

Conformational Analysis XV.* Preparation of Some Alkyl-substituted 5-Oxo-1,3-oxathiolans and Their Characterization with the Aid of Chemical Equilibration, ^1H NMR and IR Spectra

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5-Oxo-1,3-oxathiolan and seven alkyl-substituted derivatives were prepared and their ^1H NMR and IR spectra recorded. 2,4-Dimethyl- and 2-*t*-butyl-4-methyl-5-oxo-1,3-oxathiolans which were mixtures of *cis* and *trans* forms were chemically equilibrated and the obtained thermodynamic parameters used to determine the conformational energies of 2a-Me, 2a-*t*-Bu, and 4a-Me groups (7.6, 9.8, and 1.2 kJ mol $^{-1}$, respectively). All the collected data are in agreement with a ring conformation where the sulfur atom is situated at the tip of an envelope form.

In spite of the fact that the 5-oxo-1,3-oxathiolan system has been frequently studied $^{1-7}$ only two of these reports 1,2 consider simple alkyl-substituted derivatives. Farines 1 has prepared compounds 1–7 but her configurational and conformational conclusions seem to need some revision. Satsumabayashi *et al.* 2 report the preparation of 2 and (5+6) only but do not pay any attention to the isomerism of 2,4-dimethyl-5-oxo-1,3-oxathiolan (5+6).

The above observation together with our earlier studies on the 1,3-oxathiolan system $^{8-10}$ prompted us to investigate the conformational and configurational properties of alkyl-substituted derivatives in some detail using ^1H NMR, IR and chemical equilibration as tools.

EXPERIMENTAL

The compounds were synthesized from a suitable aldehyde or acetone and thioglycolic acid (E. Merck, *reinst*) or thiolactic acid (Fluka, *practicum*). 1,2 Their physical constants are collected in Table 1.

We were not able to separate *cis* and *trans* forms of 2,4-dimethyl- (5+6) and 2-*t*-butyl-4-methyl-5-oxo-1,3-oxathiolans (9+10). In the former case, however, their existence was revealed by the ^1H NMR spectrum and in the latter case also by gas chromatographic analysis (a 2 m \times 3 mm stainless steel column containing 5% Carbowax 20M on Chromosorb G, 60/80 mesh). Chemical equilibration of these epimer pairs was carried out in CCl_4 solutions at several temperatures (from 9 to 46 days) following the procedure described earlier. 9,10 The equilibrium ratios (Table 2) of the isomers were determined from the area of the 4-Me ^1H NMR signals (5+6) or from the gas chromatographic peak areas (9+10).

The ^1H NMR spectra were recorded with a Perkin-Elmer R-10 60 MHz NMR spectrometer (10% v/v CCl_4 or C_6H_6 solutions) on a precalibrated paper with TMS as an internal standard. The obtained chemical shifts and coupling constants which are means of at least six separate scans are given in Table 3.

IR spectra were recorded on a PE-180 IR spectrometer using a capillary film between KBr windows. The IR results are listed in Table 4. The accuracy of the carbonyl bands is ± 0.5 cm $^{-1}$ and of the other bands ± 3 cm $^{-1}$.

RESULTS AND DISCUSSION

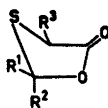
We agree with Farines 1 that due to the lactone grouping $-\text{C}-\text{O}-\text{C}(=\text{O})-\text{C}-$, the only significant conformation of the 5-oxo-1,3-oxathiolan ring (1) is the one with the sulfur

* For Part XIV see Nikander, H., Mikkala, V.-M., Nurmi, T. and Pihlaja, K. *Org. Magn. Reson.* 8 (1976). In press.

Table 1. Physical constants for the prepared 5-oxo-1,3-oxathiolans.

Substitution	B.p., K/kPa	M.p., K	n_D^{20}	d_{277}^{20}	Yield, %
Nil (1)	357/1.60		1.5181		47
2-Me (2)	343/1.20		1.4972		41
4-Me (3)	352/1.47		1.4988	1.256	74
2,2-diMe (4)	349–359/1.07		1.4835		30
2,4-diMe ^a (5+6)	349/1.73		1.4804	1.159	66
2,2,4-triMe (7)	355/1.87		1.4722		50
2- <i>t</i> -Bu (8)	365–367/1.60	289	1.4803		85
2- <i>t</i> -Bu-4-Me ^a (9+10)	371–373/1.60	297	1.4733 ^b	1.104	86

^a Mixtures of *cis* and *trans* forms. ^b At 298 K.

Table 2. ¹H NMR spectral data for the studied 5-oxo-1,3-oxathiolans.

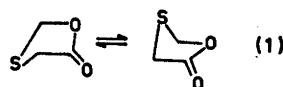
R ¹	R ²	R ³	Chemical shift (δ_{CCl_4}) and $\Delta = (\delta_{CCl_4} - \delta_{C_2H_6})$								Coupling const. (Hz)				
			H(2)	Δ	H(4)	Δ	Me(2)	Δ	Me(4)	Δ	$J_{2,4}$	$J_{2,Me}$	$J_{4,Me}$		
H	H	H	1	5.21	0.61	3.52	0.50								
Me	H	H	2	5.58	0.47	3.66	0.45	1.69	0.43				6.1		
H	H	Me	3	5.15	0.53	3.81	0.37			1.55	0.27	0.5 ^{a,d}		7.2	
Me	Me	H	4			3.75	0.37	1.75	0.35						
Me	H	Me	5	5.47	0.53	3.97	0.48	1.76	0.56	1.53	0.26	0.4	6.0	7.1	
H	Me	Me	6	5.57	0.57	3.91	0.43	1.76	0.56	1.55	0.30	0.6	5.9	7.3	
Me	Me	Me	7			4.09	0.34	1.75	0.35	1.56	0.22			7.2	
<i>t</i> -Bu	H	H	8 ^b	5.20	0.36	3.50 ^c	0.38 ^c	1.01	0.21			0.7			
						3.61	0.49					0.6			
<i>t</i> -Bu	H	Me	9	5.19	0.40	3.92	0.37	1.03	0.18	1.53	0.22	0.45 ^d		7.1	
H	<i>t</i> -Bu	Me	10	5.18	0.29	3.80	0.32	1.03	0.21	1.58	0.26	0.75 ^d		7.3	

^a In α -bromonaphthalene where $J_{2,4} = -6.9$ Hz, ^b $J_{4,4'} = -16.5$ Hz, ^c R³, ^d Based on 300 MHz spectra.

Table 3. Equilibria between isomeric 2,4-dimethyl- and 2-*t*-butyl-4-methyl-5-oxo-1,3-oxathiolans at different temperatures and thermodynamic quantities for the studied isomer equilibria.

T	$K = [cis]/[trans]$ 2,4-diMe	2- <i>t</i> -Bu-4-Me
288	1.680 ± 0.038	1.416 ± 0.014
303	1.624 ± 0.082	1.398 ± 0.008 ^a
303		1.398 ± 0.039 ^a
318	1.571 ± 0.025	1.359 ± 0.020
334	1.511 ± 0.033	1.330 ± 0.031 ^b
334		1.334 ± 0.030 ^b
356		1.297 ± 0.012 ^c
356		1.303 ± 0.014 ^c
358		1.289 ± 0.018
- ΔH° , kJ mol ⁻¹	1.84 ± 0.08	1.18 ± 0.05
- ΔS° , J mol ⁻¹ K ⁻¹	2.07 ± 0.27	1.16 ± 0.16
- $\Delta G^\circ(298)$, kJ mol ⁻¹	1.22	0.83

^{a,b,c} Parallel experiments.



atom at the tip of an envelope form. However, we do not agree with her proposal that 2-methyl-5-oxo-1,3-oxathiolan (2) exists predominantly in the envelope form with an axial methyl group (2b). On the basis of our earlier knowledge of 1,3-oxathiolans⁸⁻¹⁰ the interaction due to an axial methyl group in the position 2 should at least exceed 4 kJ mol⁻¹ which is supported by our results dealing with 4-vinylbutyrolactone.¹¹ In the light of our present

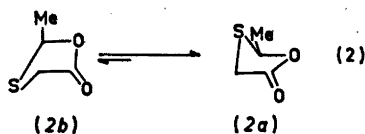


Table 4. The characteristic bands in the IR spectra of the studied 5-oxo-1,3-oxathiolans.

	Substitution	Peaks, cm^{-1} ^a
1	Nil	2910w, 2895w, 1831shw, 1771s, 1730sh, 1462w, 1403m, 1121m, 1020s, 633w
2	2-Me	2925m, 1774s, 1752.5shs, 1449w, 1439w, 1408m, 1124m, 1103w, 1069s, 1018m 940m, 900m, 616w
3	4-Me	2930m, 2895m, 2870m, 1817sh, 1768s, 1462m, 1448m, 1087m, 1052m, 1021s, 994m, 946w, 660w, 627w, 606m
4	2,2-diMe	2930m, 2870w, 1790shs, 1769.5s, 1457m, 1439m, 1413m, 1110sh, 1094s, 1030w, 979s, 937s, 910w, 623w, 595w, 565w
5+6	2,4-diMe	2930m, 2870w, 1769s, 1446m, 1078s, 1065sh, 1045s, 1015m, 995m, 928s, 607w 592w
7	2,2,4-triMe	2930m, 2870w, 1766s, 1448m, 1107s, 1088m, 1051s, 1004m, 967s, 603w, 588m
8	2- <i>t</i> -Bu	2930shs, 2900m, 2865m, 1776.5s, 1697sh, 1476s, 1462m, 1407m, 1121m, 1037s, 1012s, 937m, 916m, 900m, 655w, 576w
9+10	2- <i>t</i> -Bu-4-Me	2930m, 2900m, 2865m, 1772s, 1477m, 1462sh, 1448m, 1082w, 1058sh, 1033s, 1011s, 938m, 918m, 610w

^a The accuracy of the line positions is $\pm 3 \text{ cm}^{-1}$ except the carbonyl bands (italics) $\pm 0.5 \text{ cm}^{-1}$.

results the equatorial form (2a) really is greatly favoured. 4-Methyl-5-oxo-1,3-oxathiolan (3) also favours slightly the conformation with an equatorial methyl group in agreement with the postulation of Farines¹ (Tables 2 and 4). The ¹H NMR results confirm this conclusion since 3 gives an average signal for H(2), δ 5.15, that is 0.06 ppm shielding when compared with 1. 2-Me has a 0.37 ppm deshielding effect on H(2). In other words the average of the H(2) signals of 5 and 6 should be δ 5.52 in excellent agreement with the experimental findings. The same situation prevails in the case of H(4) for both 5+6 and 9+10.

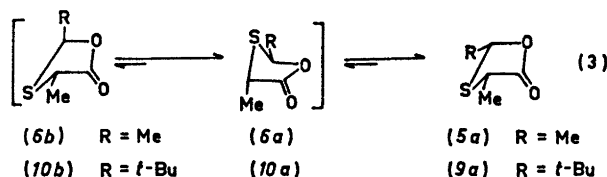
Otherwise the ¹H NMR spectra serve mainly as an analytical tool only except the ⁴J_{2,4} coupling constants for 5+6 and 9+10. The *cis* forms (5 and 9) show clearly smaller ⁴J_{2,4} values than the *trans* forms, an observation which is in excellent agreement with the ⁴J_{2,4} values in correspondingly substituted 4-oxo-1,3-dioxolans.¹²

To determine the thermodynamic quantities for the equilibria (3) we equilibrated 5+6

and 9+10 at several temperatures. The values of the equilibrium constants at several temperatures are shown in Table 3 together with the thermodynamic quantities derived from them. In agreement with the observations in the case of 2,4-disubstituted 1,3-oxathiolans¹⁰ the predominant conformation of the *trans* isomers is 6a or 10a. *Cis* isomers have anancomeric diequatorial envelope forms (5a and 9a).

By assuming that the small but definite entropy differences for the epimer equilibria are mainly due to mixing of 6a and 6b or 10a and 10b we estimate $x_{6a} \sim 0.93$ and $x_{10a} \sim 0.97$. Since the entropy difference between the *trans* envelopes is likely to be negligible we obtain $\Delta H^\circ_{\text{obs}} = 0.93x + 0.07(x + 6.4)$ for 5+6 and $\Delta H^\circ_{\text{obs}} = 0.97x + 0.03(x + 8.6)$ for 9+10 from which we obtain $-\Delta H^\circ(4a-\text{Me}) = 1.2 \pm 0.5 \text{ kJ mol}^{-1}$. Consequently, $-\Delta H^\circ(2a-\text{Me}) = 7.6 \pm 1.0$ and $-\Delta H^\circ(2a-t\text{-Bu}) = 9.8 \pm 1.0 \text{ kJ mol}^{-1}$ in reasonable agreement with similar estimates for 1,3-oxathiolans.^{10,12}

Let us finally inspect the IR results (Table 4). All compounds give main carbonyl bands in the



range 1766–1774 cm^{-1} typical of γ -lactones.¹⁴ The values for single compounds show some additivity but the variation is too small to allow any further discussion. The bands arising from C–S linkages are found between 565 and 660 cm^{-1} and depend clearly on the degree of substitution at C(2) and C(4). Strong absorption in the range 900–1100 cm^{-1} is also typical of various sulfur compounds.¹⁴ The deformation vibrations around 1450 cm^{-1} and the $\delta(\text{SCH}_2)$ bands around 1405 cm^{-1} are also characteristic for the compounds in question. The location of the bands in the range 2860–2930 cm^{-1} is also clearly modified from that found for C–H bonds in hydrocarbon radicals.¹⁴

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