TABLE I

N.M.R. PARAMETERS FOR *meso*- AND *dl*-2,5-DIPHENYLHEXANEDIOL-2,5 AT 35 AND 91°

	meso		*dl*	
	35°	91°	35°	91°
$\delta\nu$	17.85 ± 0.18	12.74 ± 0.10	13.27 ± 0.13	8.19 ± 0.11
$J_{AA'} = J_{BB'}$	11.86 ± .31	11.40 ± .22	5.07 ± .21	5.40 ± .25
$J_{AB'} = J_{A'B}$	4.81 ± .23	4.96 ± .15	11.21 ± .19	10.61 ± .14
$J_{AB} = J_{A'B'}$	−13.36 ± .22	−13.71 ± .18	−13.62 ± .14	−13.81 ± .13

values should not be taken seriously. Entropy changes are of the order of 1 e.u. or less.

In both cases the chemical shift between the A and B protons diminishes markedly with increased temperature, reflecting a more nearly equal distribution of rotamers about the single bonds joining the methylene groups with the asymmetrically substituted carbon atoms. There appears as yet to be no way of interpreting this phenomenon quantitatively.

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[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, WAYNE STATE UNIVERSITY, DETROIT, MICH.]

Mass Spectrometry in Carbohydrate Chemistry. Ethylene Dithioacetal Peracetates

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The mass spectra of the ethylene dithioacetal peracetyl derivatives of D-glucose, D-arabinose, 2-deoxy-D-glucose, and 6-deoxy-L-galactose, and of the ethylene dithioacetal pentaacetyl-d_{15} derivative of D-glucose, are discussed. The ethylene dithioacetal portion of the molecule can be recognized by the intense peak at m/e − 105 resulting from C-1–C-2 cleavage of the monosaccharide with charge retention on C-1. The characteristics of the mass spectra can be related to the position of deoxy groups in the carbohydrates; the molecular weight can be determined from a fragment peak at M − 59 (M − $OCOCH_3$).

Introduction

Dithioacetal derivatives of carbohydrates are often used for characterization and identification and as intermediates in the preparation of other sugar derivatives. Dithioacetal derivatives and their peracetates are easily prepared and are stable compounds. In the form of a dithioacetal peracetate, a carbohydrate exists in an acyclic structure.

Dithioacetal and dithioketal derivatives of carbonyl functions are reported to be desirable derivatives for mass spectrometric purposes.[1,2] Introduction of an ethylene dithioketal function into a steroid quenches the characteristic fragmentation behavior of the keto function; peaks characteristic of the ethylene dithioketal portion of the molecule predominate.[1] Since sulfur can better accommodate charge than oxygen, the dithioketals exhibit more prominent molecular ion peaks than their oxygen analogs.

Diethyl dithioacetal peracetyl derivatives of carbohydrates have been studied mass spectrometrically.[2] These derivatives, which are usually crystalline, are volatile enough and thermally stable enough for introduction into a conventional inlet system. In contrast to the acetyl,[3,4] O-methyl,[5] and O-isopropylidene[6] derivatives of carbohydrates, the diethyl dithioacetal peracetates exhibit a molecular ion peak from which the molecular weight can be directly determined. From their mass spectra, the peracetates of aldohexose, ketohexose, aldopentose, 2-deoxyhexose, and 6-deoxyhexose diethyl dithioacetals can be differentiated from each other. Stereochemical differences are of little influence on the fragmentation.

As an extension of the study of dithioacetal peracetyl derivatives of carbohydrates upon electron impact, the mass spectra of ethylene dithioacetal peracetates of D-glucose (I), D-arabinose (II), 6-deoxy-L-galactose (III), and 2-deoxy-D-glucose (IV) are presented and discussed here. The mass spectrum of D-glucose ethylene dithioacetal pentaacetate-d_{15} (I, Ac = $COCD_3$) is not shown, but the m/e positions of the peaks corresponding to those in the undeuterated analog, Fig. 1, are given in the discussion in parentheses, *e.g.*, m/e − 43(46). Metastable peaks in the mass spectra given in Fig. 1–4 are listed in Table I.

TABLE I

METASTABLE PEAKS IN FIG. 1–4

Figure	Fragmentation	Calculated	Found
1	105 → 61	35.4	35.5
	(105 → 61	35.4	35.6)[a]
	189 → 147	114.3	114.6
	(192 → 148	114.1	114.5)[a]
2	105 → 61	35.4	35.5
	189 → 147	114.3	114.6
	246 → 186	140.6	141.0
3	105 → 61	35.4	35.6
	189 → 147	114.3	114.5
4	228 → 186	151.7	152.1

[a] The position of the peak in the mass spectrum of Ia (I, Ac = $COCD_3$) is given in parentheses.

The Molecular Weight. Fragmentation Series 1 and 2.—In contrast to the mass spectra of the diethyl dithioacetal peracetates,[2] the mass spectra of the ethylene dithioacetal peracetates show no molecular

(1) G. von Mutzenbecher, Z. Pelah, D. H. Williams, H. Budzikiewicz, and C. Djerassi, *Steroids*, **2**, 475 (1963).

(2) D. C. DeJongh, *J. Am. Chem. Soc.*, **86**, 3149 (1964).

(3) K. Biemann, D. C. DeJongh, and H. K. Schnoes, *ibid.*, **85**, 1763 (1963).

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(5) N. K. Kochetkov, N. S. Wulfson, O. S. Chizhov, and B. M. Zolotarev, *Tetrahedron*, **19**, 2209 (1963).

(6) D. C. DeJongh and K. Biemann, *J. Am. Chem. Soc.*, **86**, 67 (1964).

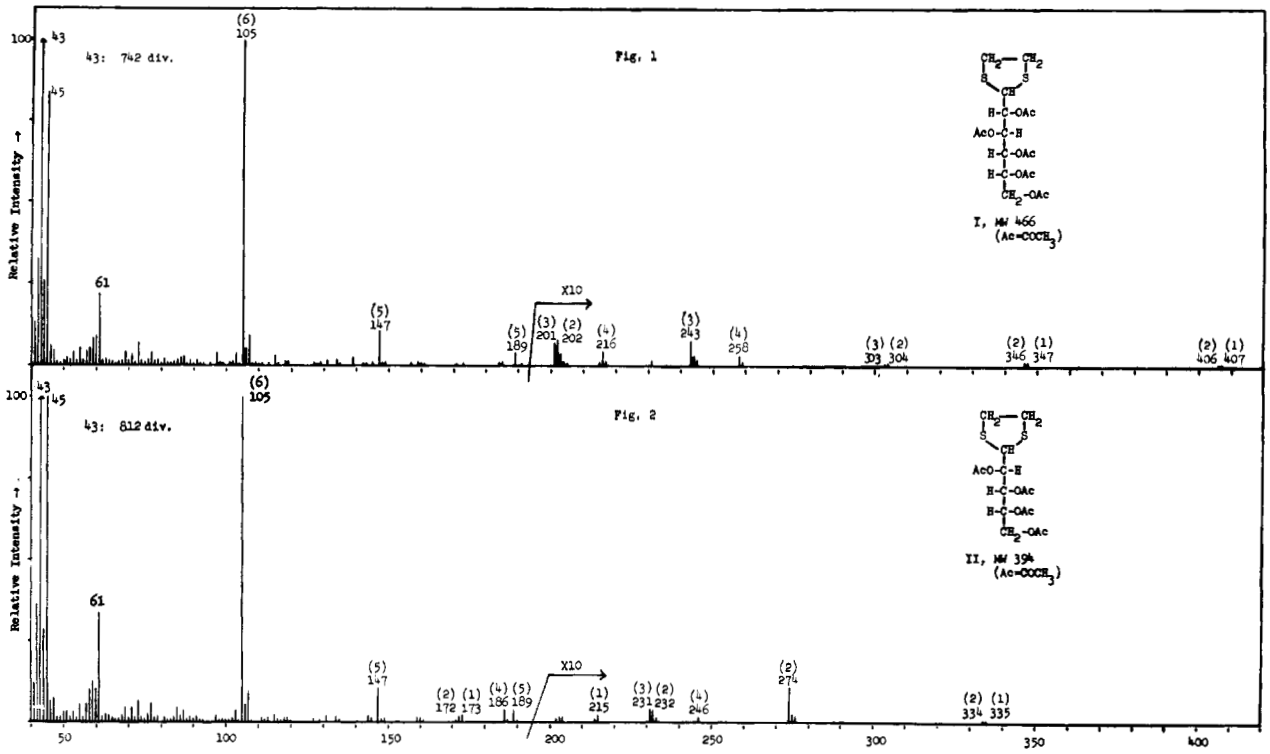


Fig. 1.—Mass spectrum of D-glucose ethylene dithioacetal pentaacetate (I).
Fig. 2.—Mass spectrum of D-arabinose ethylene dithioacetal tetraacetate (II).

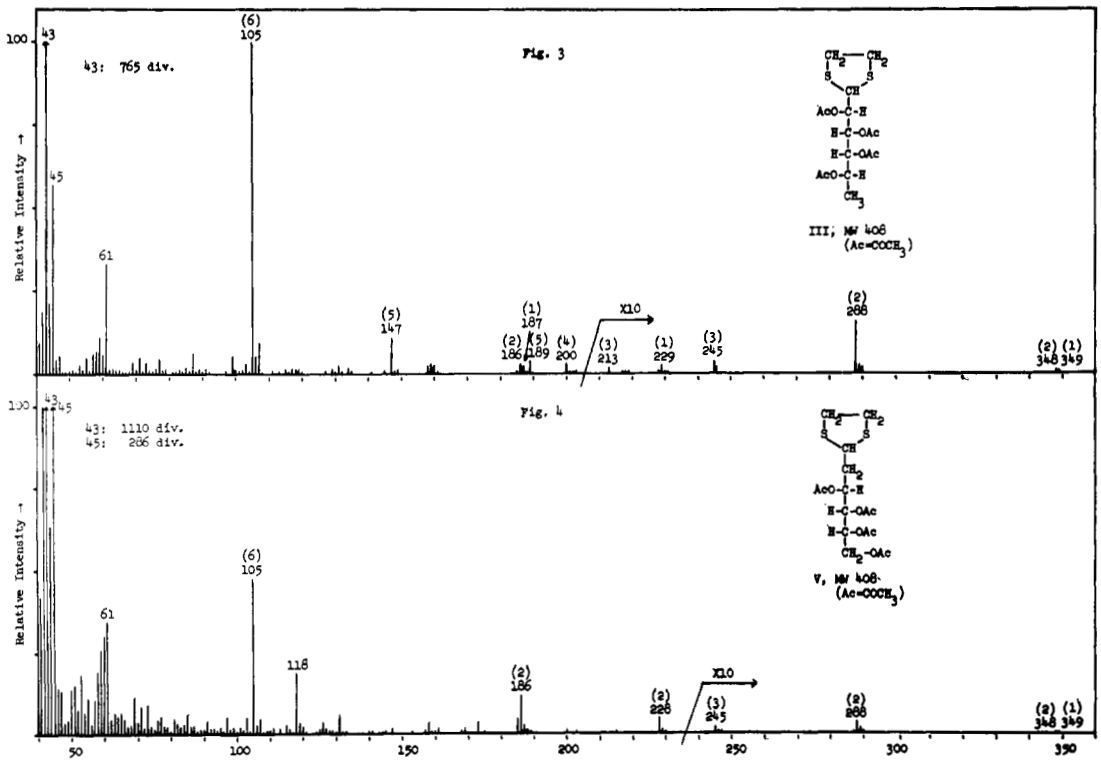


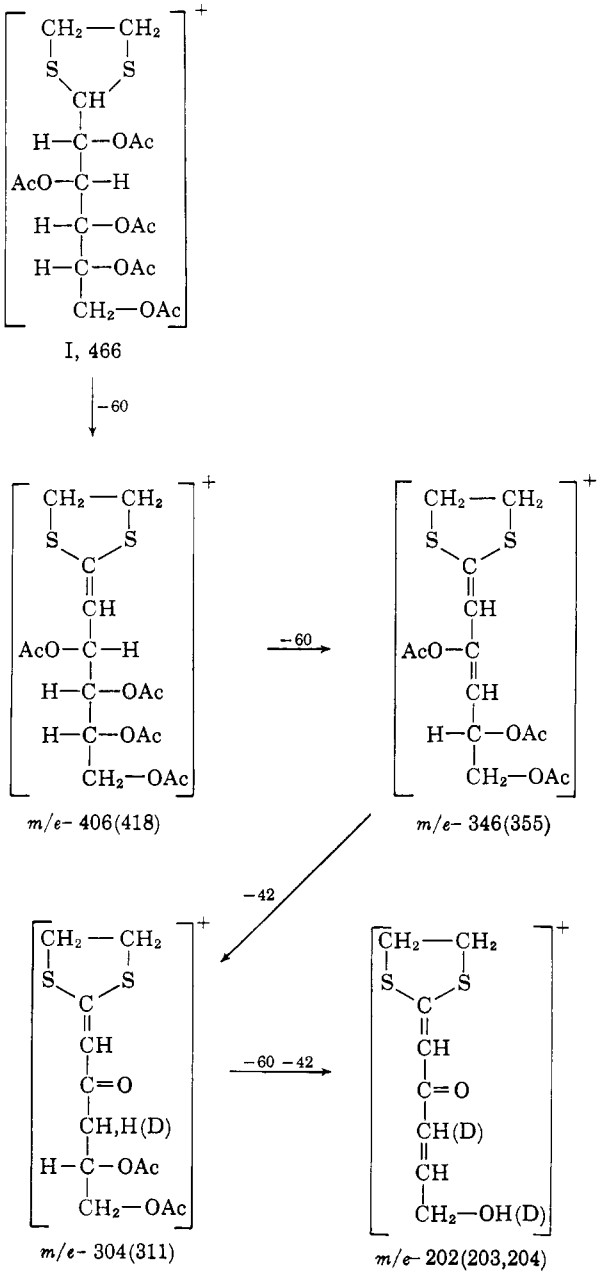
Fig. 3.—Mass spectrum of 6-deoxy-L-galactose ethylene dithioacetal tetraacetate (III).
Fig. 4.—Mass spectrum of 2-deoxy-D-glucose ethylene dithioacetal tetraacetate (IV).

ion peak. The only observable peaks in the higher mass range are due to the loss of substituents. Some of these peaks are of very low intensity and can hardly be detected under normal operating conditions.

Elimination of an acetoxyl radical from the molecular ion leads to the first observable fragment in these mass spectra. In Fig. 1 it is found at m/e − 407(419), and it is found 72 m.u. lower for the pentose derivative, Fig. 2, at m/e − 335, and 58 m.u. lower for the deoxyhexose derivatives, Fig. 3 and 4, at m/e − 349. Further loss of acetic acid [60(63) m.u.], ketene [42(44) m.u.], and acetic anhydride [102(108) m.u.], as described previously,[3] gives rise to the fragments of series 1. (In Fig. 1–4, fragments of series 1–6 have in parentheses above them the number of the series to which they belong). In Fig. 1, fragments of series 1 are found

at m/e — 407(419), m/e — 347(356), and m/e — 203 (204, 205).

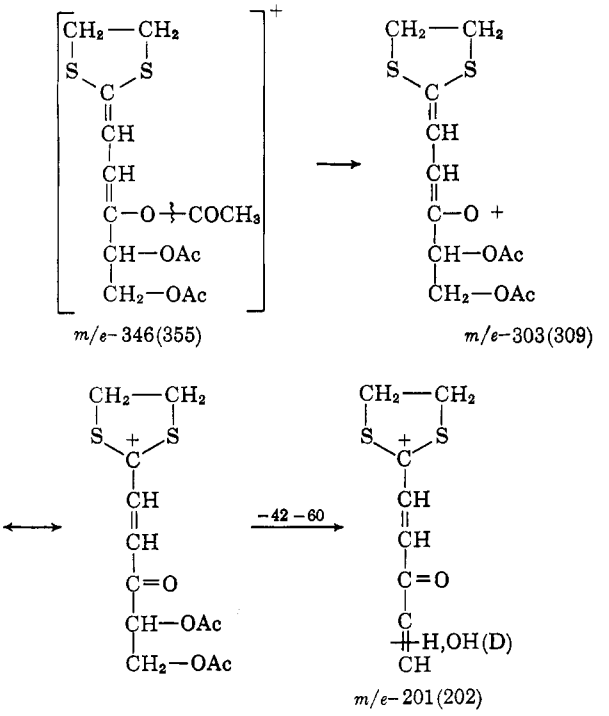
Loss of two molecules of acetic acid, followed by elimination of ketene, acetic acid, and ketene, is also an important mode of fragmentation. A possible scheme to explain the fragments of series 2 is



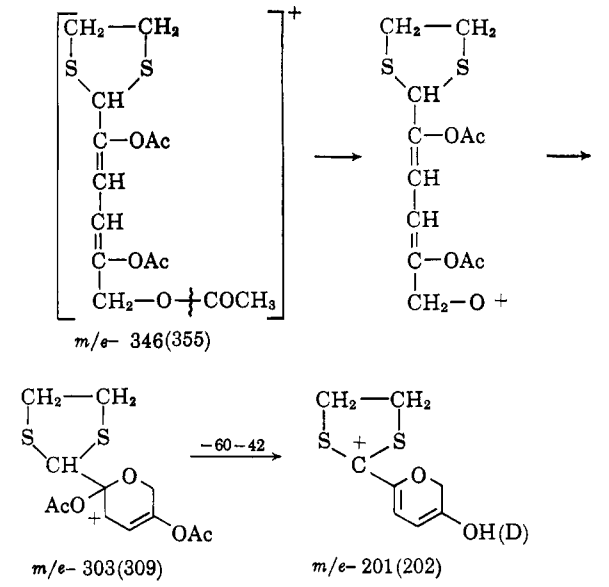
In Fig. 2, this series is 72 m.u. lower and in Fig. 3 and 4, 58 m.u. lower.

Series 3.—Fragment 303 in Fig. 1 shifts 6 m.u. higher in the mass spectrum of compound I-d_{15}, indicating that it has lost three acetyl groups and retained two. The fragment includes C-5 because it is found 72 m.u. lower (H *vs.* CHOAc) in Fig. 2, at m/e — 231, and 58 m.u. lower (CH_2 *vs.* CHOAc) in Fig. 3 and 4, at m/e — 245. Fragments 243(246) and 201(201, 202) in Fig. 1 are part of this fragmentation scheme.

A structure for fragment 303 in Fig. 1, fitting the data mentioned above, would arise upon elimination of an acetyl radical from the fragment formed when two molecules of acetic acid are lost from the molecular ion. A possible mechanism is



The charge is stabilized by the sulfur atoms and the conjugated system. Another possible mechanism, in which a six-membered ring is formed, is

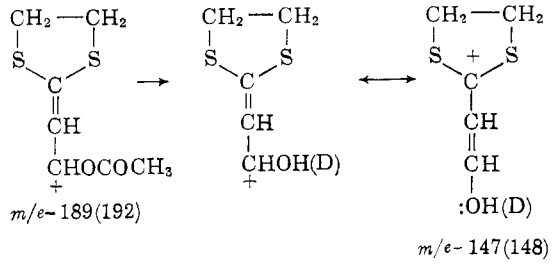


Analogous mechanisms can be formulated in which the conjugated double bonds in fragment 346 are between different atoms and are formed from different acetoxyl groups than shown.

Series 4.—The fragment in Fig. 1, m/e — 258(264), followed by m/e — 216(220), 42(44) m.u. lower, contains two acetoxyl groups. Its formation can be explained by the loss of thioacetaldehyde, CH_2S [46(46) m.u.], acetic anhydride [102(108) m.u.], and acetic acid [60(63) m.u.] from the molecular ion. In Fig. 2, the first fragment of this series is at m/e — 246, followed by m/e — 186, resulting from elimination of thioacetaldehyde and acetic anhydride or acetic acid and ketene from the molecular ion. The only fragment of this

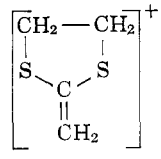
series which is present in the mass spectra of the deoxyhexoses is at m/e − 200, 58 m.u. lower than in Fig. 1; this peak is not very intense in Fig. 4.

Series 5.—Elimination of a molecule of acetic acid between C-1 and C-2 of the carbohydrate and C-3–C-4 fission with charge retention on C-3 forms a very highly stabilized fragment. This fragment and the fragment 42(44) m.u. lower comprise series 5. Metastable peaks in Table I corroborate this mechanism. These peaks



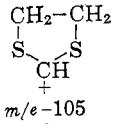
m/e-189(192) m/e-147(148)

are prominent in all the mass spectra shown except for the 2-deoxy compound IV. Compound IV forms a somewhat analogous peak at m/e − 118



m/e-118

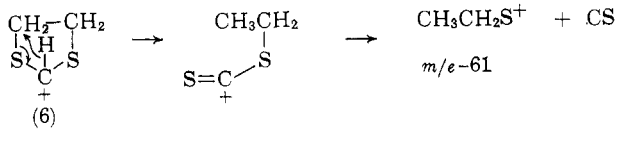
Fragment 6.—Cleavage of the C-1–C-2 bond of the carbohydrate with charge retention on C-1 gives rise to the intense peak at m/e − 105. This peak does not shift in the mass spectrum of compound I-d_{15}. This



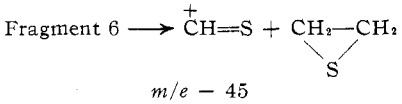
m/e-105
(6)

peak is not as intense in the mass spectrum of 2-deoxy-compound IV as in Fig. 1–3 because the cleavage of C-1–C-2 leaves a primary radical at C-2.

Metastable peaks (see Table I) indicate that fragment 61 arises from fragment 6. The expulsion of carbon monosulfide can account for this metastable peak



The peak at m/e − 45(45) also can result from fragmentation of the ethylene dithioacetal ion by formation of a thioaldehydo ion



m/e − 45

The peak at m/e − 43(46) is the acetyl ion,[3] CH_3CO^+, and is the most intense peak in these mass spectra.

Discussion

The mass spectra can be recognized as ethylene dithioacetal derivatives by the presence of the intense peak at m/e − 105, fragment 6, and as peracetyl derivatives by the intense peak at m/e − 43 and by the various series of fragments differing within the series by 42, 60, and 102 m.u. The molecular weight must be determined from a peak resulting from the elimination of an acetoxyl radical from the molecular ion.

The aldohexose, aldopentose, and deoxyaldohexose derivatives can be differentiated by series 1, 2, and 3 which differ from compound to compound by 72, 58, or 14 m.u. ($CHOCOCH_3$ *vs.* –H *vs.* CH_2), respectively. The 6-deoxyaldohexose can be differentiated from the 2-deoxyaldohexose by the presence of series 5 at m/e − 189 and m/e − 147 in the mass spectrum of the former and by the peak at m/e − 118 in the mass spectrum of the latter.

These data suggest that ethylene dithioacetal peracetates will be useful derivatives for characterizing carbohydrates mass spectrometrically. The mass spectra of the corresponding diethyl dithioacetal derivatives are more valuable because they exhibit a molecular ion peak. Hopefully, the mass spectra of dithioacetal peracetates will be useful in the determination of the structure of newly discovered sugars. Addition of carbon atoms as branching, chain extension, or methyl groups should be recognizable from the mass spectrum.

Experimental

Mass Spectra.—The mass spectra were determined with a CEC 21-103C mass spectrometer equipped with a heated stainless steel inlet system operated at 170°; ionizing potential, 70 e.v.; ionizing current, 50μa.; temperature of the ion source, 250°. The sample (~1.0 mg.) was sublimed from a glass tube into the reservoir (3 l.).[7]

Ethylene dithioacetals were prepared according to the procedure of Zinner,[8] using 1,2-ethanedithiol in place of ethanethiol: D-glucose ethylene dithioacetal, m.p. 143–145° (lit[9]. m.p. 143°); D-arabinose ethylene dithioacetal, m.p. 152–153° (lit.[10] m.p. 154.5°); 2-deoxy-D-glucose ethylene dithioacetal, m.p. 167.5–168.5°; and 6-deoxy-L-galactose ethylene dithioacetal, m.p. 190–190.5° (lit.[11] m.p. 191–191.5°).

Acetylation of the Ethylene Dithioacetals.—D-Glucose ethylene dithioacetal pentaacetate (I), m.p. 101–101.5° (lit.[9] m.p. 100.9–101.1°), D-arabinose ethylene dithioacetal tetraacetate (II), m.p. 100–101°, 6-deoxy-L-galactose ethylene dithioacetal tetraacetate (III), m.p. 138.5–139°, and 2-deoxy-D-glucose ethylene dithioacetal tetraacetate (IV), m.p. 86.5–87.0°, were prepared from 0.1–0.6 g. of the corresponding ethylene dithioacetal by acetylating with acetic anhydride and pyridine at room temperature.

D-Glucose Ethylene Dithioacetal Pentaacetate-d_{15}.—D-Glucose ethylene dithioacetal (0.1 g.) was dissolved by heating in 0.40 ml. of deuterium oxide. After the deuterium oxide was removed in a vacuum desiccator, the residue was acetylated with 0.20 ml. of acetic anhydride-d_6 and 0.10 ml. of dry pyridine; m.p. 99.5–100.5°.

Acknowledgment.—The author thanks Professor K. Biemann of the Massachusetts Institute of Technology for allowing me to use the mass spectrometer in his laboratories. Acknowledgment is made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, for support of this research.

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(8) H. Zinner, *Chem. Ber.*, **84**, 780 (1951).
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