Russian Journal of Organic Chemistry, Vol. 39, No. 10, 2003, pp. 1493–1496. Translated from Zhurnal Organicheskoi Khimii, Vol. 39, No. 10, 2003, pp. 1561–1563.

Reactions of 2,3-Dichloro- and 2,3,5-Trichloro-4,4-ethylenedioxy-2-cyclopentenones with Some *O*-, *S*-, and *N*-Nucleophiles

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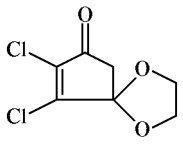
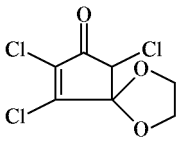
Received July 19, 2002

Abstract—2,3-Dichloro- and 2,3,5-trichloro-4,4-ethylenedioxy-2-cyclopentenones react with allyl and benzyl alcoholates and thiolates and benzylamine to give products resulting from Ad_NE substitution of the 3-chlorine atom, [1,3]-sigmatropic rearrangement, and cleavage of the C^1-C^2 bond.

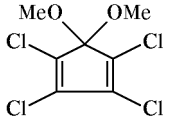
In continuation of our studies on the chemical properties of new chlorinated cyclopentenones derived from hexachlorocyclopentadiene [1], in the present work we examined reactions of clorocyclopentenones **I** and **II** [2, 3] with sodium salts of furfuryl and benzyl alcohols, phenylmethanethiol, and 2-propenethiol in THF, as well as with benzylamine. For comparison, analogous reactions of 5,5-dimethoxy-1,2,3,4-tetrachlorocyclopentadiene (**III**), which were studied previously [4], are discussed.



I



II

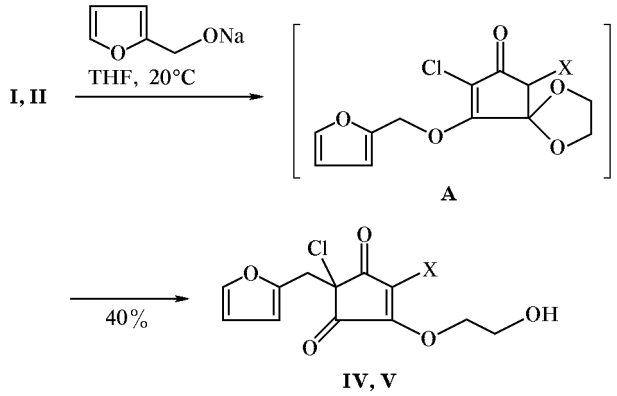


III

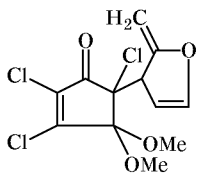
Chlorocyclopentenones **I** and **II** smoothly reacted with sodium 2-furylmethoxide in THF at 20°C to give cyclopentenedione derivatives **IV** and **V**, respectively, in moderate yields (Scheme 1). A probable mechanism of the process includes [1,3]-Wittig rearrangement of primary intermediate adduct **A** (which is formed via Ad_NE pattern) with simultaneous opening of the dioxolane ring. It should be noted that the reaction of compound **III** with sodium 2-furylmethoxide resulted in exclusive formation of [1,3]-rearrangement products **VI** and **VII** [5].

Unlike the above process, the reactions of enones **I** and **II** with sodium 2-furylmethanethiolate, sodium phenylmethoxide, and benzylamine stopped at the stage of replacement of the chlorine atom in position *3*, and the corresponding substitution products **VIII**–**XII** were obtained in good yields (Scheme 2). No

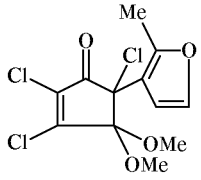
Scheme 1.



IV, X = H; **V**, X = Cl.



VI



VII

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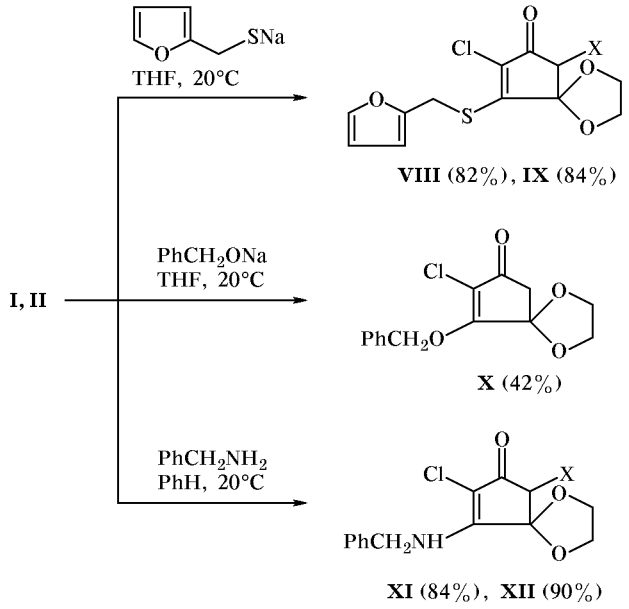
expected [3,3]- or [1,3]-sigmatropic rearrangement occurred on heating of compounds **VIII**–**XII** in boiling toluene or undecane. Analogous reaction of tetrachloroacetal **III** with sodium phenylmethoxide yielded the [1,3]-rearrangement product [4].

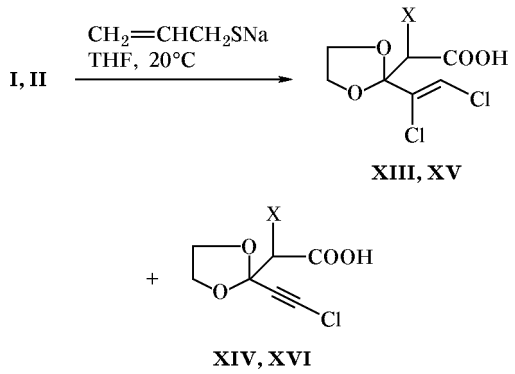
Scheme 2.



VIII, **XI**, X = H; **IX**, **XII**, X = Cl.

An anomalous pattern was observed in the reaction of compounds **I** and **II** with sodium 2-propenethiolate. The products were acyclic carboxylic acids **XIII**–**XVI** which were formed via opening of the cyclopentene ring (Scheme 3). The major products were compounds **XIII** and **XV** having a dichlorovinyl group; the ratio of **XIII**, **XV** to **XIV**, **XVI** was about 4 : 1. Reactions of enones **I** and **II** involving analogous cleavage of the cyclopentene ring were reported in [6].

Scheme 3.



XIII, **XIV**, X = H; **XV**, **XVI**, X = Cl.

Thus the examined reactions of chlorocyclopentenones **I** and **II** with nucleophiles all involve initial replacement of the chlorine atom at C^3, but the subsequent transformations are difficult to predict.

EXPERIMENTAL

The IR spectra were recorded on UR-20 and Specord M-80 spectrometers from samples prepared as thin films or suspensions in mineral oil. The ^1H and ^{13}C NMR spectra were obtained on a Bruker AM-300 instrument at 300 and 75.47 MHz, respectively, using $CDCl_3$ and $(CD_3)_2SO$ as solvents and TMS as internal reference.

5-Chloro-5-(2-furylmethyl)-2-(2-hydroxyethoxy)-2-cyclopentene-1,4-dione (IV). A solution of 0.31 g (3.15 mmol) of furfuryl alcohol in 2 ml of anhydrous THF was added dropwise with stirring to a suspension of 76 mg (3.15 mmol) of sodium hydride in 3 ml of anhydrous THF. The mixture was stirred for 10 min, and a solution of 0.5 g (2.1 mmol) of cyclopentenone **I** in 5 ml of anhydrous THF was added. The mixture was kept for 30 min at room temperature, acidified with 5% hydrochloric acid to pH 5, diluted with water, and extracted with methylene chloride. The combined extracts were washed with water, dried over $MgSO_4$, and evaporated, and the residue was subjected to chromatography on silica gel using petroleum ether–ethyl acetate (1 : 1) as eluent. Yield 42%. Oily substance. IR spectrum, ν, cm^{-1}: 1620, 1720, 3500. ^1H NMR spectrum ($CDCl_3$), δ, ppm: 3.51 d (1H, CH_2, ^2J = 14.5 Hz), 3,52 d (1H, CH_2, ^2J = 14.5 Hz), 3.98 t (2H, CH_2O, J = 4.5 Hz), 4.05–4.22 m (3H, CH_2O, OH), 6.07 d (1H, 3′-H, J = 3.1 Hz), 6.22 d.d (1H, 4′-H, J = 3.0, 3.1 Hz), 6.24 s (1H, 3-H), 7.32 d (1H, 5′-H, J = 3 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 34.05 (CH_2), 60.22 (CH_2OH), 61.23 (C^5), 73.84 (CH_2O), 109.97 ($C^{3'}$), 110.64 ($C^{4'}$), 116.02 (C^3), 142.68 ($C^{5'}$), 147.01 ($C^{2'}$), 169.71 (C^2), 191.53 (C=O), 192.29 (C=O).

3,5-Dichloro-5-(2-furylmethyl)-2-(2-hydroxyethoxy)-2-cyclopentene-1,4-dione (V) was obtained in a similar way using enone **II** as initial compound. Yield 40%. Oily substance. IR spectrum, ν, cm^{-1}: 1600, 1714, 3600. ^1H NMR spectrum ($CDCl_3$), δ, ppm: 3.51 d (1H, CH_2, ^2J = 14.5 Hz), 3.52 d (1H, CH_2, ^2J = 14.5 Hz), 3.90 t (2H, CH_2O, J = 4.3 Hz), 4.10–4.30 m (1H, OH), 4.70–4.80 m (2H, CH_2O), 6.07 d (1H, 3′-H, J = 3.1 Hz), 6.21 d.d (1H, 4′-H, J = 2.3, 3.1 Hz), 7.24 d (1H, 5′-H, ^2J = 2.3 Hz). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 34.62 (CH_2), 61.00 (CH_2OH), 61.57 (C^5), 75.54 (CH_2O), 110.05 ($C^{3'}$),

110.67 ($C^{4'}$), 121.98 (C^3), 142.97 ($C^{5'}$), 146.47 ($C^{2'}$), 162.76 (C^2), 186.15 (C=O), 188.61 (C=O).

7-Chloro-6-(2-furylmethylsulfanyl)-1,4-dioxaspiro[4.4]non-6-en-8-one (VIII) was synthesized by alkylation of compound **I** with sodium 2-furylmethanethiolate following the above procedure. Yield 82%. mp 118°C. IR spectrum, ν, cm^{-1}: 1584, 1604, 1700. ^1H NMR spectrum ($CDCl_3$), δ, ppm: 2.69 s (2H, 9-H), 3.95–4.20 m (4H, CH_2O), 4.53 s (2H, CH_2S), 6.25–6.30 m (2H, =CH), 7.34 s (1H, 5′-H). ^{13}C NMR spectrum ($CDCl_3$), δ, ppm: 27.44 (CH_2S), 46.37 (C^9), 65.42 (C^2, C^3), 109.01 ($C^{4'}$), 110.22 (C^5), 110.60 ($C^{3'}$), 131.85 (C^7), 142.39 ($C^{5'}$), 148.38 ($C^{2'}$), 162.76 (C^6), 191.53 (C=O). Found, %: C 50.59; H 4.00; Cl 12.02; S 11.58. $C_{12}H_{10}ClO_4S$. Calculated, %: C 50.44; H 3.53.; Cl 12,42; S 11.22.

7,9-Dichloro-6-(2-furylmethylsulfanyl)-1,4-dioxaspiro[4.4]non-6-en-8-one (IX) was synthesized by an analogous procedure using enone **II** as initial compound. Yield 84%. mp 120°C. IR spectrum, ν, cm^{-1}: 1584, 1620, 1700. ^1H NMR spectrum ($CDCl_3$), δ, ppm: 4.15–4.35 m (4H, CH_2O), 4.48 br.s (1H, 9-H), 4.55–4.65 m (2H, CH_2S), 6.34 br.s (2H, =CH), 7.40 br.s (1H, 5′-H). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 28.01 (CH_2S), 62.22 (C^9), 66.53 (C^2, C^3), 109.56 ($C^{3'}$), 110.22 (C^5), 110.89 ($C^{4'}$), 130.59 (C^7), 143.10 ($C^{5'}$), 148.01 ($C^{2'}$), 162.54 (C^6), 185.94 (C=O). Found, %: C 44.60; H 3.01; Cl 20.30; S 9.63. $C_{12}H_{10}Cl_2O_4S$. Calculated, %: C 44.89; H 3.14; Cl 20.11; S 9.98.

6-Benzyloxy-7-chloro-1,4-dioxaspiro[4.4]non-6-en-8-one (X) was synthesized by reaction of enone **I** with sodium phenylmethoxide. Yield 42%. mp 103°C. IR spectrum, ν, cm^{-1}: 1624, 1720, 2900. ^1H NMR spectrum ($CDCl_3$), δ, ppm: 2.76 s (2H, 9-H), 4.04–4.15 m (4H, CH_2O), 5.64 br.s (2H, OCH_2), 7.27–7.42 m (5H, H_{arom}). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 44.71 (C^9); 66.34 (C^2, C^3); 73.64 (CH_2O); 107.71 (C^5); 109.53 (C^7); 127.45, 128.65, 128.72, 135.02 (C_{arom}); 172.93 (C^6); 192.68 (C=O).

6-Benzylamino-7-chloro-1,4-dioxaspiro[4.4]non-6-en-8-one (XI). A solution of 0.5 g (2.1 mmol) of ketone **I** and 0.41 g (4.2 mmol) of benzylamine in 6 ml of benzene was vigorously stirred for 6 h. The solvent was distilled off, the residue was dissolved in 15 ml of water, and the product was extracted into chloroform (3 × 20 ml). The combined extracts were dried over $MgSO_4$ and evaporated, and the residue was subjected to chromatography on silica gel using petroleum ether–ethyl acetate (1 : 1) as eluent. Yield 84%. mp 115°C. IR spectrum, ν, cm^{-1}: 1020, 1150, 1480, 1610. ^1H NMR spectrum ($CDCl_3$), δ, ppm: 2.55 br.s (2H, 9-H), 4.05–4.13 m (4H, CH_2O), 4.79 br.s (2H, CH_2N), 5.62 br.s (1H, NH), 7.33–7.39 m (5H, H_{arom}). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 45.31 (CH_2); 47.21 (C^9); 65.10 (C^2, C^3); 103.68 (C^5); 107.76 (C^7); 127.33, 127.86, 128.79, 137.44 (C_{arom}); 160.53 (C^6); 190.04 (C=O).

6-Benzylamino-7,9-dichloro-1,4-dioxaspiro[4.4]-non-6-en-8-one (XII) was synthesized in a similar way from compound **II**. Yield 90%. mp 185°C. IR spectrum, ν, cm^{-1}: 1280, 1540, 1610, 1710. ^1H NMR spectrum (DMSO-d_6), δ, ppm: 4.01–4.32 m (4H, CH_2O), 4.55 br.s (1H, 9-H), 4.79–4.83 m (2H, CH_2N), 7.27–7.39 m (5H, H_{arom}), 8.53 br.s (1H, NH). ^{13}C NMR spectrum (DMSO-d_6), δ_C, ppm: 45.31 (CH_2); 61.52 (C^9); 66.32 and 66.52 (C^2, C^3); 106.78 (C^5); 127.08 (C^7); 126.34, 127.08, 128.47, 138.87 (C_{arom}); 159.81 (C^6); 183.95 (C=O).

3,3-Ethylenedioxy-4-penten(yn)oic acids XIII–XVI were synthesized by reaction of cyclopentenones **I** and **II** with sodium 2-propenethiolate in THF, following the procedure described above for compound **IV**. The overall yields of oily products **XIII** and **XIV** was 75%, and of **XV** and **XVI**, more than 80%. In the two cases, the ratio of pentenoic and pentynoic acids was about 4 : 1, according to the NMR data. The NMR signals were assigned from the spectra of mixtures **XIII**/**XIV** and **XV**/**XVI**.

(*Z*)-4,5-Dichloro-3,3-ethylenedioxy-4-pentenoic acid (XIII). IR spectrum, ν, cm^{-1}: 1620, 1720, 3600. ^1H NMR spectrum ($CDCl_3$), δ, ppm: 3.03 s (2H, 2-H), 4.00–4.40 m (4H, CH_2O), 6.79 s (1H, 5-H), 10.44–10.56 m (1H, COOH). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 41.05 (C^2), 65.25 (CH_2O), 106.66 (C^3), 119.43 (C^5), 133.70 (C^4), 173.39 (COOH).

5-Chloro-3,3-ethylenedioxy-4-pentynoic acid (XIV). IR spectrum, ν, cm^{-1}: 1740, 2220, 3600. ^1H NMR spectrum ($CDCl_3$), δ, ppm: 2.73 s (2H, 2-H), 4.00–4.40 m (4H, CH_2O), 9.30 br.s (1H, COOH). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 44.64 (C^2), 65.34 (CH_2O), 66.39 (C^4), 68.50 (C^5), 107.60 (C^3), 173.11 (COOH).

(*Z*)-2,4,5-Trichloro-3,3-ethylenedioxy-4-pentenoic acid (XV). IR spectrum, ν, cm^{-1}: 1620, 1720, 3600. ^1H NMR spectrum ($CDCl_3$), δ, ppm: 4.00–4.30 m (4H, CH_2O), 4.88 s (1H, 2-H), 6.87 s (1H, 5-H), 10.06 br.s (1H, COOH). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 57.28 (C^2), 66.52 and 66.16 (CH_2O), 107.53 (C^3), 121.45 (C^5), 131.25 (C^4), 170.01 (COOH).

2,5-Dichloro-3,3-ethylenedioxy-4-pentynoic acid (XVI). IR spectrum, ν, cm^{-1}: 1740, 2220, 3600.

^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 3.90–4.25 m (4H, CH_2O), 4.51 s (1H, 2-H), 10.06 br.s (1H, COOH). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm: 59.91 (C^2), 63.78 (C^5), 66.92 (C^4), 66.68 and 66.31 (CH_2O), 101.36 (C^3), 169.72 (COOH).

This study was financially supported by the Russian Foundation for Basic Research (project no. 02-03-32 594 a).

REFERENCES

1. Akhmetvaleev, R.R., Akbutina, F.A., Ivanova, N.A., and Miftakhov, M.S., *Izv. Ross. Akad. Nauk, Ser. Khim.*, 2001, no. 9, p. 1417.
2. Kuznetsov, O.M., Akhmetvaleev, R.R., Vostrikov, N.S., and Miftakhov, M.S., *Izv. Ross. Akad. Nauk, Ser. Khim.*, 1996, no. 4, p. 1027.
3. Akhmetvaleev, R.R., Imaeva, L.R., Belogaeva, T.A., and Miftakhov, M.S., *Izv. Ross. Akad. Nauk, Ser. Khim.*, 1997, no. 9, p. 1699.
4. Ismailov, S.A., *Zh. Org. Khim.*, 1989, vol. 25, p. 2238.
5. Tolstikov, G.A., Ismailov, S.A., Khalikov, R.M., and Miftakhov, M.S., *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1991, no. 10, p. 1012.
6. Akhmetvaleev, R.R., Imaeva, L.R., and Miftakhov, M.S., *Russ. J. Org. Chem.*, 1996, vol. 32, p. 1549.