J. prakt. Chem. 339 (1997) 650–651

Journal für praktische Chemie
Chemiker-Zeitung

cis-trans-Isomerization of an Ozonide and a Word of Caution Concerning Stereochemical Assignments of Ozonides Based on Elution Times

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Received July 4th, 1997

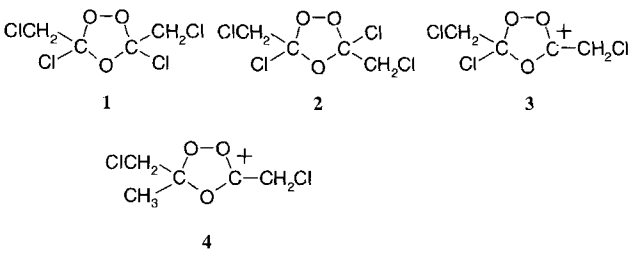
In a previous paper we had reported that ozonolysis of *trans*-1,2,3,4-tetrachloro-2-butene gave a mixture of the stereoisomeric ozonides **1** and **2**, which could be individually isolated [1]. Silver ion mediated reactions of the mixed ozonides with LiF, methanol or acetic acid gave substitution reactions in which the chlorine substituents at the ozonide ring were replaced by F, OCH_3 and $OCOCH_3$, respectively [2]. Recently, we have found that the chlorine atoms at the ozonide rings of **1** and **2** can be also substituted by allyl groups, mediated by $TiCl_4$ [3].

Results

In the present study, we have first improved the previously used [1] procedure for the isolation of **1** and **2** by crystallization of **2** and HPLC separation of **1** from the mother liquor. Subsequently, we have tried to examine the interaction between ozonides **1** or **2** and $TiCl_4$ in the absence of nucleophiles: Treatment of *cis*-ozonide **1** with an equimolar amount of $TiCl_4$ in CH_2Cl_2 at −40 °C gave a mixture of **1** and **2** in a ratio of 8:92. By the same treatment of **2**, a mixture of **1** and **2** in a ratio of 10:90 was obtained. The ozonide mixtures were isolated in more than 90% yield, and no products other than **1** and **2** could be detected.

To our knowledge, this is the first case of a successful *cis-trans*-isomerization of an ozonide. We assume, that it proceeds *via* ozonide cation **3**, which we had also assumed to be an intermediate in the above mentioned substitution reactions of **1** and **2** [3]. This cation appears to be more stable than other ozonide cations like *e.g.* **4**, which undergoes spontaneous ring opening [1]. The enhanced stability of **3** may be imparted by a combined effect of the remaining chlorine substituent at the ozonide ring and the formation of an ion pair between **3** and $TiCl_4$.

The stereochemical assignments of **1** and **2** are based on X-ray diffraction analysis of the crystalline ozonide **2** [4]. Prior to that information, we had erroneously made the opposite assignment [1]. This was based on the assumption that, as it was reported for other monocyclic [5] and bicyclic ozonides [6], the isomer with the longer chromatographic elution time exhibits *cis*-geometry. We have now found, however, that the order of elution of **1** and **2** in HPLC separations is dependent



Formula 1 Isomerizations of *cis*- and *trans*-3,5-dichloro-3,5-bis(chloromethyl)-1,2,4-trioxolane

on the solvents used: With pentane/dichloromethane, *cis*-ozonide **1** had a shorter and with hexane/diethyl ether it had a longer elution time than *trans*-ozonide **2**. Assignment of ozonide stereochemistry based on ^1H NMR data can be misleading, too. In $CDCl_3$, *cis*-ozonide **1** showed an AB system, whereas *trans*-ozonide **2** showed a singlet, as one might expect based on its higher symmetry. But in C_6D_6, *trans*-ozonide **2** showed an AB system, too [1].

Experimental

^1H and ^{13}C NMR: Bruker AC 250. – All solvents were dried and purified according to standard methods. – Chromatographic separations were carried out on silica gel by flash chromatography [7]. – HPLC separations were performed with commercially available columns packed with silica gel.

Improved Procedure for the Isolation of *cis*-(1) and *trans*-3,5-Dichloro-3,5-bis(chloromethyl)-1,2,4-trioxolane (2)

A solution of 2.90 g (15.1 mmol) of *trans*-1,2,3,4-tetrachloro-2-butene [1] in 750 ml of pentane was treated with ozone at −40 °C until the solution turned deep blue. Residual ozone was flushed off with nitrogen at −40 °C, the reaction mixture was warmed up to room temp. and subsequently extracted with 100 ml of a saturated aqueous solution of $NaHCO_3$. The organic layer was dried over $MgSO_4$, and the solvent was distilled off at room temperature and reduced pressure to leave

1.26 g of a liquid residue. The combined products of two ozonolyses (2.46 g) were dissolved in 10 ml of pentane/dichloromethane (98:2) and cooled to –20 °C under an atmosphere of nitrogen, whereby **2** crystallized. The crystals of **2** were filtered off, the filtrate was concentrated at room temperature and reduced pressure, and the residue of 690 mg was purified by flash chromatography (column 60×3.0 cm, 200 g silica gel, petroleum ether/ether, 96:4) to give 360 mg of a 1:1-mixture of **1** and **2**. HPLC separation of 320 mg of this mixture (column 250×32 mm Europrep 60, 10 µm (Knauer, Berlin); 70 ml/min of pentane/dichloromethane, 98:2; 6.2 MPa, UV detection at 225 nm) gave 116 mg (1.6%) of **1**. The crystals of **2** (1.60 g) were recrystallized from 10 ml of pentane/dichloromethane (98:2) at –3 °C to yield 1.20 g (16%) of **2**.

cis-3,5-Dichloro-3,5-bis(chloromethyl)-1,2,4-trioxolane (**1**)

Colorless liquid. – ^{1}H NMR ($CDCl_3$, TMS): AB system with δ_A = 4.07 ppm, δ_B = 4.13 ppm (J = 13.1 Hz) [8]. – HPLC-t_R = 7.0 min.

trans-3,5-Dichloro-3,5-bis(chloromethyl)-1,2,4-trioxolane (**2**)

Colorless solid, *m.p.* 41 °C. – ^{1}H NMR ($CDCl_3$, TMS): δ = 4.22 ppm (s) [8]. (C_6D_6, TMS): AB system with δ_A = 3.29 ppm, δ_B = 3.35 ppm (J = 13.5 Hz) [8]. – HPLC-t_R = 7.5 min.

Treatment of cis-3,5-Dichloro-3,5-bis(chloromethyl)-1,2,4-trioxolane (**1**) *with* $TiCl_4$

To a solution of 24 mg (100 µmol) of **1** in 445 µl of CH_2Cl_2 kept at –40 °C, 200 µl of a 1M solution of $TiCl_4$ in CH_2Cl_2 was added with stirring and under a nitrogen atmosphere. After 100 min water was added, the organic phase was extracted with an aqueous solution of $NaHCO_3$, dried with $MgSO_4$ and the solvent was distilled off at reduced pressure to leave 24 mg (100%) of a 8:92-mixture of **1** and **2**, as evidenced by ^{1}H NMR analysis.

Treatment of trans-3,5-Dichloro-(3,5-bis(chloromethyl)-1,2,4-trioxolane (**2**) *with* $TiCl_4$

By the same procedure, treatment of 27 mg (112 µmol) of **2** in 500 µl of CH_2Cl_2 with 240 µl of 1M solution of $TiCl_4$ in CH_2Cl_2 gave 25 mg (93%) of a 10:90-mixture of **1** and **2**.

Reversed Order of Elution of 1 and 2 in HPLC Separation

Using a special recycling technique [9], two identical columns (250×25 mm, LiChrosorb Si60, 7µm, Merck) have been put in series, and 32 mg of a 1:1-mixture of **1** and **2** were chromatographed with hexane/ether, 97:3. After five cycles, peak separation was sufficient to isolate 8 mg of **1** (t_R = 17.5 min) and 10 mg of **2** (t_R = 17.1 min).

References

[1] K. Griesbaum, K. Schlindwein, M. Hilß, Chem. Ber. **126** (1993) 1843
[2] K. Griesbaum, K. Schlindwein, J. Org. Chem. **60** (1995) 8062
[3] R.–O. Quinkert, Dissertation, Universität Karlsruhe (1997)
[4] K. Griesbaum, K. J. McCullough, I. Perner, R.–O. Quinkert, G. M. Rosair, Acta Cryst. **C53** (1997), in print
[5] P. S. Bailey, Ozonation in Organic Chemistry, Vol. I, Academic Press, New York 1978, p. 52
[6] K. Griesbaum, V. Ball, J. Beck, K. J. McCullough, Justus Liebigs Ann. **1995**, 1993
[7] W. C. Still, M. Kahn, A. Mitra, J. Org. Chem. **43** (1977) 2923
[8] In our previous work [1], we had obtained the same data, but they were ascribed to the wrong isomer.
[9] K. K. Unger (Publ.), Handbuch der HPLC, Teil 2: Präparative Säulenflüssig-Chromatographie, GIT-Verlag Darmstadt 1994, p. 89

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