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Thionation of the monoacetal of pentacyclo[5.4.0.0^{2,6}.0^{3,10}.0^{5,9}]undecane-8,11-dione

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Abstract—As part of a programme to synthesize thione derivatives with pentacyclo[5.4.0.0^{2,6}.0^{3,10}.0^{5,9}]undecane moieties it was decided to sulfurize the monoacetal **6** of pentacyclo[5.4.0.0^{2,6}.0^{3,10}.0^{5,9}]undecane-8,11-dione **2**. Unexpectedly the diol **9** was isolated as the product.

It was previously reported[1] that the dithione **1** can be obtained from the dione **2** by treatment with bis(tricyclohexyltin)sulfide and boron trichloride. It was claimed[1] that **1** is formed in solution only and is extremely labile and not amenable to isolation. It was anticipated[1] that structural modifications could lead to isolable derivatives. Recently,[2] the reaction of **2** with a gaseous H_2S/HCl mixture in methanol was described by Romański and Marchand who reported the formation of a mixture of two sulfur-bridged cage compounds, which were isolated and characterized.[2] However, our efforts for the preparation of thione derivatives from the diones **2**, **3**, **4** and **5** (Fig. 1) with different thionating reagents proved to be unsuccessful. These diones could not be thionated to their respective dithione derivatives with silicon disulfide (SiS_2), boron sulfide (B_2S_3), bis(tricyclohexyltin)sulfide, hydrogen sulfide, tetraphosphorus-decasulfide or Lawesson's reagent (LR). Material, which could not be characterized or starting material was recovered in each case. Efforts to sulfurize the same diones with H_2S and HCl(g) in methanol at low temperatures were also unsuccessful and only starting material could be isolated.

Sulfuration of ketones with SiS_2, B_2S_3 and bis(tricyclohexyltin) sulfide proceeds via the formation of relatively large complex intermediates.[1,3–6] In the case of sterically hindered carbonyl groups the thionation reaction is probably retarded. The intercarbonyl distances of the above mentioned diones may play a vital role in the thionation process. Molecular power field calculations with HYPERCHEM PRO's MM+ programme[7] shows that the intercarbonyl carbon atom distance of **2** is 0.2748 nm while the corresponding distances in **3**, **4** and **5** are 0.2795, 0.2691 and 0.2703 nm, respectively, and are indicative of vulnerability to steric effects. These calculations were verified with calculations using the SPARTAN PRO-programme[8] with a MMFF 94 power field.

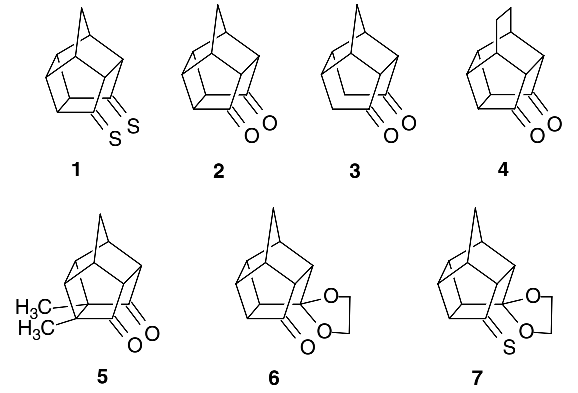

Figure 1.

It is well known that only one carbonyl group of pentacyclo[5.4.0.0^{2,6}.0^{3,10}.0^{5,9}]undecane-8,11-dione reacts with ethylene glycol and *p*-toluenesulfonic acid in

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Keywords: Sulfuration; Thionation; Lawesson's reagent; Thione; Pentacyclo[5.4.0.0^{2,6}.0^{3,10}.0^{5,9}]undecane-8,11-dione.

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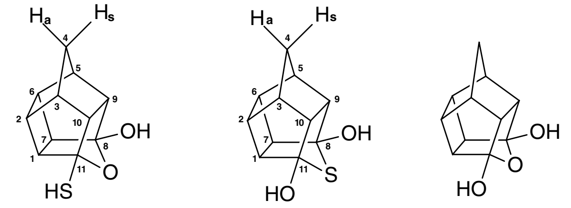


8 **9** **10**

Figure 2.

benzene to form the monoacetal **6**[9] (Fig. 1). It was therefore decided to sulfurize the monoacetal in an attempt to obtain the thione **7**.

Thionation of **6** (1 g, 4.59 mmol) with Lawesson's reagent[10,11] (0.926 g, 2.29 mmol) in dry tetrahydrofuran (70 mL) under a nitrogen atmosphere yielded a light yellow reaction mixture from which the thione **7** could not be isolated. Instead, a colourless product formed of which the IR-spectrum (KBr-disc) exhibited a strong hydroxylic OH-stretch absorption at 3240 cm^{-1}.

The mass spectrum (EI) registered a molecular ion at m/z 208 corresponding to a molecular formula of $C_{11}H_{12}SO_2$. The thione **7** is probably hydrolyzed by dithiophosphonic acid derivatives in Lawesson's reagent. Two structures correspond with these data, namely structures **8** and **9** (Fig. 2).

No SH-stretch absorption could be seen in the 2600–2550 cm^{-1} region of the IR-spectrum, however this does not exclude compound **8** as SH stretch absorptions are normally very weak.[12] On the basis of ^{1}H and ^{13}C NMR studies structure **9** was allocated to the product. The ^{1}H and ^{13}C NMR data are collected in Table 1.

The 75 MHz ^{13}C NMR spectrum [$(CD_3)_2SO$] of **9** exhibited only six carbon resonance signals that were supportive of a symmetrical molecule. The quaternary carbon resonance at δ_C 101.9 can be associated with carbon atoms C-8 and C-11, which are linked to strong electronegative atoms. The methylene carbon atom C-4 resonated at δ_C 41.3. The remainder of the ^{13}C NMR spectrum consisted of four signals at δ_C 40.1, 44.8, 52.7 and 62.4.

The ^{13}C chemical shifts of **9** correspond with those of compound **10** (Fig. 2, Table 1). The carbon resonance signals in the ^{13}C NMR spectrum of **10** were assigned previously[13] from proton–proton 2D chemical shifts (COSY) and heteronuclear (^{13}C, ^{1}H) 2D correlation (HETCOR) experiments. The assignments were verified with ^{13}C and ^{1}H selective population inversion (SPI) experiments.[14]

Different authors[15–18] have shown that the interpretation of the ^{1}H NMR spectra of compounds like **9** is difficult, even with 500 MHz acquisitions because long distance interactions (over more than three bonds) occur, which give broad undefined resonance signals. The 300 MHz NMR spectrum of **9** showed an AB spin system for the methylene protons of C-4 and three broad complex signals in the highfield region due to long distance proton–proton interactions.

Signals at δ_H 2.52 and 2.62 integrated for two protons each and a signal at δ_H 2.76 integrated for four protons. A broad deuterium exchangeable proton signal occurred around δ_H 6.38, which was assigned to the two hydroxyl group protons in compound **9**.

The assignment of the signals in the ^{1}H and ^{13}C NMR spectra of compound **9** to specific nuclei was derived from HETCOR and COSY 2D experiments. These data were backed by correlation spectroscopy in which direct and long distance couplings of proton–carbon interactions were detected (COLOC[19] and LRHETCOR).[20] On the basis of previous studies[21–24] the doublet at δ_H 1.55 ($J = 10.3$ Hz) was allocated to H-4a and the doublet at δ_H 1.88 ($J = 10.3$ Hz) to H-4s.

A COSY experiment showed cross correlation signals between the resonance signals of H-4 and the resonance signals at δ_H 2.52. This correlation was associated with H-3 and H-5. Interactions between the signals at δ_H 2.52 (H-3, H-5) and δ_H 2.74 were associated with H-9 and H-10. The signal at δ_H 2.76 was assigned to H-1 and H-7.

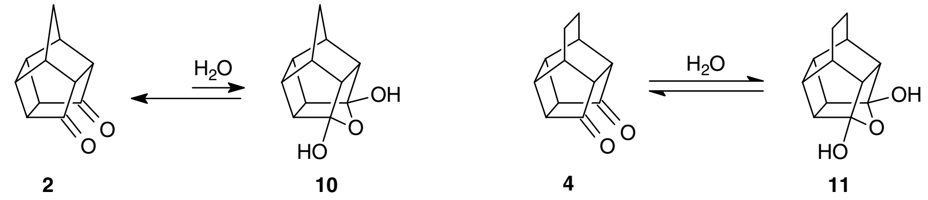
A HETCOR experiment showed long distance correlations between the quaternary carbon resonance at δ_C 101.9 and the signals at δ_H 2.74 and 2.76, therefore the signal at δ_H 2.62 can be assigned to H-2 and H-6. The ^{13}C resonance signal assignments were derived from a

Table 1. ^{1}H and ^{13}C NMR spectroscopic data[a] of **9**

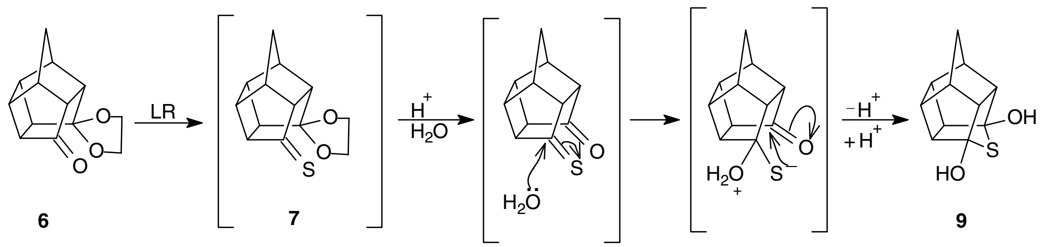
Carbon/hydrogen	δ_H[b] (ppm)	J (Hz)	δ_C[b] (ppm)	^1J (Hz)	δ_C[b] (ppm) of 10[12]
1 (7)	2.76		52.7 d	150.2	47.5
2 (6)	2.62		40.1 d	148.1	41.3
3 (5)	2.52		44.8 d	149.9	43.5
4 a	1.55 d	10.3	41.3 t	131.5	42.9
4 s	1.88 d	10.3			
8 (11)			101.9 s		112.2 s
9 (10)	2.74		62.4 d	145.5	57.4
OH	6.38 br				

[a] ^{1}H-spectrum: 300 MHz, ^{13}C-spectrum: 75 MHz.

[b] Solvent $(CD_3)_2SO$. Capital letters refer to splitting patterns, which are attributed to direct coupled protons and small letters refer to couplings over more than one bond. s = singlet, d = doublet, t = triplet.



Scheme 1.



Scheme 2.

HETCOR experiment utilizing the assigned ^{1}H NMR spectrum and are collected in Table 1.

The transformation of the monoacetal **6** into the diol **9** demonstrates the influence of interatomic distances on the transannular reactions of the pentacyclo-undecane system. It has previously been shown[13] that the dione **2** is not prone to transannular reactions while the dione **4** with smaller intercarbonyl group distances is more prone to transannular reactions (Scheme 1).

The diol **10** is highly unstable and easily suffers dehydration to give the dione **2**.[13] The stability of **9** can be attributed to the bigger sulfur atom, which probably forms a more stable bridge.

The formation of compound **9** from the monoacetal **6** can be explained schematically as shown in Scheme 2.

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