Carbohydrate Research, 65 (1978) 144–152
© Elsevier Scientific Publishing Company, Amsterdam – Printed in Belgium

Note

Synthesis of dithiobis(thioformate) and (*S*-methyldithiocarbonate) derivatives of cellulose and amylose, and some of their reactions

NORMAN W. H. CHEETHAM
School of Chemistry, The University of New South Wales, P.O. Box 1, Kensington, N.S.W. 2033 (Australia)

(Received October 6th, 1977; accepted for publication, January 5th, 1978)

As a part of studies on the chemical modification of polysaccharides, dithiobis(thioformates) and *S*-methyldithiocarbonates of 6-*O*-tritylamylose and 6-*O*-tritylcellulose were needed. The degrees of substitution (d.s.) obtained by using aqueous alkali–dimethyl sulfoxide–carbon disulfide[1] were not sufficiently high. When the 6-*O*-trityl derivatives were dissolved in dimethyl sulfoxide and then treated with methylsulfinyl anion[2], carbon disulfide, and either iodomethane [for di-(*S*-methyldithiocarbonate)s] or acidified sodium nitrite solution [for dithiobis(thioformate)s], good yields of the desired derivatives, having a high d.s., were obtained (see Table I).

TABLE I

YIELDS AND DEGREE OF SUBSTITUTION OF DERIVATIVES OF 6-*O*-TRITYLAMYLOSE AND 6-*O*-TRITYLCELLULOSE

Derivative No.	*6-O-Trityl derivative*	*Yield (%)*	*D.s.*	*Figure*
1	Cellulose dithiobis(thioformate)	89	1.8	1a
2	Cellulose 2,3-thionocarbonate from **1**	75	0.58	1b
3	Cellulose 2,3-di-(*S*-methyldithiocarbonate)	88	1.90	3a
4	Thermally rearranged derivative of **3**	75	1.60	3b
5	Amylose dithiobis(thioformate)	85	1.85	2a
6	Amylose 2,3-thionocarbonate from **5**	80	0.70	2b
7	Amylose 2,3-di-(*S*-methyldithiocarbonate)	79	1.72	4a
8	Amylose 2,3-thionocarbonate from **7**	80	0.86	4b

RESULTS AND DISCUSSION

Evidence for the formation of the dithiobis(thioformates) (**1** and **5**) and di-(*S*-methyldithiocarbonate)s (**3** and **7**) rested on the infrared spectra (see Figs. 1a, 2a, 3a, and 4a, respectively) and the elemental analyses.

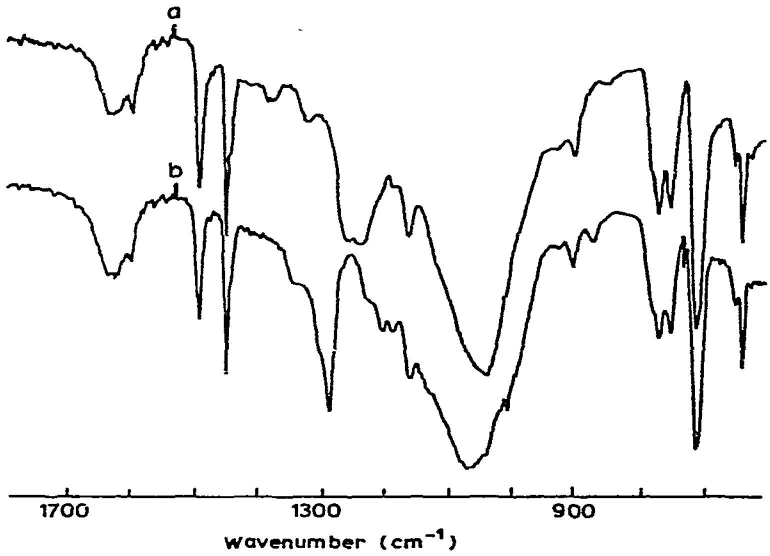


Fig. 1. Infrared spectra of (a) 6-*O*-tritylcellulose dithiobis(thioformate) (**1**); (b) 6-*O*-tritylcellulose 2,3-thionocarbonate (**2**).

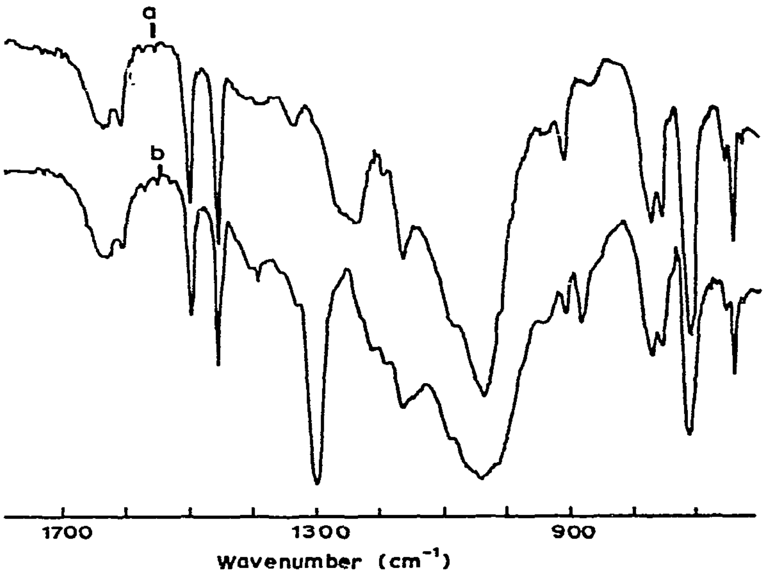


Fig. 2. Infrared spectra of (a) 6-*O*-tritylamylose dithiobis(thioformate) (**5**); (b) 6-*O*-tritylamylose 2,3-thionocarbonate (**6**).

Fig. 3. Infrared spectra of (a) 6-*O*-tritylcellulose 2,3-di-(*S*-methyldithiocarbonate) (3); (b) product (4) from thermal rearrangement of 3.

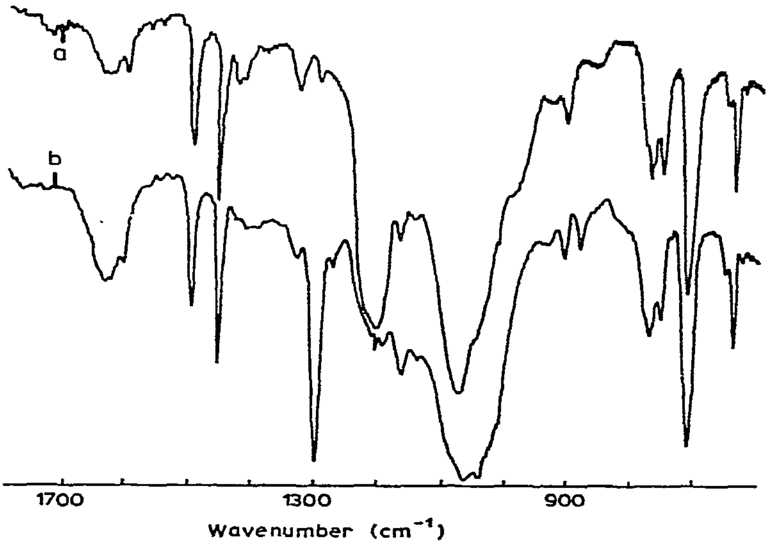
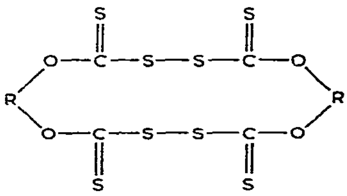
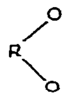


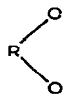
Fig. 4. Infrared spectra of (a) 6-*O*-tritylamylose 2,3-di-(*S*-methyldithiocarbonate) (7); (b) 6-*O*-tritylamylose 2,3-thionocarbonate (8) from thermal decomposition of 7.

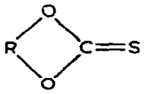
For dithiobis(thioformate)s and di-(*S*-methyldithiocarbonate)s of high d.s., it was essential to have the 6-*O*-tritylated polysaccharides thoroughly dissolved, and then stirred for at least an hour with methylsulfinyl anion to effect ionization of hydroxyl groups before addition of carbon disulfide; this is similar to the observation of Hakomori on methylation of polysaccharides by use of methylsulfinyl anion[2].

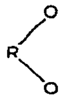
Dithiobis(thioformates). In the case of the dithiobis(thioformate)s **1** and **5**, heating with pyridine[1], or with dimethyl sulfoxide containing a small proportion of triethylamine[3], yielded the corresponding thionocarbonates **2** and **6** (see Figs. 1b and 2b). Only carbon disulfide was evolved during the reactions, as shown by u.v. analysis of the piperidine complex formed by passing the reaction gas into a cold, 1% solution of piperidine in hexane[4,5]. Trimnell *et al.*[5] have shown that dithiobis(thioformate)s decompose thermally in two ways. Evolution of carbon disulfide indicates a rearrangement to thionocarbonate, whereas evolution of carbonyl sulfide indicates a rearrangement to dithiocarbonate. The pathway involving the formation of thiono-

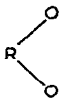


1  = 6-*O*-tritylcellulose residue

5  = 6-*O*-tritylamylose residue



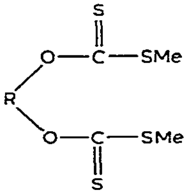
2  = 6-*O*-tritylcellulose residue

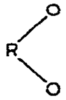
6 or 8  = 6-*O*-tritylamylose residue

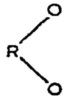
carbonate appears to be favored, in the presence of base[5], for the derivatives having higher d.s. values, and the present work confirms this observation.

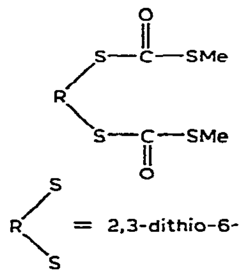
Examination of the i.r. spectra of all of the thionocarbonates studied showed a small, but consistent, peak at 880 cm^{-1} (see Figs. 1b, 2b, and 4b) the intensity of which is proportional to that of the larger band at 1290 cm^{-1}; it is probable that the 880-cm^{-1} band is characteristic of the cyclic thionocarbonate group. Such a peak is also present in the i.r. spectra of two cyclic thionocarbonates of monosaccharides examined[6]. In all experiments, the formation of the amylose thionocarbonate was more satisfactory, and yielded a product having a higher d.s. than that of the cellulose derivative. The shapes of the thionocarbonate peaks at 1290 cm^{-1} in Figs. 1b, 2b, and 4b are characteristic and reproducible.

S-*Methyldithiocarbonates.* It has been shown[7,8] that pyrolysis of terminal bis-*S*-dimethyl dithiocarbonate gives good yields of dimethyltrithioorthocarbonates. Heating of the 2,3-di-(*S*-methyldithiocarbonate)s **3** and **7**, alone, to 150° caused no discernible changes. Temperatures higher than 150° caused decomposition involving loss of trityl groups, so heating in dimethyl sulfoxide was attempted, with unexpected results.



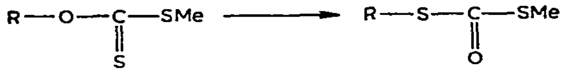
3  = 6-*O*-tritylcellulose residue

7  = 6-*O*-tritylamylose residue



4 = 2,3-dithio-6-*O*-tritylcellulose residue

On being heated in dry dimethyl sulfoxide to 150°, the 6-*O*-tritylcellulose 2,3-di-(*S*-methyl dithiocarbonate) (**3**; see Fig. 3a) did not dissolve to any extent, and, after 8 h, yielded derivative **4** (see Fig. 3b). The peak at 1760 cm^{-1} and the analytical figures indicated a rearrangement of the following type[9,10].

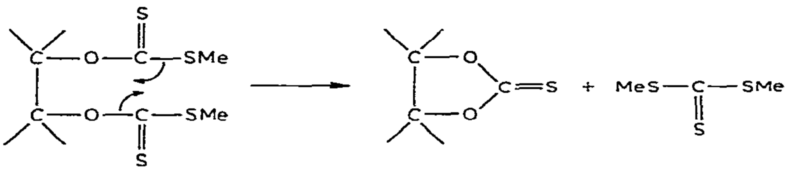


$$R{-}O{-}\underset{\underset{S}{\|}}{C}{-}SMe \longrightarrow R{-}S{-}\underset{\underset{O}{\|}}{C}{-}SMe$$

Saponification of **4** yielded a product having an i.r. spectrum very similar to that of 6-*O*-tritylcellulose. There was no band at 1760 cm^{-1}, and the band at 1220 cm^{-1} had also disappeared. The sulfur content (5.75%) of the saponified material indicated that thiolation of the cellulose had occurred, d.s. ~0.7. Acetolysis of the saponified material yielded a product that showed two carbonyl bands in the i.r. spectrum, at 1740 (*O*-acetyl, strong) and 1690 cm^{-1} (*S*-acetyl, medium)[5].

Analysis of the gases from the decomposition of **3** showed that a small proportion of carbonyl sulfide was evolved, as well as a little carbon disulfide. Fig. 3b indicates the presence of some unchanged starting-material. Extension of the time of heating to 20 h diminished the size of the 1220-cm^{-1} peak, but resulted in some loss of trityl group. On being heated under the same conditions in dimethyl sulfoxide, the corresponding amylose derivative **7** (see Fig. 4a) dissolved completely in 1 h, and, in 5 h, yielded derivative **8**, the i.r. spectrum (see Fig. 4b) and analysis of which indicated the formation of thionocarbonate (*cf.*, Fig. 2b).

Analysis, as the piperidine–hexane complex, of the decomposition gases from the heating of **7** showed that carbon disulfide, but not carbonyl sulfide, was evolved; however, the proportion was only ~5% of that required by stoichiometry, and it was probably a minor by-product, or decomposition product, of the major reaction. A tentative mechanism for thionocarbonate formation is as follows.



Why the cellulose *S*-methyldithiocarbonate should rearrange differently from the corresponding amylose derivative is not obvious. It must be added that, sometimes, slight variations of the reaction conditions during the heating of **7** with dimethyl sulfoxide led to rearrangement, partly as for the cellulose derivative **3**, and partly to the thionocarbonate **8**.

For **7**, the two pathways operated at higher concentrations, and also if the flask was plunged into a preheated oil bath at 150°, instead of being heated from room temperature. In all experiments, the thionocarbonate pathway was the major one, as determined by relative intensities of i.r. peaks at 1760 and 1290 cm^{-1}. In no instance, however, did the cellulose derivative **3**, on heating, afford a derivative that had the thionocarbonate band (at 1290 cm^{-1}).

A possibility that must be considered is that the thionocarbonates **2**, **6**, and **8** are wholly, or partly, intermolecular, rather than 2,3-cyclic. Such intermolecular crosslinking is considered unlikely, considering the ready solubility of derivatives **2**, **6**, and **8** in dimethyl sulfoxide and in pyridine. A further possibility is the formation of intramolecular 2,2′-, 2,3′-, and 3,3′-thionocarbonates between different D-glucosyl residues in the same polysaccharide chain.

EXPERIMENTAL

Microanalyses were performed in the Chemistry School, The University of New South Wales (for C and H), and by the Australian Microanalytical Service, CSIRO, Melbourne (for S). Infrared spectra (for KBr discs) were recorded with a Hitachi EPIG 2 double-beam spectrophotometer (in the Molecular Spectroscopy Laboratory, The University of New South Wales).

6-*O*-Tritylcellulose of d.s. 1.01 was prepared according to Green[11], and 6-*O*-tritylamylose of d.s. 0.99 by the method of Whistler and Hirase[12].

6-O-Tritylcellulose dithiobis(thioformate) (**1**). — 6-*O*-Tritylcellulose (1.0 g) was dissolved in dry dimethyl sulfoxide (50 mL) at room temperature. Methylsulfinyl anion (3.2M, 2.5 mL) was added, and the viscous solution was stirred for 1 h under a slow stream of nitrogen. Carbon disulfide (1.5 mL, 4-fold excess) was added, and the resulting, dark-red solution was stirred for a further 30 min at room temperature. Ice-cold acetic acid (10%; 5 mL) was slowly added to the mixture, causing the color to change to orange-yellow. Water at 0° (20 mL) containing sodium nitrite (1.5 g) was slowly added, the flask at this stage being immersed in water at 5°. More 10% acetic acid (40 mL) was then added; the solution turned yellow, and a yellow precipitate formed, which, after 15 min, was filtered off, washed successively with water, ethanol, absolute ethanol, carbon disulfide, and ether, and dried, giving a pale-yellow powder (1.23 g, 89%); see Fig. 1a. Its analysis corresponded to a d.s. of ~1.8.

Anal. Calc. for $C_{27}H_{22}O_5S_4$: C, 58.5; H, 3.97; S, 23.1. Found: C, 59.6; H, 4.18; S, 21.3.

6-O-Tritylamylose dithiobis(thioformate) (**5**). — The synthesis of **5** (see Fig. 2a) in 85% yield was conducted essentially as described for **1**, except that the reaction mixture was initially warmed to 50° (to dissolve the 6-*O*-tritylamylose), and stirring with methylsulfinyl anion was conducted for 2 h at room temperature. The analysis of **5** corresponded to a d.s. of ~1.85.

Anal. Calc. for $C_{27}H_{22}O_5S_4$: C, 58.48; H, 3.97; S, 23.1. Found: C, 59.36; H, 4.08; S, 21.8.

6-O-Tritylcellulose 2,3-thionocarbonate (**2**) *and 6-O-tritylamylose 2,3-thionocarbonate* (**6**). — Samples of **1** and **5** (500 mg) were individually heated in dry dimethyl sulfoxide (10 mL) containing triethylamine (0.1 mL) for 15 min at 125°, and then poured, with stirring, into ethanol. The precipitated thionocarbonates **2** (see Fig. 1b) and **6** (see Fig. 2b) were successively washed with ethanol, carbon disulfide, and diethyl ether, and dried *in vacuo* at room temperature, to give **2** (300 mg, 75%) or **6** (320 mg, 80%). These conditions provided derivatives giving the best analytical figures. Heating with sodium acetate as the catalyst, in dimethyl sulfoxide, or with pyridine, was less effective.

Anal. Calc. for $C_{26}H_{22}O_5S$: C, 69.95; H, 4.93; S, 7.17. Found (for **2**): C, 71.10; H, 5.54; S, 4.3 (d.s. ~0.58); (for **6**): C, 70.50; H, 5.07; S, 5.3 (d.s. ~0.70).

6-O-Tritylcellulose 2,3-di-(S-methyldithiocarbonate) (**3**) *and 6-O-tritylamylose 2,3-di-(S-methyldithiocarbonate)* (**7**). — 6-*O*-Tritylcellulose (1.0 g) was dissolved in dry dimethyl sulfoxide (25 mL) under dry nitrogen, with stirring, at room temperature. Methylsulfinyl anion (2.9M; 3.5 mL) was added, and stirring was continued for 3 h. Carbon disulfide (2.0 mL) was then added slowly, and stirring was continued for 30 min at room temperature. Iodomethane (3 mL; a 3-fold molar excess over methylsulfinyl anion) was added, and stirring was continued for 1 h. The solution initially turned yellow and became gel-like, and was finally pale-brown and viscous; it was poured into ice–water (250 mL), and the mixture was stirred to yield a precipitate that was filtered off, successively washed thoroughly with water, ethanol, and ether, and dried *in vacuo* at room temperature, to yield **3** (1.27 g, 88%); see Fig. 3a.

Similarly, 6-*O*-trityamylose (1.0 g) was converted into **7** (1.14 g, 79%); see Fig. 4a.

Anal. Calc. for $C_{29}H_{28}O_5S_4$: C, 59.58; H, 4.79; S, 21.9. Found (for **3**): C, 60.00; H, 4.81; S, 20.8 (d.s. ~1.90); (for **7**): C, 60.88; H, 4.79; S, 19.7 (d.s. ~1.72).

Thermal rearrangement of **3**. — Derivative **3** (200 mg) in dry dimethyl sulfoxide (20 mL) was heated and stirred for 8 h at 150° under nitrogen; the solid partly dissolved. Evolved gases were analyzed as the piperidine complex; this showed the presence of a small amount of carbonyl sulfide. The reaction mixture was poured into water, and the fawn-colored solid was successively washed with ethanol, carbon disulfide, and ether, and dried, to yield **4** (161 mg); see Fig. 3b. The analytical figures indicated some decomposition of the *S*-methyldithiocarbonate group, as well as rearrangement.

Anal. Calc. for $C_{29}H_{28}O_5S_4$: C, 60.0; H, 4.81; S, 20.8. Found: C, 61.5; H, 4.97; S, 18.1 (d.s. ~1.60).

Saponification and acetolysis of **4**. — Derivative **4** (100 mg) was suspended in a mixture of dimethyl sulfoxide (10 mL) and 4% aqueous sodium hydroxide (10 mL), heated for 3 h at 105°, and successively washed with aqueous methanol, methanol, absolute ethanol, ether, carbon disulfide, and ether. After being dried *in vacuo* at 55°, the product (60 mg) had a sulfur content of 5.75%, indicating thiolation, d.s. ~0.7. There was no i.r. band at 1760 or at 1220 cm^{-1}. Acetolysis[5] of the saponified product (50 mg) with acetic anhydride (2 mL), sodium acetate (50 mg), and zinc dust (400 mg) for 90 min at 120° yielded a white solid (12 mg) that showed carbonyl bands in the i.r. spectrum at 1740 (*O*-acetyl) and 1690 cm^{-1} (*S*-acetyl).

Thermal decomposition of **7**. — Derivative **7** (250 mg) in dry dimethyl sulfoxide (25 mL) under nitrogen was stirred, and the temperature was raised to 150°. All of the solid had dissolved within 1 h. Analysis of the effluent gases as the piperidine complex showed the presence of a small amount (~5% of the stoichiometric) of carbon disulfide. After 6 h, the reaction mixture was poured into water, giving a milky liquid, but no filterable precipitate was formed. The mixture was dialyzed overnight against running, distilled water, and freeze-dried, to yield **8** (200 mg); see Fig. 4b. The analytical figures indicated incomplete conversion into thionocarbonate. The d.s. by the thiocarbonate group was somewhat less than 0.86.

Anal. Calc. (for thionocarbonate from **7**, which would have a maximum d.s. of 0.86): C, 70.5; H, 5.03; S, 6.25. Found: C, 69.4; H, 4.81; S, 6.80.

ACKNOWLEDGMENTS

The author thanks Mrs. H. E. Slusarczyk for technical assistance, and the Faculty of Science of the University of New South Wales for financial support by means of a Special Projects Grant.

REFERENCES

1 E. I. Stout, W. M. Doane, B. S. Shasha, C. R. Russell, and C. E. Rist, *Carbohydr. Res.*, 3 (1967) 354–360.
2 S. Hakomori, *J. Biochem. (Tokyo)*, 55 (1964) 205–208.
3 B. S. Shasha, D. Trimnell, and W. M. Doane, *Carbohydr. Res.*, 32 (1974) 349–359.
4 L. J. Brady, *Anal. Chem.*, 20 (1948) 512–514.
5 D. Trimnell, B. S. Shasha, W. M. Doane, and C. R. Russell, *J. Appl. Polym. Sci.*, 17 (1973) 1607–1615.
6 N. W. H. Cheetham, unpublished results.
7 G. Descotes and A. Faure, *Synthesis*, (1976) 449–450.
8 D. H. R. Barton, R. V. Stick, and R. Subramanian, *J. Chem. Soc., Perkin Trans. 1*, (1976) 2112–2116.
9 R. G. Zhbankov, *Infrared Spectra of Cellulose and its Derivatives*, Consultants Bureau, New York, 1966, p. 146.
10 K. Freudenberg and A. Wolf, *Ber.*, 60 (1927) 232–238.
11 J. W. Green, *Methods Carbohydr. Chem.*, 3 (1963) 327–331.
12 R. L. Whistler and S. Hirase, *J. Org. Chem.*, 26 (1961) 4600–4605.