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THE CHIROPTICAL PROPERTIES OF ETHYLENE DITHIOACETALS AND DIETHYL DITHIOACETALS OF SOME ALDOSES

M. K. Hargreaves and D. L. Marshall

Department of Chemistry, North East London Polytechnic, Romford Road, Stratford, London E15 4LZ (Great Britain)

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ABSTRACT

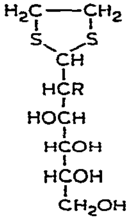
The circular dichroic spectra (down to ~220 nm) have been measured for some aldose ethylene dithioacetals and diethyl dithioacetals. Cotton effects have been observed at either 245 or 235 nm and at <220 nm for the ethylene dithioacetal series. For D-glucose ethylene dithioacetal, all three transitions were observed. The sign of the Cotton effect of longest wavelength is apparently related to the configuration of C-3 in the parent carbohydrate. For the diethyl dithioacetals, Cotton effects observed at <220 nm appear to be related to the configurations at C-2, C-3, and C-4; *e.g.* if the configuration is (DLD), the effect is positive. The nature of these transitions is discussed in terms of electronic perturbations of the chromophores by the asymmetric centres.

RESULTS AND DISCUSSION

The c.d. bands of sulphur compounds, which are observed in the region 200–250 nm, have been variously interpreted[1,2]. The o.r.d. curves of some ethane dithioacetals in the steroid series have been reported as showing a maximum at 250 nm in methanolic solution[3]; more recently, the nature of the 1,3-dithiolane chromophore has been discussed with respect to c.d. absorption[4].

In the steroid series, perturbation of the symmetric dithiolane chromophore was found to produce only one substantial c.d. absorption band in the accessible region (in the absence of other chromophoric groups) although other transitions are reported, whereas in the present work, where the same chromophore is attached to an aldose residue, one, two, or even three maxima are found.

It is of interest to compare the spectra of compounds (**1**) containing the 1,3-dithiolane ring system with those for the corresponding open system such as the diethyl dithioacetals (**2**). In both series of compounds, bands are found at 230–250 nm and below 220 nm in the c.d. spectrum, but the band at longer wavelength is more strongly represented in the ethylene dithioacetal series. In the c.d. measurements, the top of the band below 220 nm was not always accessible; therefore, $\Delta\varepsilon$ could not be measured, although an indication of its magnitude is given and it was always possible to determine the sign.



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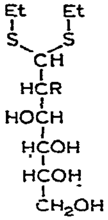

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R=OH, OMe, or H

The D-*gluco* configuration is shown in the conventional Fischer projection; for convenience in the Tables, such a configuration is shown as DLDD. Other monosaccharides are labelled in an analogous manner.

Table I shows that a second c.d. band at longer wavelengths is observed with two members of the diethyl series (galactose and arabinose), whereas in the ethylene series (Table II) xylose and glucose also give a further band.

The data in the Tables show that there is no overall relationship between the configurational pattern and the sign of the c.d. bands; however, in the compounds so far examined, there does appear to be a correlation between the sign of the absorption of longer wavelength in the ethylene dithioacetal series and the configuration at C-3. In the diethyl dithioacetal series, there is a correlation between the sign of the band at ~216 nm and the algebraic sum of the configurations at C-2, C-3, and C-4.

In deciding whether these correlations have any significance, it is first necessary to establish the extent to which it is reasonable to expect a particular band to shift

TABLE I

CIRCULAR DICHROISM OF ALDOSE DIETHYL DITHIOACETALS[a]

Monosaccharide	*Configuration*				*C.d. maxima*[b]			
					<220 nm		*250 nm*	
	C-2	*C-3*	*C-4*	*C-5*	*Sign*	*$\Delta\varepsilon$*	*Sign*	*$\Delta\varepsilon$*
D-Ribose	D	D	D		+	>0.5		
D-Arabinose	L	D	D		+	>0.5	−	0.16
D-Xylose	D	L	D		+	>0.3		
D-Lyxose	L	L	D		−	>0.3		
L-Arabinose	D	L	L		−	>0.6	+	0.18
D-Glucose	D	L	D	D	+	>0.5		
D-Mannose	L	L	D	D	−	>0.3		
D-Galactose	D	L	L	D	−	1.0 (218 nm)	+	0.23
3-*O*-Me-D-glucose	D	L	D	D	+	>0.4		
2-*O*-Me-D-glucose	D	L	D	D	+	>0.3		

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[a] Measured in aqueous solution. [b] Where > is indicated, the values of $\Delta\varepsilon$ have been measured for the shortest wavelength reached. The maxima in these cases were not accessible with the available instrumentation.

TABLE II

CIRCULAR DICHROISM OF ALDOSE ETHYLENE DITHIOACETALS[a]

Monosaccharide	*Configuration*				*C.d. maxima*[b]					
					<220 nm		*235 nm*		*245 nm*	
	C-2	*C-3*	*C-4*	*C-5*	*Sign*	*Δε*	*Sign*	*Δε*	*Sign*	*Δε*
D-Ribose	D	D	D				−	0.84		
D-Arabinose	L	D	D		−	>0.2			−	0.47
D-Xylose	D	L	D		+	>0.3			+	0.1
D-Lyxose	L	L	D				+	1.18		
D-Glucose	D	L	D	D	+	>0.3	−	0.19	+	0.2
D-Mannose	L	L	D	D			+	1.30		
D-Galactose	D	L	L	D	+	>0.3			+	0.44
2-Deoxy-D-*arabino*-hexose		L	D	D			+	1.12		
2-Deoxy-D-*lyxo*-hexose		L	L	D			+	1.32		
2-Deoxy-D-*erythro*-pentose		D	D		+	>0.6	−	1.22		
L-Rhamnose	D	D	L	L			−	1.09		
D-Fucose	D	L	L	D	+	>0.6			+	0.67
3-*O*-Me-D-glucose	D	L	D	D			−	0.1	+	0.1

[a]Measured in aqueous solution. [b]Where > is indicated, the values of Δε have been measured for the shortest wavelength reached. The maxima in these cases were not accessible with the available instrumentation.

under the influence of environment. In terms of u.v. absorption spectra, a shift of 5–10 nm is reasonable[5], but it would be unacceptable to postulate a shift of absorption maxima from 218–250 nm within series of compounds of this kind. Furthermore, such a shift would be expected to show clearly in the u.v. absorption as well as in the c.d. Therefore, the appearance of a c.d. band at 250 nm, as in arabinose in the diethyl series, must involve the effect of dissymmetry on a band which is absorbing in a symmetrical way for the other members of the series so that there is no differential absorption giving rise to c.d. spectra.

We find that, in methanolic solution, the 1,3-dithiolanes have u.v. absorption bands at ~9-nm longer wavelength than the acyclic diethyl dithioacetals. The u.v. spectrum of each ethylene dithioacetal shows two distinct bands, the first at 202–204 nm ($\log_{10} \varepsilon$ 3.2–3.4) and a less-intense band at 242–244 nm ($\log_{10} \varepsilon$ 2.3–2.6). The u.v. spectra of the dialkyl dithioacetals in methanolic solution again show two bands, one at ~207 nm ($\log_{10} \varepsilon$ 3.3–3.5) and the other at 233 nm ($\log_{10} \varepsilon$ 2.4–2.7). This shift to ~9-nm longer wavelength in the absorption of the ethylene dithioacetals compared with the diethyl dithioacetals has been attributed to an increased overlap between the sulphur orbitals in the former compounds[5]. We have reported the c.d. for aqueous solutions; in such solutions, the two bands in the u.v. spectra of each series have essentially the same intensities, but are less resolved than when the solvent is methanol. Indeed, the band of longer wavelength for the acyclic diethyl dithioacetals is almost a shoulder to the more-intense band of lower wavelength. This shift is to be expected in changing from methanol to water which is a more-polar solvent. In each compound of both series, the u.v. band of longer wavelength is broad.

The origin of the c.d. bands in the 240-nm region is open to question; in the steroid series, they could be attributed to orbital overlap between the two sulphur atoms[4,5], yet bands have been observed in a similar region by Mislow[6] for cyclic sulphides, and by Salvadori[2] for a series of dialkyl sulphides of general formula $Et(Me)CH(CH_2)_nSEt$, where $n = 0$–2. When $n = 0$, there may be a degree of steric interaction due to overcrowding, but with $n = 1, 2$, etc., this should not be the case, yet the spectra of all the members of this series of compounds were very similar in form[2].

The problem of the origin of these bands has also been discussed, *inter alia*, by Jaffé and Orchin[7]. In particular, these authors discussed the bathochromic shift in *gem*-disulphides compared with the absorption maximum at 230 nm in dialkyl sulphides. The intensities in the ethylene dithioacetal series compare well with these figures, and the displacement of the band is similar or rather greater. Jaffé and Orchin distinguished the bands at 230 nm from those at ~210 nm, pointing out that the band at 230 nm does not necessarily stem from interaction between a pair of sulphur atoms in the ground state but that it appears to involve the excitation of lone-pair electrons into the *d* shell of the sulphur atoms. They also say that the 210-nm bands in simple alkyl sulphides involve excitation of a lone-pair of electrons into a *d* orbital.

Horton and Jewell[8] have treated the spectra in the 210-nm region as deriving from some mixing of *d* electrons with the $n \rightarrow \sigma^*$ transition of the C–S σ bond. It follows that the sulphur atoms in a *gem*-disulphide would interact to a degree through their bonding to the geminal carbon atom as well as through spatial interferences of their orbitals. The u.v. data for diethyl dithioacetals in ethanolic solution[8] are in good agreement with our data when methanol and water were the solvents.

Recently, the electronic spectra of compounds with 1,3 interactions have been further reported[9]. For 1,3-dithiane and its 2-methyl and 2,2-dimethyl derivatives, four transitions have been observed at <200 nm and at ~210, ~230, and ~250 nm, the two bands of longer wavelength being ascribed to charge-transfer interactions between the sulphur atoms. Since the 1,3-dithiane ring may be intermediate in behaviour between the two chromophores on which this work is based, the c.d. transitions reported here might be anticipated to correspond broadly to the u.v. bands of this ring. Reference to Tables I and II shows that such c.d. transitions are found.

Since the observed changes in the u.v. absorption are not as great as the changes in the c.d. in either series, it seems likely that bands at 235–250 nm exist in all members of the series but that the absorption is symmetrical in some cases; where optical activity is shown this may be ascribed to the presence of some inter- or intra-molecular conformational rigidity. The n.m.r. spectra of acetylated diethyl dithioacetals[10] show that the two ethyl groups are non-equivalent; it follows that the sulphur groups must be non-equivalent.

It appears that the dissymmetry of the splitting of the dithioacetal environment has less effect on the absorption in some cases than in others. In particular, the influence of the aldose moiety on the sulphur chromophore may be expected to depend on the extent to which it can be symmetrically disposed in relation to the chromophoric group. The influence of a dissymmetric molecule on the two sulphur chromophores will be different. The available data suggest that removal of HO-2 results in an enhanced intensity at 235 nm in the ethylene series. This indicates either that a contribution of opposite sign in the same region originates from position 2, or that removal of HO-2 allows the C-3 asymmetric centre to come into a more-favourable conformation to cause perturbation in the chromophore.

If, in the ethylene dithioacetal series, the c.d. is thought to be dominated by C-3 (opposite sign relation), then C-2 affects the c.d. at 235 nm only to the extent of reducing the intensity of the dichroism. For the diethyl dithioacetals, this opposite sign relation also obtains with C-3 in the compound where c.d. absorption is observed at 250 nm. So far as the absorption at 220 nm is concerned, in the diethyl dithioacetal series, the sign corresponds to the algebraic sum of the configurations at C-2, C-3, and C-4, but possibly combined with a dominant influence of C-2. This could be related to the greater flexibility of this chromophore over the 1,3-dithiolane chromophore where C-2 substituents are essentially at right angles with the ring.

Clearly, the rotatory power and the circular dichroic absorption and their signs are influenced by a number of factors (acetylation of the sugar chain produces[11] a change in the sign of the absorption at 245 nm), one of which must be the arrangement of the groups in the molecule. The fact that methylation of HO-2 and HO-3 makes no significant difference to the c.d. spectra of the glucose derivatives indicates that hydrogen bonding is not an all-important factor. The complexity of the stereochemistry makes an analysis of the origins of these c.d. bands difficult to determine, but it is also likely that a detailed study of the effect of alteration in the structure of each functional group, in turn, would prove rewarding.

EXPERIMENTAL

The c.d. spectra were obtained by using Jouan Dichrographe and Fica Spectropol I instruments. The u.v. spectra were recorded on Unicam S.P. 700 and Optica FR4 spectrophotometers. The concentration ranges were 10–2mM, and the cell path-lengths were 0.1, 0.2, or 0.5 cm. In both u.v. and c.d., the longer wavelength, more-accessible bands were measured for 10mM solutions in 0.5-cm cells. Then the shorter wavelength bands were measured with suitable dilutions down to 2mM in 0.1-cm cells. All spectra were obtained at room temperature.

The compounds used were prepared according to methods established in the literature, and were characterised by $[\alpha]_D$, t.l.c., and melting point.

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