[CONTRIBUTION FROM THE DEPARTMENT OF RESEARCH IN ORGANIC CHEMISTRY, MELLON INSTITUTE]

NOTE[1] ON THE TOSYLATION OF DIETHYL MUCATE

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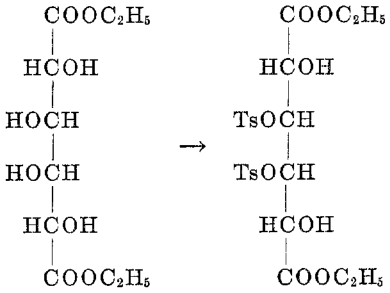
In connection with certain studies on sulfonic esters of sugar derivatives, a sample of diethyl tetra-O-*p*-tolylsulfonylmucate (*p*-tolylsulfonyl = "tosyl"; Ts) was desired. Its preparation, by reaction of diethyl mucate (galactarate) with *p*-toluenesulfonyl chloride in pyridine, was expected to be a simple procedure. However, under all conditions tried, we were unable to isolate any of the compound.[5]

In initial experiments, recrystallized diethyl mucate (I) was treated with 4.4 molar equivalents of the sulfonyl chloride in dry pyridine during 2 hours at 0° (1); a low yield of a crystalline diethyl di-O-tosylmucate (II) resulted. Presence of two free hydroxyl groups in II was shown by the formation of a crystalline diacetate on acetylation. Compound II reacted with Finkelstein's reagent [sodium iodide dissolved in acetone (2)], under standard conditions (3), to give free iodine plus a practically quantitative yield of sodium *p*-toluenesulfonate. Because this behavior is associated with the presence of contiguous tosyloxy groups (4), and since tosylation of I should occur symmetrically, compound II is tentatively assigned the structure of diethyl 3,4-di-O-tosylmucate (the only formulation which fulfills both these conditions):



I II

On re-attempting to obtain the tetra-O-tosyl derivative, either by various more drastic tosylations of diethyl mucate or by tosylating the diethyl di-O-tosylmucate, a new crystalline compound (III) was isolated; III had an analysis corresponding to that calculated for a diethyl di-O-tosyldidehydrodideoxy-

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[1] Owing to changed circumstances, this study cannot be brought to completion here; it is published with the hope that other workers may continue the investigation.

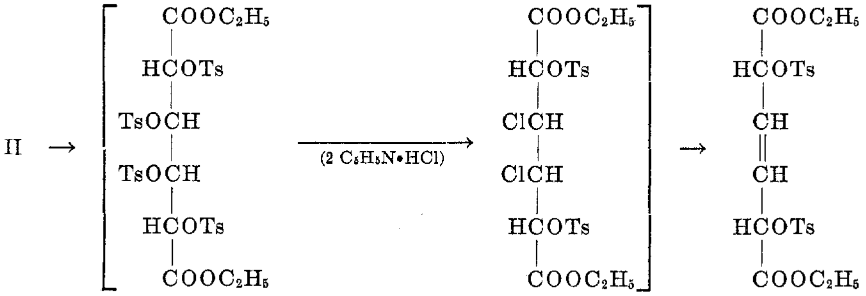
[2] Present position: Senior Fellow; Parke, Davis and Company Multiple Fellowship in Medicinal Chemistry, Mellon Institute.

[3] Died on May 17, 1951.

[4] First received August 10, 1951.

[5] A very brief account of this work was given in E. R. Weidlein, *Current Scientific Researches in Mellon Institute*, 1951, p. 10, Pittsburgh, Pa.

mucate (diethyl ditosyloxydihydromuconate). The compound absorbed hydrogen, on catalytic hydrogenation, in an amount indicating the presence of one double bond per molecule. It could not be acetylated and therefore had no free hydroxyl groups (confirmed by its infrared absorption spectrum). It was unaffected by Finkelstein's reagent under the standard conditions, indicating the absence of contiguous tosyloxy groups. (This treatment afforded an elegant method for separating it from II, at the sacrifice of the latter.) For these reasons, III is tentatively assigned the structure of diethyl 2,5-di-O-tosyl-3,4-didehydroxymucate. A possible mechanism for its formation involves (5) the action of pyridinium chloride on the (unisolated) diethyl tetra-O-tosylmucate, as follows:



$$\text{II} \rightarrow \left[\begin{array}{c} COOC_2H_5 \\ | \\ HCOTs \\ | \\ TsOCH \\ | \\ TsOCH \\ | \\ HCOTs \\ | \\ COOC_2H_5 \end{array} \xrightarrow[\text{(2 } C_5H_5N{\cdot}HCl)]{} \begin{array}{c} COOC_2H_5 \\ | \\ HCOTs \\ | \\ ClCH \\ | \\ ClCH \\ | \\ HCOTs \\ | \\ COOC_2H_5 \end{array}\right] \rightarrow \begin{array}{c} COOC_2H_5 \\ | \\ HCOTs \\ | \\ CH \\ \| \\ CH \\ | \\ HCOTs \\ | \\ COOC_2H_5 \end{array}$$

III

EXPERIMENTAL

Ultraviolet absorption spectra were obtained[6] by means of a Cary recording spectrophotometer with a maximum error in wave-length calibration of ±5Å. *Infrared absorption spectra* were recorded[6] on a Baird spectrophotometer having a wavelength accuracy of better than ±0.1 micron. All such spectra (see Fig. 1) were obtained for suspensions of the solid samples in Nujol. The infrared absorption spectrum[6] of mucic acid[7] is given in Figure 1 (curve A).

Diethyl mucate (I). Contrary to Limpricht (6), this compound is readily prepared, in excellent yield, by refluxing a suspension of mucic acid in absolute ethanol containing sulfuric acid; indeed, this method is superior to any hitherto described (6–10). No advantage was gained by using *p*-toluenesulfonic acid as catalyst (11, 12); instead, removal of traces of the latter, to give a spectroscopically pure diethyl mucate, was tedious.

A mixture of 20 g. of dry mucic acid,[7] 515 ml. of absolute ethanol, and 4 ml. of concentrated sulfuric acid was boiled gently (boiling stone, GlasCol mantle) under a reflux condenser slanting at 45° (ground-glass joint, Drierite tube) during 24 hours, giving a very pale yellow solution which was cooled and then kept overnight in the refrigerator. The resulting colorless crystals were filtered off, thoroughly washed with 50 ml. of absolute ethanol, and dried in the vacuum-desiccator over phosphorus pentoxide and soda-lime; yield, 18 g.; m.p. 135–140°. The alcoholic mother liquor and washings were united and evaporated almost to dryness under diminished pressure at 30°; the yellow, partly crystalline residue was suspended in 25 ml. of absolute ethanol, filtered, and the crystals dried; wt., 5 g. Total yield,

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[6] Determination made in the Department of Research in Chemical Physics, Mellon Institute.

[7] Kindly presented by Avoset Company, Gustine, California.

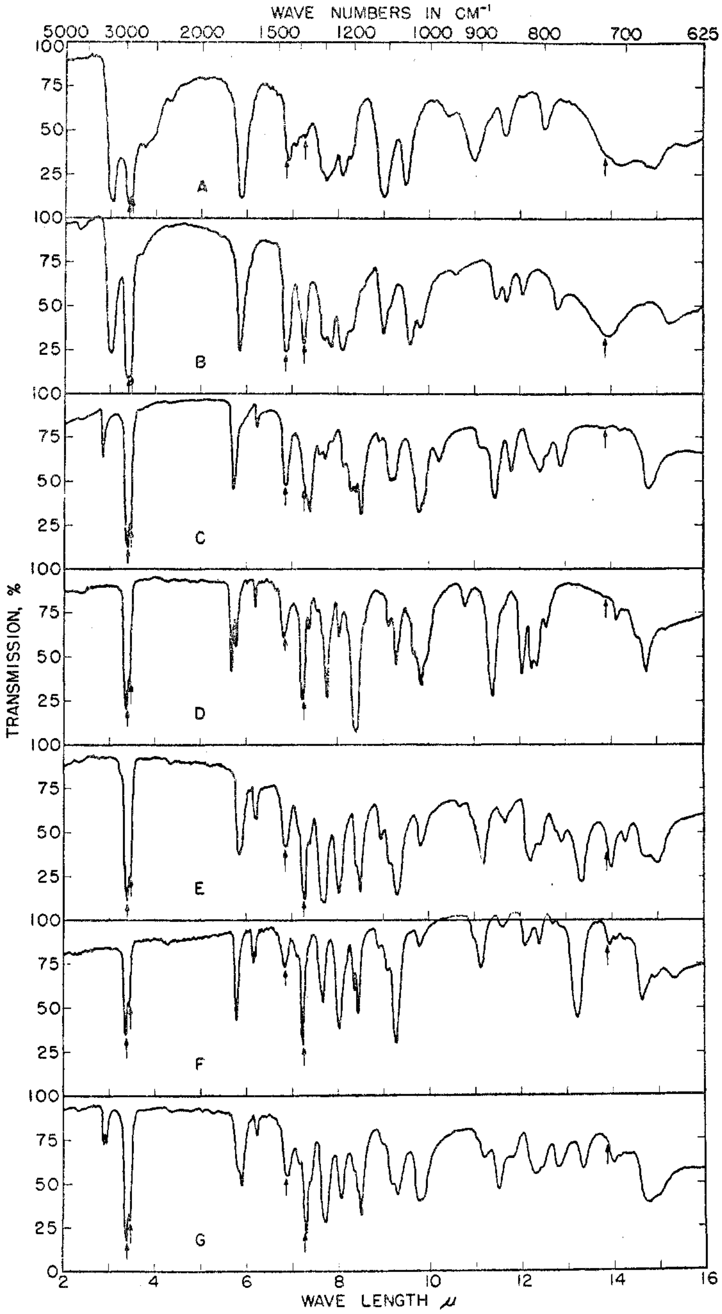

FIG. 1. INFRARED ABSORPTION SPECTRA. A. Mucic acid; B. Diethyl mucate; C. Diethyl di-O-tosylmucate; D. Diethyl di-O-acetyldi-O-tosylmucate; E. Diethyl ditosyloxydihydromuconate; F. Diethyl ditosyloxytetrahydromuconate; G. Mixture *M* (m.p. 153–154°) of C and E. (Arrows indicate bands of Nujol)

91%. It was recrystallized from 20 vols. of absolute ethanol; wt. (dry), 20 g., m.p.[8] 171–172° (remelt, 169–170°). [Malaguti (7) and Limpricht (6) gave m.p. 158°; Behrend and Heyer (10), 163–164°; Skraup (8), 172°.] There was no change in m.p., and no appreciable loss in weight, on drying at 80°/20 mm. for 66 hours. It was insoluble in warm benzene, chloroform, or ether; and soluble in cold pyridine, warm water, ethyl acetate, acetone, dioxane, absolute methanol, or absolute ethanol.

Anal. Calc'd for $C_{10}H_{18}O_8$: C, 45.11; H, 6.8; OEt, 33.85.
Found: C, 45.23; H, 6.9; OEt, 33.98.

[The mother liquor from the recrystallization afforded, besides more diethyl mucate, another crystalline product (m.p., 128–130°), of undetermined composition.] The ultraviolet absorption spectrum[6] (see Fig. 2, curve 1) of a 0.01 *M* solution in 95% ethanol showed no bands (220–400 mμ). The infrared absorption spectrum[6] is recorded in Fig. 1 (curve B); since no conjugation is possible, the position of the C=O band at 1710 cm^{-1} (normal ester position, 1755 to 1735 cm^{-1}) indicates hydrogen bonding.

Tosylation of diethyl mucate in pyridine. The procedure used was the "general method" previously described (1), except that, because of the low solubility of diethyl mucate, double the proportion of dry pyridine was employed. In initial tests, the effect of *4.4 molar equivalents* of *p*-toluenesulfonyl chloride was studied (see Table I); for experiments 1, 2, and 3, the colorless solution was cooled to −5° in ice-salt before adding the sulfonyl chloride. In experiment 1, the elementary analysis of the recrystallized product agreed with that calculated for II; it was devoid of chlorine, and was practically insoluble in warm ether; fairly soluble in warm benzene, absolute methanol, or absolute ethanol; and very soluble in cold pyridine and in warm acetone, chloroform, or ethyl acetate. In experiments 2 and 3, with each increase in reaction time, the yield of crystals was increased, but the melting point of the product (once recrystallized from absolute ethanol) was diminished (see Table I); repeated recrystallization from ethanol effected no change in m.p. Thus, recrystallization of *M* (13.6 g.; expt. 3; *Anal.* Found: S, 11.43; Cl, zero.) from absolute ethanol (15 vols.) gave 13.0 g. of colorless crystals; m.p. unchanged.

Anal. Found: C, 50.95; H, 4.9; S, 11.97; N, zero.

This was again recrystallized in the same manner, giving colorless crystals, *N*; 12.3 g.; m.p. 154–155° (softening at 133°); its infrared absorption spectrum[6] was very little different from that of *M*. There was negligible loss in weight on drying at 80°/20 mm. for 22 hours.

Anal. Found: C, 51.66, 51.65; H, 5.2, 5.3; S, 11.60, 11.55; OEt,[9] 14.23.

In no case did the yield approach that calculated for the tetra-O-tosyl ester, and no material having its composition was recognized. Elementary analysis of these products suggested that they were mixtures.

Separation into two components (II and III) could be achieved by fractional recrystallization from pyridine-water and then from ethanol; or, better, from benzene and then from ethanol. Thus, in expt. 2, the colorless crystals (12.8 g.) were recrystallized from 15 vols. of cold *pyridine* (by the dropwise addition of 5 vols. of *water*, followed by preservation in the refrigerator overnight), affording 11.0 g. of crystals; these were again recrystallized from 10 vols. of absolute ethanol, giving 8.8 g. of colorless crystals, m.p. 170–171°, whose analysis corresponded to that calculated for II. Similarly, recrystallization of 10.0 g. of mixture *M* (expt. 3) from 20 vols. of cold pyridine plus 2 vols. of water gave 6.0 g. of colorless crystals; these were recrystallized from 10 vols. of boiling absolute ethanol, yielding 5.0 g. of colorless crystals which had the m.p. and elementary analysis of II. Addition of 80 ml. of water to the aqueous pyridine mother liquor gave quantitative recovery of the rest of the material; this was recrystallized from 5 vols. of absolute ethanol, yielding 3.5 g. of colorless crystals; m.p. 135–145° (softening at 127°).

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[8] All compounds herein described, although colorless and beautifully crystalline, showed slight preliminary softening before melting occurred.

[9] Ethoxyl analyses by Dr. Adalbert Elek, who states that compounds containing both sulfur and ethoxyl usually give "found" ethoxyl values which are 1 to 2% low.

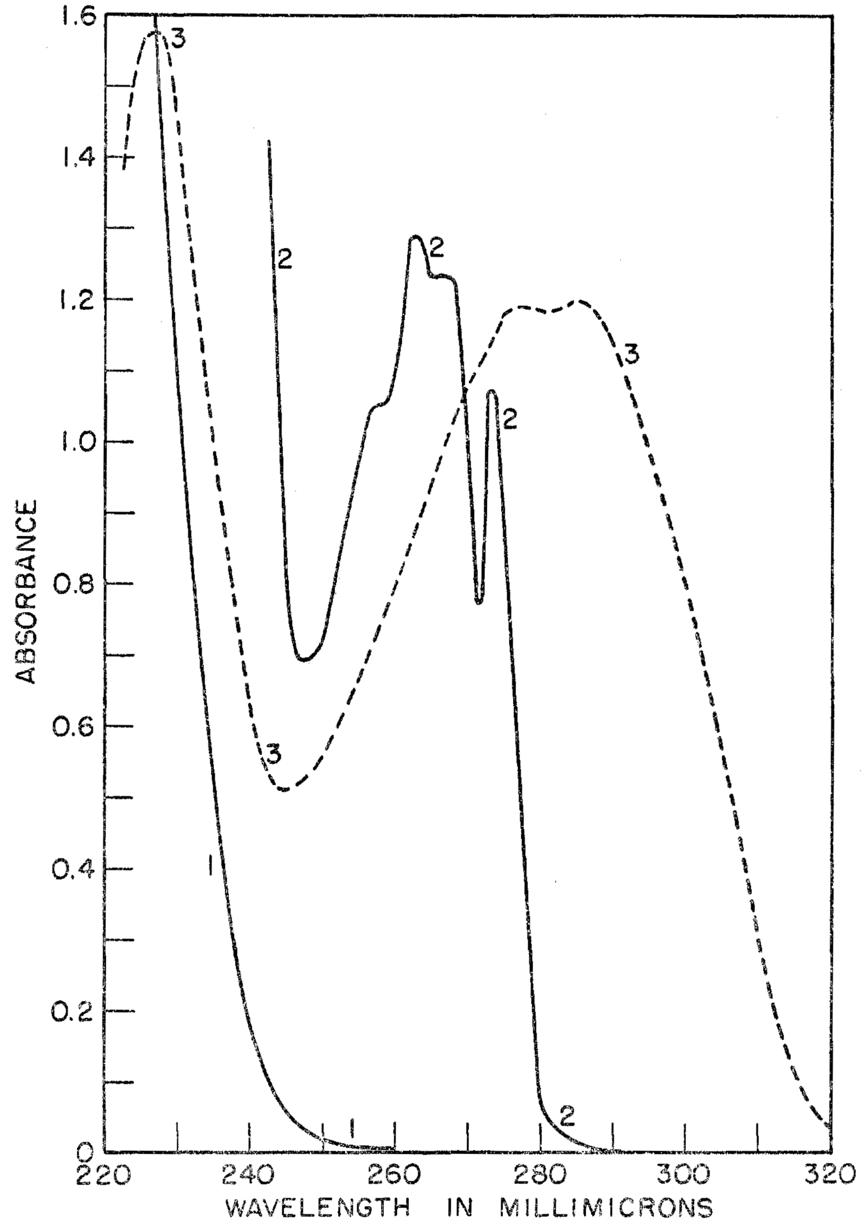

FIG. 2. ULTRAVIOLET ABSORPTION SPECTRA OF SOLUTIONS IN 95% ETHANOL. 1. 0.01 *M* Diethyl mucate. 2. 0.001 *M* Diethyl di-O-tosylmucate. 3. 0.00005 *M* Diethyl ditosyloxydihydromuconate

Since it appeared likely that diethyl di-O-tosylmucate is first formed and then gradually transformed to III, experiment 4 was repeated, except that only *2.2 molar equivalents of p-toluenesulfonyl chloride* were employed. The final reaction solution was dark brown and *no* pyridinium chloride separated at any time. The product was isolated in the usual manner;

8.2 g. of beige crystals; m.p. 162–163°. [Elementary analysis of the crude material showed that it was devoid of chlorine and *consisted largely* of II; this was confirmed as follows: a sample (0.50 g.) was treated with 0.52 g. of sodium iodide under the standard conditions, giving some free iodine plus 0.29 g. of sodium *p*-toluenesulfonate (Calc'd for $C_{24}H_{30}O_{12}S_2$: 0.34 g.).] A sample (7.5 g.) was recrystallized from 35 vols. of boiling *benzene*, yielding crop 1; 5.8 g. of beige crystals; m.p. 168–169°. This was recrystallized from 30 vols. of benzene, affording 5.3 g. of colorless crystals (m.p. 170–171°) whose analysis agreed with that calculated for II. By reworking the mother liquors, a further 0.9 g. of pure II and 0.06 g. of pure III were obtained; thus, formation of III was diminished, but not eliminated.

Diethyl ditosyloxydihydromuconate (III). Dry, recrystallized diethyl mucate (10 g.) was dissolved in 200 ml. of dry pyridine, 31.6 g. of *p*-toluenesulfonyl chloride was added, the solution was kept at 26° for 72 hours, and the product was isolated as previously described (1), giving *X* (see experiment 4, Table I); brownish crystals; m.p. 128–130°. This was analyzed before recrystallization (to make sure that the latter treatment introduced no solvent of crystallization).

Anal. Found: C, 53.46; H, 5.1; S, 11.53, 11.72; OEt,[9] 14.94; Cl, zero. Treatment of *X* (0.50 g.) with 0.68 g. of anhydrous sodium iodide under "standard conditions" (in 5 ml. of acetone, in a sealed tube at 100° for 3 hours) gave a trace of free iodine plus 0.10 g. of sodium *p*-toluenesulfonate (Calc'd for $C_{24}H_{30}O_{12}S_2$: 0.34 g.); this indicated a content of *ca.* 30% of II. The ultraviolet absorption spectrum[6] of a 0.002705% solution of *X* in 95% ethanol is shown in Fig. 3 (curve 3). Since the absorbance at 290 mμ = 0.715, *X* was a mixture of 37% of II with 63% of III.

TABLE I

ACTION OF *p*-TOLUENESULFONYL CHLORIDE (4.4 *Molar* EQUIVALENTS) ON DIETHYL MUCATE (10 g.) IN PYRIDINE

EXPT. NO.	TIME (Hours)	TEMP. (°C.)	PYRIDINIUM CHLORIDE FORMED	FINAL COLOR OF SOLUTION	YIELD[a] OF CRUDE CRYSTALS (g.)	ONCE RECRYSTALLIZED FROM ABSOLUTE ETHANOL		
						Ethanol used (Vols.)	Yield (g.)	M. P. (°C.)
1	2	0	None	Pale yellow	7.0	10	4.4	170–171
2	24	5	Small amount	Yellow	17.8	10	12.8	158[b]
3	48	5	Fair amount	Yellow	18.5–21.1[c]	10	13.6[d]	153–154[b]
4	72	26	Trace	Dark brown	15[e]	12	11.2	132–134

[a] Theoretical yields: for diethyl tetra-O-tosylmucate, 33.16; for II, 21.58; for III, 20.30 g. [b] Softening at 133°. [c] Range, in 18 repetitions. [d] Product referred to as "*M*"; its infrared absorption spectrum[6] is given in Fig. 1 (curve G). [e] Product referred to as "*X*"

Recrystallization of *X* from benzene (10 vols.) permitted separation and afforded samples of pure III (and pure II). *X* (15 g.) thus gave crop 1; 4.4 g. of beige crystals; m.p. 163°. [*Crop 1* was twice recrystallized from 30 vols. of boiling benzene, affording 3.6 g. of colorless crystals (m.p. 170°) whose analysis corresponded to that calculated for II.] The mother liquor of crop 1 was evaporated to dryness and the residue crystallized from absolute ethanol (15 vols.), giving crop 2; 8.4 g. of brownish crystals (m.p. 134–135°) which were then recrystallized from absolute ethanol (20 vols.), giving 7.6 g. of cream-colored crystals; m.p. 137–138°, unchanged by recrystallization from benzene (3 vols) or absolute ethanol (20 vols.). [Further crops of III (and of II) were obtained by reworking the mother liquors.] This material had $[\alpha]^{25}_{D}$ 0° (*c*, 1.01, in chloroform) and was completely soluble in 15 vols. of benzene at room temperature.

Anal. Calc'd for $C_{24}H_{28}O_{10}S_2$: C, 53.32; H, 5.2; S, 11.86; OEt, 16.67.

Found: C, 53.49; H, 5.0; S, 11.89; OEt,[9] 15.84.

The ultraviolet absorption spectrum[6] of a 0.002705% (0.00005 *M*) solution in 95% ethanol

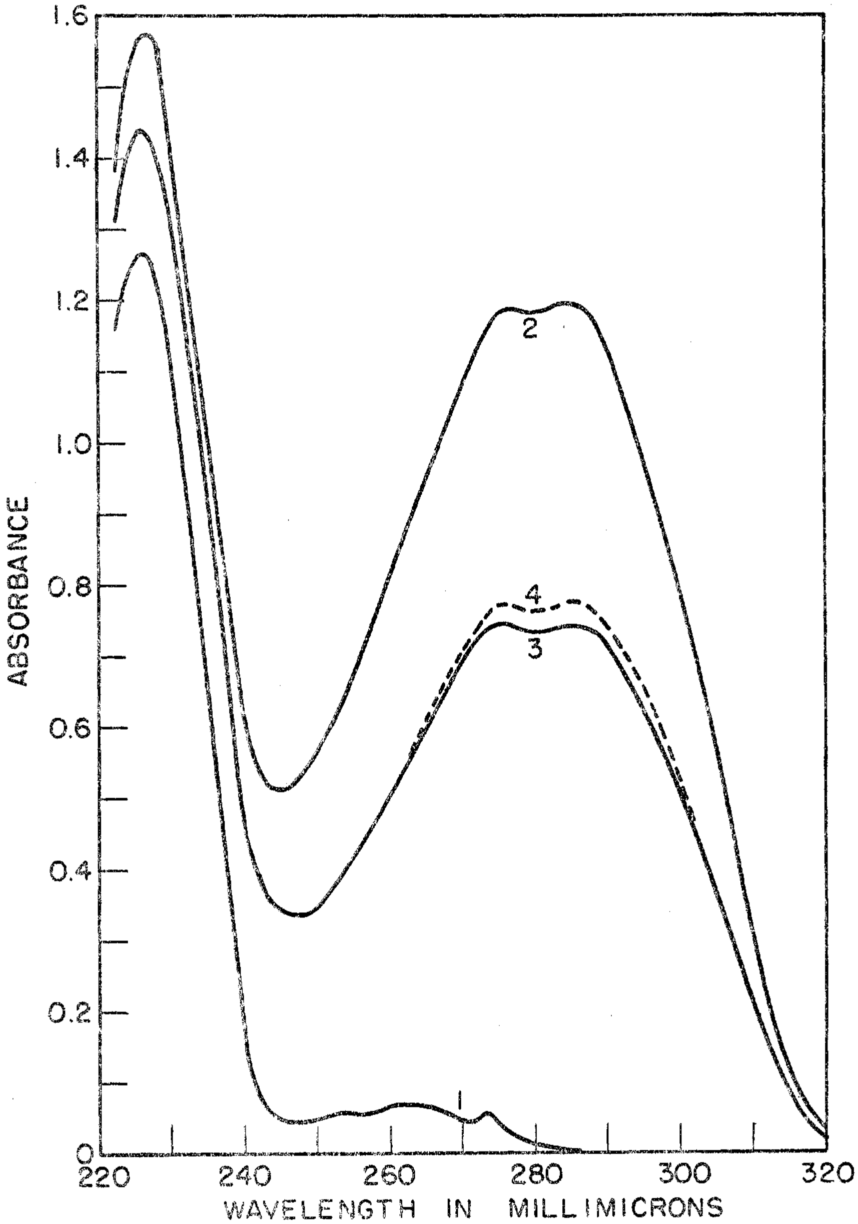

FIG. 3. ULTRAVIOLET ABSORPTION SPECTRA (of 0.002705% solutions in 95% ethanol). 1. Diethyl di-O-tosylmucate. 2. Diethyl ditosyloxydihydromuconate (0.00005 *M*). 3. Crop X (72 hours' treatment at 26°). 4. Crop X, recrystallized 3 times from absolute ethanol

is shown in Fig. 2 (curve 3). Its infrared absorption spectrum[6] is given in Fig. 1 (curve E); this showed *no evidence for the presence of OH*. Supposing that the compound contains a double bond, a *cis* orientation at the double bond is indicated by the absence of a band at

965 cm^{-1} (characteristic of a *trans* orientation) and by the presence of a band at 700 cm^{-1}. Phenyl groups are indicated by the band at 1600 cm^{-1}; $ROSO_2R'$ by the band at 1178 cm^{-1} (and, perhaps, at 1370 cm^{-1}). The C=O band (at 1710 cm^{-1}) is surprisingly low; this could be due to conjugation but is presumably occasioned by hydrogen bonding.

Under a polarizing microscope, at magnifications of 75× and 300×, at least two well-defined crystalline habits were observed[6]: (a) platelike crystals, usually in the form of parallelograms with rather variable angles and with edges ranging from straight to rounded; (b) prismatic crystals, roughly equidimensional, with welldeveloped faces. Types (a) and (b) showed inclined and parallel extinction, respectively, with plane-polarized light and crossed Nicol prisms.

TABLE II

X-Ray Powder Diagrams[6]

COMPOUND III		COMPOUND III, HYDROGENATED	
d(Å.)	I	d(Å.)	I
11.5	ms	11.8	w
9.5	m	9.5	vs
8.2	s	8.1	w
7.1	m		
6.8	mw	6.9	ms
		6.0	vw
5.7	mw	5.5	m
5.35	m		
		5.01	mw
4.75	s	4.73	s
4.32	w		
4.20	vs	4.23	vs
3.88	ms	3.98	mw
3.62	mw	3.75	ms
		3.42	m
3.30	m	3.27	mw
3.12	m	3.12	ms
2.95	w	2.99	w
2.81	w	2.88	w
2.74	w	2.77	m
2.58	w		
2.52	w	2.55	w
2.42	vw	2.48	mw
2.36	vw		
2.29	m	2.30	vw
		2.23	mw
		2.18	w
		2.00	mw

d(Å.) = interplanar spacing in Ångstrom units; I = estimated relative intensity; m = medium; s = strong; v = very; w = weak.

A sample was prepared for diffraction analysis as previously described (13); the x-ray powder diagram was obtained[6] in a Debye-Scherrer camera of 114.6-mm. diameter, using CuK$_\alpha$ radiation and an exposure of 1 hour. The resulting pattern (see Table II) was a complicated one consisting of many rather sharp lines, indicative of a well-crystallized product.

A sample (0.5 g.), treated with sodium iodide under the standard conditions, gave no sodium *p*-toluenesulfonate. There was also no formation of the latter when 2 g. of material plus 2 g. of sodium iodide in 100 ml. of acetic anhydride was boiled under reflux (Drierite tube) during 5 hours; however, similar treatment in 100 ml. of acetonylacetone during 6 hours gave 0.4 g. of sodium *p*-toluenesulfonate.

A microhydrogenation[10] (of 0.2995 g. in 30 ml. of ethyl acetate, over 0.0350 g. of Pd-$BaSO_4$ catalyst) indicated the presence of one double bond per molecule. (However, iodine absorption[10] was negligible.) To a solution of 5 g. of III in 135 ml. of ethyl acetate was added 0.1 g. of Adams' platinum catalyst, and the suspension was shaken at room temperature with hydrogen (initial pressure, 28 lb. per sq. inch) in the Burgess-Parr apparatus. After absorption of hydrogen had ceased, the suspension was filtered, and the filtrate evaporated to dryness. The residue (5 g.) was recrystallized from ethyl acetate (5 vols.); 3.8 g. of colorless crystals; m.p. 137–138°. This was recrystallized from ethanol (15 vols.); 3.6 g.; m.p. unchanged. Mixture m.p. with III, partial melt at 137–138°, complete melt at 138–139°.

Anal. Calc'd for $C_{24}H_{30}O_{10}S_2$: C, 53.12; H, 5.6; S, 11.82; OEt, 16.61.
Found: C, 53.78; H, 5.0; S, 12.09; OEt,[9] 16.18.

The ultraviolet and infrared (Fig. 1, curve F) absorption spectra[6] differed but little from those of III. Under a polarizing microscope[8] at a magnification of 300 ×, the crystals were seen to be predominantly platelike with some straight but a great many curved edges. Most of the crystals were of but one species. There was no welldefined extinction direction with respect to important edges. The x-ray powder diagram[6] *differed greatly* from that of the unhydrogenated material (see Table II) and indicated well-crystallized material. [Under similar conditions of hydrogenation, treatment of II (3.7 g.) in ethyl acetate (150 ml.) resulted in no absorption of hydrogen, and a quantitative yield of unchanged starting material was recovered. This indicated that the tosyl and carbethoxy groups remain unaffected.]

TABLE III

Action of *p*-Toluenesulfonyl Chloride on Diethyl Mucate (10 g.) in Pyridine-Benzene

EXPT. NO.	MOLAR PROPORTIONS OF SULFONYL CHLORIDE	PYRIDINE (ml.)	BENZENE (ml.)	TIME (hrs.)	TEMP.	YIELD OF PYRIDINIUM CHLORIDE (g.)	YIELD OF CRUDE CRYSTALS (g.)	YIELD OF PURE II (g.)	YIELD OF PURE III (g.)	YIELD OF IV (g.)
5	4.4	200	300	43.5[a]	26°C.	4.8	14.0	6.4	—[b]	—[b]
6	8.8	200	350	72[a]	26°C.	8.6	20.0	9.8	1.2	—[b]
7	2	120	125	108[c]	72°F.	5.0	16.5	6.3	0	4.1
8	1	100	100	48[d]	72°F.	0.2	8.5[e]	0	0	6.3

[a] Final color of solution: brown. [b] Not determined. [c] Final color: black. [d] Final color: green. [e] Pale-brown gum.

Tosylation of diethyl mucate in pyridine-benzene. With the object of determining if, in the tosylation of diethyl mucate, formation of III could be kept to a minimum by lowering the proportion, and suppressing the ionization, of dissolved pyridinium chloride, the effect of adding benzene (14) to the initial reaction solution was studied. The proportion of III then resulting was considerably diminished, but its formation was not necessarily eliminated. The results of employing various molar porportions of *p*-toluenesulfonyl chloride are given in Table III. In *experiment 7*, treatment of the crude product (16.5 g.) with benzene (30 vols.) gave 6.3 g. of crystalline II and 4.1 g. of crystals (IV) having m.p. 102–103°. Twice recrystallized from 30 vols. of benzene, the m.p. of the latter was unchanged. It was soluble in 6 vols. of ethanol at room temperature, devoid of nitrogen and chlorine, and had

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[10] Kindly performed by Dr. Bernard F. Daubert, then at the University of Pittsburgh.

an elementary analysis close to that calculated for a diethyl mono-O-tosylmucate; its ultraviolet and infrared absorption spectra differed from those of II. In *experiment 8*, the resulting pale-brown gum (8.5 g.), treated with 3 vols. of benzene, afforded 6.3 g. of colorless crystals; m.p. 102–103°. Recrystallized from 30 vols. of benzene, the m.p. was unchanged. The elementary analysis and ultraviolet and infrared absorption spectra were almost identical with those of IV described above.

Diethyl di-O-tosylmucate (II). Dry, recrystallized I (10 g.) was dissolved in 200 ml. of dry pyridine at room temperature, 63.2 g. (8.8 molar equivalents) of *p*-toluenesulfonyl chloride (see expt. 6, Table III) was added in one portion, and the flask was closed with a rubber stopper through which a thermometer was inserted. The suspension was swirled until all the sulfonyl chloride had dissolved (3 minutes), and then 350 ml. of dry, redistilled benzene was added. After 72 hours at 26°, the pyridinium chloride which had crystallized out was filtered off, washed with three 25-ml. portions of benzene, and dried; wt., 8.6 g. The brown filtrate was cooled in ice-salt to −1°, and then water (20 ml.) was added in portions in the usual way (1), followed by 600 ml. of water. This gave two layers which were transferred to a separatory-funnel, together with the benzene washings of the pyridinium chloride, and shaken. The aqueous pyridine layer was re-extracted with two 400-ml. portions of chloroform, and the combined chloroform-benzene extracts were chilled, washed successively with ice-cold 5 *N* hydrochloric acid and distilled water, dried with sodium sulfate, and evaporated to dryness under diminished pressure at 35°, yielding 20 g. of brown crystals. This material was twice recrystallized from boiling benzene (12 vols. and then 30 vols.), affording 9.8 g. of II as colorless crystals; m.p. 170–171°. (The first mother liquor gave 1.2 g. of III).

Anal. Calc'd for $C_{24}H_{30}O_{12}S_2$: C, 50.16; H, 5.3; S, 11.16; OEt, 15.68.
Found: C, 50.35; H, 5.3; S, 11.10; OEt,[9] 15.29.

The ultraviolet absorption spectrum[6] of a 0.0575% (0.001 *M*) solution in 95% ethanol is shown in Fig. 2 (curve 2). Its infrared absorption spectrum[6] is given in Fig. 1 (curve C). That the compound has free hydroxyl groups is shown by the band at 3440 cm^{-1}. The C=O frequency at 1740 cm^{-1} is in the normal range for a carboxylic ester. Phenyl is indicated by the band at 1600 cm^{-1}, and $ROSO_2R'$ by those at 1350 and 1172 cm^{-1}.

Treatment of II (0.5 g.) with 0.68 g. of dry *sodium iodide* under the standard conditions gave free iodine plus 0.32 g. of sodium *p*-toluenesulfonate (Calc'd for $C_{24}H_{30}O_{12}S_2$: 0.34 g.); the reaction even proceeded slowly at room temperature. Boiled gently under reflux (Drierite tube) during 4 hours, a solution of 5 g. of II plus 5.2 g. of sodium iodide in (a) 50 ml. of acetone, afforded 1.4 g. of sodium *p*-toluenesulfonate; (b) 150 ml. of acetic anhydride, gave 1.7 g. of sodium *p*-toluenesulonate (plus 0.1 g. of crystalline diethyl di-O-acetyldi-O-tosylmucate, by pouring onto 300 ml. of ice).

Acetylation of dry, recrystallized II (5 g.) with 25 ml. of acetic anhydride in 100 ml. of dry pyridine during 18 hours at room temperature, followed by pouring onto 300 ml. of chopped ice and neutralization of free acid with sodium bicarbonate, gave colorless crystals. These were filtered off, washed with water, and dried; wt., 5.6 g.; m.p. 200° (decomp.). It was recrystallized from boiling acetone (250 vols.); wt., 4.8 g.; m.p. 202° (decomp.).

Anal. Calc'd for $C_{28}H_{34}O_{14}S_2$: C, 51.05; H, 5.2; S, 9.73; OEt, 13.68.
Found: C, 51.27; H, 5.4; S, 9.90; OEt, [9] 11.91.

Its infrared absorption spectrum[6] is recorded in Fig. 1 (curve D). Diethyl di-O-acetyldi-O-tosylmucate exhibits no band due to OH stretching (at 3440 cm^{-1}), whereas diethyl di-O-tosylmucate shows this band. Furthermore, the latter compound displays only one carbonyl stretching frequency (at 1740 cm^{-1}), but its diacetate has two (at 1760 and 1725 cm^{-1}).

Re-tosylation experiments. On treating diethyl di-O-tosylmucate with pyridinium chloride in pyridine (72 hours at 26°), a quantitative yield of unchanged starting material was recovered; and *p*-toluenesulfonyl chloride (2 moles) in pyridine-benzene solution afforded 70% of unchanged material. However, in pyridine alone, considerable conversion to III occurred; this behavior could be employed for obtaining III from mixtures of II and III. For example, a three-times recrystallized mixture *N* (expt. 3; 60 g.; m.p. 154–155°) was dissolved in 600 ml. of dry pyridine, 43.8 g. of *p*-toluenesulfonyl chloride was added, and the solution was kept (stoppered) at 26° for 72 hours. No pyridinium chloride had crystallized out, but the solution was now dark-brown in color; it was cooled to 0° and the product isolated as usual; beige crystals; wt., 50 g.; m.p. 129–131°. This material was recrystallized from boiling benzene (10 vols.) giving crop 1 (9.4 g. of colorless crystals; m.p. 164–165°) which, recrystallized from benzene (30 vols.), gave 8.3 g. of colorless crystals; m.p. 170–171° (II). The mother liquor of crop 1, evaporated to dryness and the residue crystallized from absolute ethanol (15 vols.), gave crop 2; 35 g. of beige crystals; m.p. 137–138°, unchanged by recrystallization from benzene, ethanol, or ethyl acetate. Its ultraviolet and infrared absorption spectra[6] agreed with those for III.

Behavior of mixture N towards sodium iodide in acetone; purification of Compound III. A mixture of 10 g. of *N* with 13.6 g. of dry sodium iodide was dissolved in 100 ml. of acetone, and the colorless solution was heated in a sealed tube at 100° during 3 hours. The solution turned dark-brown in color, and colorless, flaky crystals separated out. After cooling, the crystals were filtered off, washed with acetone, and dried at 60°; wt. 4.9–5.4 g. (range, in 13 repetitions); completely soluble in water. The acetone filtrate and washings were combined and evaporated to dryness. The dark-brown crystalline mass was dissolved in a mixture of chloroform and water, and sodium thiosulfate solution was added until, on shaking, the color of the free iodine disappeared. The chloroform solution was washed with water, dried with sodium sulfate, filtered, and the clear, brown filtrate evaporated to dryness, giving 4–4.5 g. of brown gum, containing crystals. A sample (17.1 g.) of this gummy product (from 4 such experiments) was dissolved in 6 vols. of boiling absolute ethanol and the solution was cooled, yielding 8.9 g. of tan crystals; m.p. 134–136°. A sample (8.4 g.) of this material, twice recrystallized from 15 vols. of absolute ethanol gave 6.4 g. of colorless crystals; m.p. 136–137°. Recrystallized from 20 vols. of ethanol, this gave 6.3 g. of colorless crystals; m.p. 137–138°. Its analysis corresponded to that calculated for III; it was devoid of iodine.

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SUMMARY

1. A simple method is described for the preparation of diethyl mucate in high yield.

2. Treatment of diethyl mucate with *p*-toluenesulfonyl chloride in dry pyridine at various temperatures (for various times) gives rise to crystalline mixtures of a diethyl di-O-tosylmucate with a diethyl ditosyloxydihydromuconate. Methods for the separation of these compounds have been devised, and some of their properties are described. On the basis of their respective behavior towards sodium iodide in acetone, and other properties, structures for the two compounds are tentatively proposed.

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