-isomers of bicyclooctenes **IIIa**, **IVa** and **IIIb**, **IVb**. So, for these compounds the C^5H and C^6H protons signals are close for *exo*-isomers **IIIb**, **IVb** (Δδ 0.15–0.20 ppm) and are separated from each other for *endo*-isomers **IIIa**, **IVa** (Δδ 0.45–0.48 ppm). For example, in the spectrum of *endo*-**IIIa** with the signals of the protons at 5.98 (H^5) and 5.50 ppm (H^6) Δδ is 0.48 ppm, and in the spectrum of *exo*-**IIIb** this value is Δδ 0.15 ppm [5.85 (H^5) and 5.70 ppm (H^6)]. According to this parameter (Δδ 0.48 ppm), the stereohomogeneous nitrobicyclooctenylcarboxylate **IIIa** is of the *endo*-configuration. Analyzing the integral intensities of the non-overlapping signals of the olefinic protons at 5.50–5.98 ppm and the upfield signals of the bridge protons at 1.10–2.22 ppm in the ^{1}H NMR spectra of a mixture of compounds **IVa** and **IVb**, it is possible to conclude that the ratios of the *endo/exo*-stereoisomers **IIIa**:**IIIb** and **IVa**:**IVb** equal 5:1 and 6:1, respectively.

The ^{1}H NMR spectrum of compound **VI** contains the signals of aromatic protons in the range of 6–9 ppm [19, 20]. The signal at 8.20 ppm belongs to the C^6H proton. The C^3H proton experiencing the greatest impact from an electron-withdrawing nitro group resonates in a weaker field at 8.80 ppm. The signals of the C^4H and C^5H protons appear at 7.75 and 7.70 ppm, respectively, which is consistent with the spectra of the structurally similar compounds [10, 21].

Ethyl 3-nitrobicyclo[2.2.2]-5-octen-2-ylcarboxylates (IIIa, IIIb). To a solution of 0.72 g (0.005 mol) of ethyl 3-nitroacrylate **I** in 5 ml of anhydrous benzene was added 0.1 g of hydroquinone and 0.47 ml (0.005 mol) of 1,3-cyclohexadiene. The reaction mixture was boiled for 36 h with the continuous stirring. After the solvent removal, the residue was chro-

matographed eluting with benzene. Yield 0.73 g (87%), yellow oily substance, which is a mixture of *endo*- and *exo*-isomers in a ratio of 5:1, R_f 0.62, 0.65. ^{1}H NMR spectrum, δ, ppm: **IIIa**, 2.32–2.37 m (1H, H^1), 3.33–3.36 m (1H, H^2), 5.02–5.07 m (1H, H^3), 3.38–3.44 m (1H, H^4), 5.96–5.99 m (1H, H^5), 5.48–5.52 m (1H, H^6), 1.20–1.40 m (2H, CH_2^7), 1.60–1.80 m (2H, CH_2^8), 1.30–1.38 m (3H, CH_3), 4.15–4.34 m (2H, OCH_2); **IIIb**, 2.50–2.55 m (1H, H^1), 3.68–3.72 m (1H, H^2), 4.82–4.88 m (1H, H^3), 3.63–3.68 m (1H, H^4), 5.83–5.86 m (1H, H^5), 5.68–5.71 m (1H, H^6), 1.10–1.20 m (2H, CH_2^7), 1.60–1.80 m (2H, CH_2^8), 1.15–1.34 m (3H, CH_3), 4.10–4.28 m (2H, OCH_2). Found, %: C 58.60, 58.71; H 6.71, 6.74; N 6.26, 6.27. $C_{11}H_{15}NO_4$. Calculated, %: C 58.67; H 6.67; N 6.22.

The *endo*-isomer **IIIa** was isolated individually by the repeated chromatography of the mixture in a yield of 65% (eluent chloroform). IR spectrum, ν, cm^{-1}: 1379, 1575 (NO_2), 1735 (C=O), 1045, 1195 (C–O–C). Found, %: N 6.20, 6.22. $C_{11}H_{15}NO_4$. Calculated, %: N 6.22.

Ethyl 3-bromo-3-nitrobicyclo[2.2.2]-5-octen-2-ylcarboxylates (IVa, IVb), ethyl 3-nitrobicyclo [2.2.2]-2,5-octadien-2-ylcarboxylate (V), ethyl 2-nitrophenylcarboxylate (VI). To a solution of 0.6 g (0.002 mol) of ethyl 3-bromo-3-nitroacrylate **II** in 10 ml of anhydrous benzene was added 0.1 g of hydroquinone and 0.16 g (0.002 mol) of 1,3-cyclohexadiene. The reaction mixture was boiled for 11 h at stirring. After the solvent removal, the residue was chromatographed eluting with benzene. Yield 0.4 g, yellow oily substance, which is a mixture of nitrobicyclodiene **V** and nitroarene **VI**. ^{1}H NMR spectrum, δ, ppm: **V**, 3.4 m (1H, C^1H), 3.55 m (1H, C^4H), 6.13–6.55 m (2H, C^5H, C^6H), 1.10–2.05 m (4H, C^7H, C^8H); **VI**, 8.80–8.83 m (1H, C^3H), 7.68–7.77 m (2H, C^4H, C^5H), 8.17–8.23 m (1H, C^6H), 1.35–1.48 m (3H, CH_3), 4.31–4.54 m (2H, OCH_2).

When eluting with chloroform, 0.27 g (45%) of a mixture of *endo*- and *exo*-isomers **IVa, IVb** in a ratio of 6:1 was isolated as a yellow oily substance. R_f 0.48, 0.55. IR spectrum, ν, cm^{-1}: 1380, 1560 (NO_2), 1745 (C=O), 1020, 1125 (C–O–C). ^{1}H NMR spectrum, δ, ppm: **IVa**, 3.18–3.25 m (2H, H^1, H^4), 3.58–3.62 m (1H, H^2), 6.45 d.d (1H, H^5, $J_{5,6}$ 5.60 Hz), 6.00 d.d (1H, H^6, $J_{6,5}$ 5.60 Hz), 1.25–1.38 m (2H, CH_2^7), 2.18–2.26 m (2H, CH_2^8), 1.25–1.40 m (3H, CH_3), 4.18–4.45 m (2H, OCH_2); **IVb**, 2.58–2.61 m (1H, H^1), 3.78–3.82 m (1H, H^2), 3.17–3.25 m (1H, H^4), 6.30 d.d (1H, H^5, $J_{5,6}$ 6.0 Hz), 6.10 d.d (1H, H^6, $J_{6,5}$ 6.0 Hz), 1.35–1.42 m (2H, CH_2^7), 2.07–2.15 m (2H, CH_2^8), 1.20–1.42 m (3H, CH_3), 4.10–4.38 m (2H, OCH_2). Found, %: C 43.47, 43.48; H 4.63, 4.66; N 4.58, 4.62. $C_{11}H_{14}BrNO_4$. Calculated, %: C 43.42; H 4.61; N 4.61.

The IR spectra were registered on an InfraLUM FT 02 instrument for the samples in a chloroform solution (*c* 0.1–0.001 M). The ^{1}H NMR spectra were recorded on a Bruker AC-200 instrument (200 MHz) in $CDCl_3$ relative to external HMDS with accuracy up to ±0.5 Hz.

The purification and isolation of the individual substances was performed by the column chromatography on silica gel Chemapol 100/200 or on alumina using a Trappe series of the solvents [22]. The individuality of the substances obtained and the reaction progress were monitored by the thin layer chromatography (TLC) on Silufol-254 plates eluting with a hexane–acetone mixture (3:1) and detecting with iodine vapor. The starting nitro- and *gem*-bromonitroacrylates **I**, **II** were prepared as in [23, 24].

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