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SHORT COMMUNICATIONS

Dedicated to Full Member of the Russian Academy of Sciences
O.N. Chupakhin on his 85th anniversary

Oxidative Cyclization of Lithium 4-Ethoxy-1,1,1-trifluoro-4-oxobut-2-en-2-olate

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Abstract—Diethyl 2,5-dihydroxy-2,5-bis(trifluoromethyl)tetrahydrofuran-3,4-dicarboxylate has been synthesized for the first time by reaction of lithium 4-ethoxy-1,1,1-trifluoro-4-oxobut-2-en-2-olate with manganese(III) acetate. The structure of its (2*S**3*S**4*S**5*S**) stereoisomer has been confirmed by X-ray analysis.

Keywords: lithium 4-ethoxy-1,1,1-trifluoro-4-oxobut-2-en-2-olate, manganese(III) acetate, diethyl 2,5-dihydroxy-2,5-bis(trifluoromethyl)tetrahydrofuran-3,4-dicarboxylate, crystal structure, X-ray analysis.

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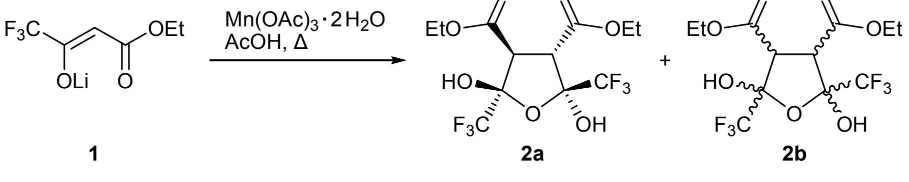
It is known that manganese(III) acetate promotes oxidative addition of 1,3-dicarbonyl compounds to alkenes, alkynes, arenes, alkadienes, and alkenynes with the formation of various polyfunctional compounds. The addition products can undergo further cyclization provided that the arrangement of functional groups appearing as a result of these reactions is favorable. For example, the reactions of acetylacetone with styrene, α-methylstyrene, 2-methylpent-2-ene, and oct-1-ene are accompanied by oxidative cyclization to 4,5-dihydrofuran derivatives. 4,5-Dihydrofuran derivative is also formed in the reaction of ethyl acetoacetate with styrene under similar conditions [1].

We have found that ethyl 4,4,4-trifluoro-3-oxobutanoate lithium salt (**1**, lithium 4-ethoxy-1,1,1-trifluoro-4-oxobut-2-en-2-olate) reacts with $Mn(OAc)_3$ to give an oxidative cyclization product, diethyl 2,5-dihydroxy-2,5-bis(trifluoromethyl)tetrahydrofuran-3,4-dicarboxylate (**2**). We have found no published data on the formation of tetrahydrofuran derivatives in reactions of fluorinated β-keto esters or enolates derived therefrom with metal acetates. Compound **2** has not been found by SciFinder and Reaxys search engines.

The reaction of **1** with $Mn(OAc)_3$ afforded an oily material which was subjected to chromatography. We thus isolated a white powder, and reprecipitation of the latter from methylene chloride with hexane gave an analytical sample and single crystals of **2**. The elemental compositions of these samples were consistent with the structure of **2**. The ^1H and ^{19}F NMR spectra displayed two sets of signals due to two stereoisomers **2a** and **2b** at a ratio of ~5 : 1. According to the X-ray diffraction data, the major isomer (**2a**) has (2*S**3*S**4*S**5*S**) configuration (Fig. 1). It crystallized in $P2_1/c$ space group belonging to the monoclinic crystal system; unit cell parameters: $a = 7.8741(9)$, $b = 16.0999(17)$, $c = 12.8069(15)$ Å; $\beta = 98.969(9)°$; $\mu = 0.170$ mm^{-1}. Total of 9174 reflection intensities were measured in the range $2.62 < \theta < 28.29°$, and 3921 reflections were independent ($R_{int} = 0.0344$). Final diver-



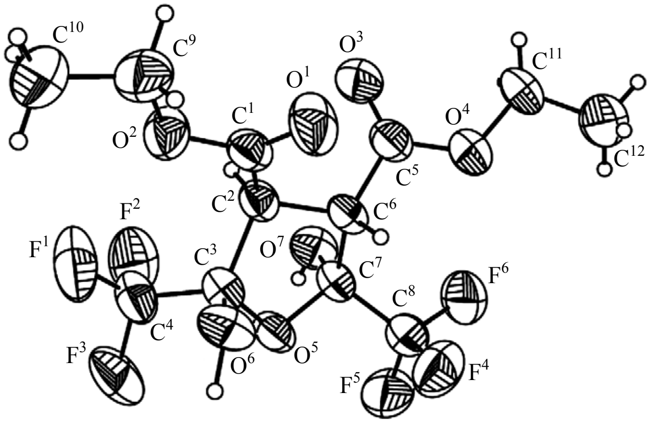


Fig. 1. Structure of the molecule of diethyl (2*S**3*S**4*S**5*S**)-2,5-dihydroxy-2,5-bis(trifluoromethyl)tetrahydrofuran-3,4-dicarboxylate (**2a**) according to the X-ray diffraction data; non-hydrogen atoms are shown as thermal vibration ellipsoids with a probability of 50%.

gence factors: $R_1 = 0.1254$, $wR_2 = 0.0794$ (for all independent reflections); $R_1 = 0.0406$, $wR_2 = 0.0736$ [for reflections with $I > 2\sigma(I)$]; goodness of fit $S = 1.000$; residual electron density peaks (max/min) 0.174/–0.123 $\bar{e}$Å^{-3}. The complete set of X-ray diffraction data was deposited to the Cambridge Crystallographic Data Centre (CCDC entry no. 1911465).

Thus, we have found a new reaction of lithium 4-ethoxy-1,1,1-trifluoro-4-oxobut-2-en-2-olate and synthesized a new tetrahydrofuran derivative as a mixture of two stereoisomers; the steric structure of the major isomer (2*S**3*S**4*S**5*S**) has been determined by X-ray analysis. It should be noted that fluorinated keto ester lithium salts are accessible compounds; they can be obtained in one step by condensation of fluorocarboxylic acid esters with ethyl acetate in the presence of lithium hydride as condensing agent [2].

Lithium 4-ethoxy-1,1,1-trifluoro-4-oxobut-2-en-2-olate (**1**) was synthesized by condensation of ethyl trifluoroacetate with ethyl acetate according to [2]. Manganese(III) acetate was prepared as described in [3] (method *a*) or generated *in situ* (method *b*).

Diethyl 2,5-dihydroxy-2,5-bis(trifluoromethyl)-tetrahydrofuran-3,4-dicarboxylate (2). *a*. Compound **1**, 1 g (0.0053 mol), was added with stirring to a solution of 4.83 g (0.018 mol) of manganese(III) acetate dihydrate in 10 mL of acetic acid. The mixture was stirred for 4 h at 60–70°C and left to stand for 15 h at 18–20°C, the solvent was distilled off, and the oily residue was subjected to chromatography using diethyl ether as eluent. The eluate was evaporated, and the residue was reprecipitated from methylene chloride with hexane. Yield 0.25 g (26%), white powder, mp 102–104°C. IR spectrum, ν, cm^{-1}: 1154 m (C–F), 1198 s (C–F), 1253 s (C–F), 1274 m (C–F), 1723 s (C=O), 3200–3416 br (OH). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: isomer **2a**; 1.30 t (6H, CH_3, ^3J = 7.13 Hz), 4.01 s (2H, CH), 4.21–4.40 m (4H, CH_2),[1] 4.64 br.s (2H, OH); isomer **2b**: 1.35 t (6H, CH_3, ^3J = 7.12 Hz), 4.03–4.04 m (2H, CH), 4.21–4.40 m (4H, CH_2),[1] 4.64 br.s (2H, OH). ^{19}F NMR spectrum ($CDCl_3$), δ_F, ppm: 78.02 s (**2a**), 81.00 s (**2b**) (CF_3). Found, %: C 37.29; H 3.53; F 29.40. $C_{12}H_{14}F_6O_7$. Calculated, %: C 37.51; H 3.67; F 29.67.

b. Potassium permanganate, 0.11 g (0.7 mmol), was added in small portions with stirring to a solution of 0.65 g (2.7 mmol) of manganese(II) acetate tetrahydrate in 10 mL of acetic acid. The mixture was heated for 15 min at 60–70°C, 1 g (5.3 mmol) of compound **1** was added with stirring, and the mixture was stirred for 4 h at 60–70°C and left to stand for 15 h at 18–20°C. A 5-mL portion of acetic acid was distilled off, and the residue was poured into water and extracted with diethyl ether. The extract was evaporated, and the residue was reprecipitated from diethyl ether with hexane. Yield 0.24 g (25%), white powder, mp 102–104°C. The spectral parameters were identical to those of a sample obtained as described above in *a*.

The ^{1}H and ^{19}F NMR spectra were recorded on a Bruker Avance-500 spectrometer using tetramethylsilane (^{1}H) or C_6F_6 (^{19}F) as internal standard. The IR spectra of solid samples (diffuse reflectance) were recorded in the range 400–4000 cm^{-1} on a Perkin Elmer Spectrum One FT-IR instrument. The elemental analyses were obtained with a Perkin Elmer PE 2400 analyzer.

The X-ray diffraction study was performed on an Xcalibur 3 automated diffractometer with a CCD detector according to standard procedure [Mo K_α radiation, graphite monochromator, ω-scanning through a step of 1°, temperature 295(2) K]. The structure was solved by the direct method and was refined against F^2 by the full-matrix least-squares method in anisotropic approximation for all non-hydrogen atoms. Hydrogen atoms linked to carbons were placed in geometrically calculated positions, and the positions of NH and OH hydrogens were refined independently in isotropic approximation. All calculations were carried out using SHELX software package [4].

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[1] Signals of the CH_2 groups of isomers **2a** and **2b** overlapped each other and the OH signal.

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CONFLICT OF INTERESTS

The authors declare no conflict of interests.

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