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SUCROSE HYDROGEN PHTHALATES AND HYDROGEN SUCCINATES

ANN PARKIN AND ROBERT C. POLLER
Department of Chemistry, Queen Elizabeth College, Campden Hill Road, London W8 7AH (Great Britain)

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ABSTRACT

Sucrose hydrogen phthalates and hydrogen succinates have been prepared by reaction of sucrose and the appropriate anhydride. The nature of the mixed products obtained has been examined by a number of techniques, and the products have been used to obtain organometallic derivatives of sucrose.

INTRODUCTION

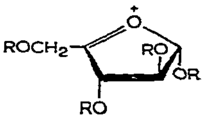
Although phthalic and succinic half-esters of sucrose[1] have been used in the preparation of organotin derivatives of sucrose, the biocidal properties of which are reported elsewhere[2], there is no information on their composition and structure. We now report on the constitution of half-ester derivatives formed by treating sucrose with 3 mol. of phthalic or succinic anhydride in *N*,*N*-dimethylformamide at 60° for 5 h.

The overall composition of the respective, crude reaction products (**1** and **4**), determined by titration of the free acid functions and by elemental analysis, corresponded to monosubstitution. Chemical analysis of **1** and **4** was complicated by the base-lability of the ester linkage. Attempts to tritylate the free primary hydroxyl groups or to fully methylate **1** and **4** (methyl iodide–silver oxide) resulted in ester migration. However, acetylation of **1** and **4** resulted in products of various d.s. which could be separated by chromatography. Thus, **1** gave sucrose octa-acetate (41 %) and sucrose hydrogen phthalates containing seven (**2**, 35 %) and six (**3**, 23 %) acetyl groups, together with 1 % of a product assumed to be a tri(hydrogen phthalate)-penta-acetate. Likewise, acetylation of **4** gave sucrose octa-acetate (25 %) and sucrose hydrogen succinates containing seven (**5**, 43 %), six (**6**, 31 %), and, presumably, five (1 %) acetyl groups. Confirmation of the compositions of **2**, **3**, **5**, and **6** was obtained by electron-impact (70 eV) mass spectrometry of the products obtained by methylation with diazomethane.

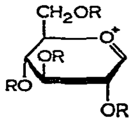
The methylated derivative of **2** gave ions at *m/e* 451 [corresponding to $C_6H_7O_5(OAc)_3(COC_6H_4COOMe)^+$] and 331 (**7** or **8**). In addition to these ions, the methylated derivative of **3** gave an ion at *m/e* 571 [corresponding to $C_6H_7O_5(OAc)_3(COC_6H_4COOMe)_2^{+}$]. These data indicated a mixture of products in which some molecules contained two phthalate groups on one ring (glucose or fructose) (*m/e* 571 and 331), and others contained one phthalate group on each ring (*m/e* 451).

Similarly, **5** was shown to be a monosuccinate by the presence of ions at *m/e* 403 [corresponding to $C_6H_7O_5(OAc)_3(COCH_2CH_2COOMe)^+$] and 331 (**7** or **8**) in the mass spectrum of the methylated product. The additional ion at *m/e* 475 [corresponding to $C_6H_7O_5(OAc)_2(COCH_2CH_2COOMe)_2^{+}$] produced by the methylated derivative of **6** was indicative of a disuccinate.

Trimethylsilylation of the phthalate **1** followed by g.l.c. revealed, in addition to octa-*O*-(trimethylsilyl)sucrose, four phthaloylated components (see Experimental) comprising ~60% of the total peak area. The mass spectrum of each of these phthaloylated components showed ions at *m/e* 599 [corresponding to $C_6H_7O_5(SiMe)_3(COC_6H_4COOSiMe_3)^+$] and 451 [corresponding to $C_6H_7O_5(SiMe_3)_4^{+}$].



7 R = Ac



8 R = Ac

Similarly, trimethylsilylation of the succinate **4** followed by g.l.c. gave a series of overlapping peaks of retention time longer than that of octa-*O*-(trimethylsilyl)-sucrose, and corresponding to ~70% of the total peak area. The mass spectrum of each of these peaks showed ions at *m/e* 551 [corresponding to $C_6H_7O_5(SiMe_3)_3(COCH_2CH_2COOSiMe_3)^+$] and 451.

The acetylation and trimethylsilylation data indicate the d.s. of the components of the mixtures of half esters, but do not indicate the position of substitution other than that, for the disubstituted derivatives, isomers exist with two substituents on one ring, and one substituent on each ring.

^{13}C-N.m.r. spectroscopy was used to investigate the positions of substitution in the crude half-ester mixtures **1** and **4**. The spectrum of the phthalate mixture **1** (see Experimental), in which free sucrose is known to be present, shows a distinct set of resonances from carbon atoms that are deshielded compared with those from the carbon atoms in sucrose. The complexity of the spectrum prevents complete analysis, but certain features in the higher field range provide useful information.

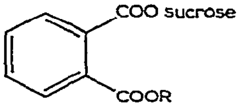
In the phthaloylated molecule, C-6 and C-6′ are deshielded by −3.2 and −2.5 p.p.m., respectively, compared to the corresponding carbons in sucrose, and indicate acylation at these positions. Also, C-6 is weakly deshielded (−0.6 p.p.m.), corresponding to a long-range effect due to the 4-substituent. Similarly, C-4 is deshielded (−0.4 p.p.m.) due to the 6-substituent. The signal for C-4 carrying a substituent is probably obscured by the resonance for C-2 in free sucrose, a slight shoulder being apparent (deshielded by ~ −3.4 p.p.m. compared to C-4 in sucrose).

Acylation of an alcohol usually causes shielding of the carbon adjacent to the alcohol function[3], and this appears to be the case for C-5 (+3.4 p.p.m.) and C-5′ (+2.7 p.p.m.). The complexity of the spectrum makes further analysis difficult, but from the data it seems reasonable to postulate substitution at positions 4, 6, and 6′.

This would be consistent with general substitution patterns in sucrose chemistry[4] as far as positions 6 and 6′ are concerned, but substitution at position 4 is less common.

The ^{13}C-n.m.r. spectrum of the succinate mixture **4** showed very few differences from that of sucrose. Apparently, the electronic effect of the aromatic groups in the phthalates is the main factor in increasing the deshielding effect of the carbonyl sufficiently to allow the substituted carbons to be identified. This view is supported by the fact that, in sucrose octabenzoate, C-6, C-6′, and C-1′ resonate, respectively, at 62.5, 64.3, and 64.9 p.p.m. downfield from the signal for Me_4Si, whereas, in sucrose octa-acetate, they appear at 61.8, 62.8, and 63.6 p.p.m., respectively.

The mixed half-esters **1** and **4** of sucrose have been used to prepare a number of organotin derivatives[2], and they provide a very simple route to other organometallic derivatives. Organolead (**9**) and organogermanium (**10**) derivatives have been prepared by the reaction of **1** with Ph_3PbOH and $(Bu_3Ge)_2O$.



9 R = Ph_3Pb
10 R = Bu_3Ge

The i.r. spectra of these organometallic derivatives (sucrose-$OCOC_6H_4COOR$) show two characteristic carbonyl absorptions, the lower of which shifts to lower frequency as the metal becomes more electropositive: R = Bu_3Ge, 1720 and 1680 cm^{-1}; R = Ph_3Sn, 1730 and 1640 cm^{-1}; R = Ph_3Pb, 1720, 1570, and 1540 cm^{-1}.

EXPERIMENTAL

Sucrose hydrogen phthalates (**1**). — A mixture of solutions of sucrose (34.2 g, 0.1 mol) in dry *N*,*N*-dimethylformamide (110 ml) and phthalic anhydride (44.4 g, 0.3 mol) in *N*,*N*-dimethylformamide (90 ml) was stirred at 60° for 5 h under anhydrous conditions. The solvent (75%) was removed under reduced pressure to produce, after precipitation and washing with chloroform, **1** (36.0 g, 73%) (Found: C, 46.9; H, 5.5; equiv. wt. 488.5. $C_{20}H_{26}O_{14}$ calc.: C, 49.0; H, 5.3%; equiv. wt. 490). Details of ^{13}C-n.m.r. spectrum over the region of sucrose carbon resonances, *i.e.*, 60 p.p.m. to 10 p.p.m. downfield from DSS (s = strong absorption, m = medium, and w = weak; * denotes carbon of unsubstituted sucrose molecule): 62.8* m, 63.4 m, 64.1* m, 65.0* m, 66.0 m, 66.6 m, 70.3 m, 71.9* s, 72.3 s, 73.7* s, 74.1 m, 75.0* s, 75.2* s, 76.8* s, 77.2 m, 78.4 m, 78.6 m, 79.2* s, 84.0* s, 94.8* s, 98.6 m, 100.7 w, 106.3* m, and 106.6 m.

Acetylation of **1**. — Acetic anhydride (103 ml) was added to a solution of **1** (11 g) in pyridine (100 ml), and the mixture was stirred at room temperature for 24 h, poured into ice–water, and extracted with chloroform. The dried ($MgSO_4$) extract was concentrated, and pyridine was removed by azeotropic distillation with toluene, the last traces being removed by shaking with aqueous cadmium chloride.

A portion (9 g) of the residual syrup (17.9 g) was eluted from a column of silica gel (400 g), initially with chloroform and then with chloroform–methanol (20:1, 10:1, and 5:1), to give sucrose octa-acetate (2.28 g), followed by monophthaloylated hepta-acetates (**2**, 1.95 g) (Found: C, 52.15; H, 4.8. $C_{34}H_{40}O_{21}$ calc.: C, 52.05; H, 5.1%), diphthaloylated hexa-acetates (**3**, 1.28 g) (Found: C, 54.4; H, 4.5. $C_{40}H_{42}O_{23}$ calc.: C, 53.9; H, 4.75%), and a slower-moving component (0.02 g).

Treatment of **2** (0.116 g, 0.15 mmol) with excess of diazomethane in ether gave the methylated derivatives (0.11 g, 93%) (Found: C, 52.35; H. 5.3. $C_{35}H_{42}O_{21}$ calc.: C, 52.6; H, 5.3%).

The methylated derivative (87%) of **3** was similarly obtained by using diazomethane in dichloromethane–ether (Found: C, 52.0; H, 6.2. $C_{42}H_{46}O_{23}$ calc.: C, 54.9; H, 5.0%. The unsatisfactory analyses obtained for this compound and for the corresponding derivative of the succinate **5** appear to result from incomplete combustion; each compound had a high ash content.

Sucrose hydrogen succinates (**4**). — Using the conditions described for the preparation of **1**, sucrose (34.2 g, 0.1 mol) in dry *N*,*N*-dimethylformamide (110 ml) was treated with succinic anhydride (30 g, 0.3 mol) in dry *N*,*N*-dimethylformamide (90 ml), to give crude **4** (33.7 g, 76%) (Found: C, 43.6; H, 5.9; equiv. wt., 413. $C_{16}H_{26}O_{14}$ calc.: C, 43.4; H, 5.9%; equiv. wt., 442).

Acetylation of **4**. — Acetic anhydride (55 ml) was added to a solution of **4** (5.3 g) in pyridine (60 ml), and the mixture was stirred at room temperature for 48 h and then worked-up as described for **1**. The syrupy product (7.9 g) was eluted from a column of silica gel (300 g) with chloroform, followed by chloroform–methanol (20:1, 10:1, and 5:1), to give sucrose octa-acetate (1.2 g), followed by monosuccinate hepta-acetates (**5**, 2.1 g) (Found: C, 49.1; H, 5.4. $C_{30}H_{40}O_{21}$ calc.: C, 48.9; H, 5.5%), disuccinate hexa-acetates (**6**, 1.5 g) (Found: C, 48.6; H, 5.0. $C_{32}H_{42}O_{23}$ calc.: C, 48.4; H, 5.3%), and a slower-moving component (0.05 g).

Treatment of **5** with excess of diazomethane in ether produced the methylated derivative (98%) (Found: C, 49.5; H, 5.6. $C_{31}H_{42}O_{21}$ calc.: C, 49.6; H, 5.6%). Similar treatment of **6** gave the methylated derivative (82%) (Found: C, 46.0; H, 5.3. $C_{34}H_{36}O_{23}$ calc.: C, 49.6; H, 5.6%. See note above concerning the analysis of the methylated derivative of **3**).

Trimethylsilylation reactions. — Solutions (0.5 ml) of samples (5–10 mg) of the sucrose phthalates (**1**) and succinates (**4**) in pyridine (0.5 ml) were treated with hexamethyldisilazane (0.1 ml) with gentle warming for 5 min, followed by chlorotrimethylsilane (0.05 ml) and gentle warming for a further 5 min. The product mixtures were subjected to g.l.c. at 240° on a Pye model 104 gas chromatograph equipped with F.I.D. and a glass column (5 ft) packed with Diatomite C-AW HMDS (100–120 mesh) coated with 1% of OV 101; the nitrogen flow-rate was 30 ml/min.

The product from **1** contained octa-*O*-(trimethylsilyl)sucrose (40%; *T* 4.5 min) and four trimethylsilylated phthalates (*T*, 27, 34, 36.5, and 42 min; 60% of total silylated product).

The product from **4** contained octa-*O*-(trimethylsilyl)sucrose (30%; *T*, 4.5 min) and several overlapping peaks for trimethylsilylated succinates (*T*, 12–19 min; 70% of total silylated product).

Organometallic derivatives. — (*a*) To a solution of triphenyl-lead hydroxide (0.31 g) in AR chloroform (10 ml) was added sucrose phthalate **1** (0.35 g), and the mixture was stirred at 50° for 30 min, centrifuged, and concentrated to give the triphenyl-lead derivative **9** (0.54 g, 86%) (Found: C. 49.35; H, 4.4. $C_{38}H_{40}O_{14}Pb$ calc.: C, 49.2; H, 4.3%).

(*b*) In a manner similar to that in (*a*), triphenyl-lead hydroxide (0.32 g) was reacted with sucrose succinate **4** (0.42 g) to produce the triphenyl-lead derivative (0.50 g, 82%) (Found: C, 46.8; H, 4.1. $C_{34}H_{40}O_{14}Pb$ calc.: C, 46.4; H, 4.6%).

(*c*) Tributylgermanium oxide (0.27 g) and sucrose phthalate **1** (0.7 g) were heated at 100° for 6 h in the presence of molecular sieves (Linde Type 4A). Charring occurred and the sticky material was extracted with boiling, dry ether. The extract was centrifuged and concentrated to give the tributylgermanium derivative **10** as an oil (0.31 g, 40%) (Found: C, 52.8; H, 8.1. $C_{32}H_{52}GeO_{14}$ calc.: C, 52.4; H, 7.15%).

ACKNOWLEDGMENT

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REFERENCES

1 V. Kollonitsch, *Sucrose Chemicals*, International Sugar Research Foundation Inc, Bethesda, 1970, p. 89.

2 A. Parkin and R. C. Poller, *Int. Pest Control*, 19 (1977) 5–7.

3 E. Breitmaier and W. Voelter, *^{13}C NMR Spectroscopy*, Verlag Chemie, Weinheim, 1974, pp 141–143; J. B. Stothers, *Carbon-13 NMR Spectroscopy*, Academic Press, New York, 1972, pp. 140–141; M. Christl, H. J. Reich, and J. D. Roberts, *J. Am. Chem. Soc.*, 93 (1971) 3463–3468.

4 A. H. Haines, *Adv. Carbohydr. Chem. Biochem.*, 33 (1976) 11–109.