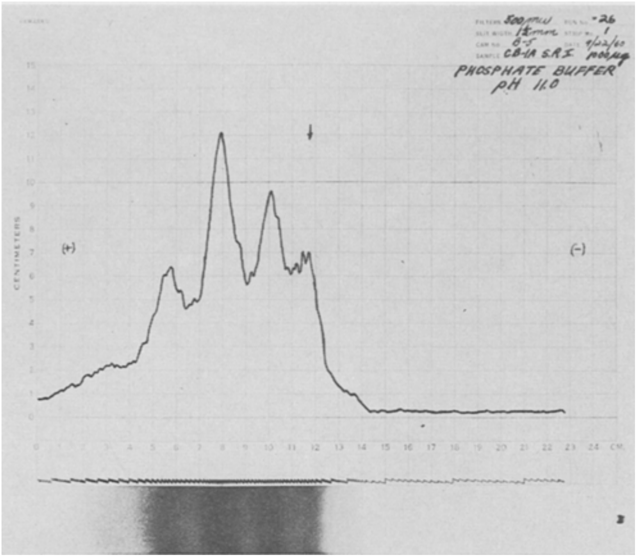


FIG. 11. Electrophoretogram of crude castor seed protein in phosphate buffer at pH 11.0 and ionic strength 0.048.

Spies and coworkers (6) designed their purification procedure on the premise that the castor seed allergen was a basic protein that was combined ionically in various proportions with polysaccharidic carbohydrate. Their stated objective was to free the specific allergenic protein from the acidic polysaccharide in order to determine the role of the polysaccharide moiety. At completion of their electrophoretic purification they combined the contents of the four cells on the cathodic side of the six-cell electrophoresis train in order to to recover the protein relatively free of the acidic component in the anode cells. In this step of the procedure no attempt was made to determine whether or not protein fractionation had occurred.

Electrophoretic procedures used by the authors of this paper utilized different buffers with several different pH values and ionic strengths, hence would be expected to reveal any existing electrophoretic heterogeneity. The banded structure in the strip electrophoretograms was clearly visible, little or nothing was lost, and each and every band was easily available for isolation and immunological testing of the protein.

Each band of the electrophoretograms of CB-1C E.U. and CB-1A S.R.I. ran at pH 7.4, and at pH 8.0 ($\mu = 0.05$) was tested for antigenicity in passively sensitized guinea pigs as described. Each and every band elicited a positive reaction in the passive cutaneous anaphylaxis test. This indicated that all of the dye-binding bands contained antigen.

Similar tests were run on Philippine monkeys passively sensitized with serum from castor bean-allergic humans; these tests indicated that at least five distinct allergenic specificities were affecting allergic humans.

The biological testing techniques used for human allergic sera and the evidence of resolution of the protein into immunologically specific allergenic components will be discussed in separate papers (9,10).

REFERENCES

1. Layton, L.L., Moss, L.K., and DeEds, F., Federation Proc., *19*, No. 1, A-195 (1960).
2. Layton, L.L., Moss, L.K., and DeEds, F., J. Am. Oil Chemists' Soc., *38*, 76–80 (1961).
3. Coulson, E.J., J. Allergy, *24*, No. 5, 458 (1953).
4. Spies, J.R., and Coulson, E.J., J. Am. Chem. Soc., *65*, 1720 (1943).
5. Spies, J.R., Coulson, E.J., Chambers, D.C., Bernton, H.S., Stevens, H., and Shimp, J.H., J. Am. Chem. Soc., *73*, 3995 (1951).
6. Spies, J.R., Coulson, E.J., Chambers, D.C., Bernton, H.S., and Stevens, H., J. Am. Chem. Soc., *66*, 748 (1944).
7. Coulson, E.J., Spies, J.R., Stevens, H., and Shimp, J.H., J. Allergy, *21*, No. 1, 34 (1950).
8. Layton, L.L., and DeEds, F., to be published.
9. Layton, L.L. Lee, S., Dante, B.T., and DeEds, F., to be published.
10. Layton, L.L., Lee, S., and DeEds, F., Federation Proc., *20*, No. 1, Part 1, 17 (1961).

[Received February 13, 1961]

Sucrose Ether- and Ester-Linked Surfactants

**V.R. GAERTNER, Research Department, Research and Engineering Division,
Monsanto Chemical Company, Dayton, Ohio**

Several effective nonionic surface-active agents in which a single sucrose moiety is the only solubilizing group were described. Alkylsucroses, prepared *via* sodium sucrate in dimethyl sulfoxide (DMSO) and higher alkyl bromides, are believed to be the first sugar-based surfactants which are at least equivalent to the best anionics and nonionics in cloth detergency on the basis of laboratory data; they were also active lime-soap dispersants. Another ether-linked type, the (3-alkoxy-2-hydroxypropyl) and (2-hydroxyalkyl) sucroses, derived from glycidyl ethers or olefin oxides, although second in detergency to the first type, included exceptional nonionic lathering agents. t-Dodecylbenzylsucrose, from dodecylbenzyl chloride, was also a rather active detergent and lime-soap dispersant. Less active but easily prepared sucrose half-esters from alkenylsuccinic anhydrides were described.

One sucrose moiety in ether-linked surfactants was an effective hydrophile for alkyl hydrophobes at least as large as hexadecyl, but tridecyl derivatives were superior in activity.

Major importance was attached to the choice of solvent, catalyst, and time/temperature factors. Evidence was presented to show that sucrose derivatives were partially degraded by the alkaline conditions required in this work and that this degradation was both detrimental to detergency and initially beneficial to lather in specific cases.

An improved procedure involving the use of DMSO for the alkaline dehydrochlorination of higher alkoxychloropropanols to glycidyl ethers was described.

MANY SURFACE-ACTIVE DERIVATIVES of sucrose and other sugars or sugar derivatives have been described in the literature. These may be divided broadly into two types: simple, in which the saccharide is the only solubilizer, and mixed or complex, which contain additional hydrophilic groups in addition to the carbohydrate. No attempt will be made to summarize this voluminous detail. An excellent recent review (3) has included this field within the broader one of long-chain derivatives of mono- and oligosaccharides.

Among all of these varied products, only simple sucrose mono-esters of fatty acids (17) have received widespread attention as surfactants. These compounds have utility in several applications (11.18,20), but their use is considerably limited by low aqueous solubility (3).

The current commercial status of these products was also summarized recently (22). A very recent study (13) has concerned the solubilization of diesters of sucrose by multiple additions of ethylene oxide, an example of a complex type.

It has been concluded as the result of an extensive review that "in order that a fatty derivative of a carbohydrate be sufficiently water-soluble to be an effective surface-active agent in aqueous media, it appears to be necessary either for at least two separate carbohydrate groups to be present or to increase the solubility of a compound which contains only a single carbohydrate moiety by the introduction of (other) solubilizing groups" (3). Although some workers may wish further qualification of this conclusion, it seems correct to state that no sugar-based surfactant either simple or complex, has yet been described which approaches the best commercial anionic and nonionic products in important functional properties, such as cloth detergency, lather, wetting, solubility, and the like.

However there are attractive potential advantages which might be expected for sucrose as a solubilizing group for surfactants in addition to the fact that sugar is among the cheapest of raw materials. Sucrose as a polyhydroxy compound should not be as subject to salting-out of solution by inorganic salts, such as the alkali phosphates, sulfates, etc., used in "built" detergent compositions, as are the nonionic polyether surfactants or the ionic sulfonates and sulfates. The nonionics also exhibit inverse solubility, that is, insolubility above a cloud-point temperature caused by reversal of hydration of ether linkages, an effect not as likely with sucrose even in concentrated solutions. These considerations led to the expectation that sucrose surfactants would be especially effective for heavy-duty liquid formulations if soluble, highly-active detergents could be prepared. For reasons of cost, etc., secondary or complex solubilization of sucrose surfactants was excluded.

In this laboratory several approaches to the use of sucrose as the solubilizer in a practicable, general-purpose surfactant have been investigated. One of these (9) involved the preparation of a disucrose alkenylsuccinate by transesterification of dimethyl triisobutenylsuccinate, for example, with at least two equivalents of sucrose. Although this type had exceptional aqueous solubility, it did not qualify as a practical, general-purpose surfactant.

The present paper describes the preparation and properties of four classes of surface-active products in which only one sucrose moiety serves to solubilize a higher alkyl hydrophobe. Not only are these products, all of which are isomeric mixtures, water-soluble, but for some of them laboratory data are presented to show that important functional properties, notably cloth detergency and lather, are fully equivalent to those of available commercial surface-active agents. The best products are mono-ethers of sucrose, classes which have not been described previously.

Discussion

In describing these products, we shall find it desirable to consider synthetic factors and surface-active evaluation data together since they are interdependent. It should be borne in mind that structures have not been established unequivocally since no pure crystalline materials could be isolated and complete separation of these complex reaction mixtures was impractical. Structures have been inferred by analogy with known reactions and from secondary experimental evidence. The results of evaluation of the products as surface-active agents has been the deciding factor in determining the optimum synthetic procedure in every case, and within these limitations meaningful correlations have been possible.

It is considered important for good aqueous surface-activity to avoid disubstitution of sucrose by hydrophobic groups. This imposed the use of a polar solvent in which sucrose is soluble and in which the reactive hydrophobe is at least partially soluble.

Solvents for sucrose have been described in detail (14). Both dimethylformamide (DMF) and dimethyl sulfoxide (DMSO) have been used for surfactant syntheses; however the choice of catalyst and solvent may be critical for optimum yields and properties, as will be apparent for the specific classes of this paper.

Alkylsucroses. It has now been found that excellent surface-active agents can be prepared by simply etherifying sucrose with higher alkyl halides to give O-alkylsucroses. The general reaction may be summarized as follows:

$$RX + C_{12}H_{22}O_{11} \rightarrow ROC_{12}H_{21}O_{10} + HX$$

Expermentally, satisfactory conversions and products were obtained only with a new reagent, sodium sucrate in DMSO, and alkyl bromides. This reagent was prepared conveniently by the exchange reaction of sucrose with sodium methoxide, preferably as a solution in methanol, which was added to an excess (50–100%) of sucrose dissolved in DMSO at 75–85°. After removal of the methanol by vacuum distillation, the reagent solution was treated with alkyl bromide at 20–25°. Under these conditions the bromide was not completely soluble but reacted at a useful rate with efficient shaking or stirring. The process then comprised two steps:

$$C_{12}H_{22}O_{11} + CH_3ONa \xrightarrow{\text{DMSO}} C_{12}H_{21}O_{10}ONa + CH_3OH\uparrow$$

$$C_{12}H_{21}O_{10}ONa + RBr \xrightarrow{\text{DMSO}} \underset{(1)}{ROC_{12}H_{21}O_{10}} + NaBr$$

After suitable isolation and purification, the products (1) were obtained as viscous gums or brittle glasses, light to medium amber in color. They are doubtless multicomponent, isomeric mixtures since any one of the eight hydroxyls may have been etherified; and also alcohol mixtures were used in some cases to prepare the bromides. DMSO was very difficult to remove, even *in vacuo*, and long heating periods often resulted in some loss of properties. Contamination also was caused by alkaline degradation of the sugar, resulting in low carbon contents although sucrose was removed by precipitation with isopropyl alcohol. The several examples listed in Table IA were obtained in 24–62% conversions ("maximum," see Experimental) with estimated "active contents" of 73–100%; the latter data are possibly 10–20% high, based on analyses.

TABLE I

Surface-Active Properties of Sucrose Derivatives

Run	R(Z)	Detergency[a] %			Wetting[b] Draves, sec. at 0.25%	Lather,[c] cm. Ross Miles				Lime-soap dispersion[d] ml.	DuNuoy surface tension[e] dynes/cm., 0.25%
		A	B	C		A		B			
A.	Alkylsucroses: $ROC_{12}H_{21}O_{10}$										
1.	*oxo*-$C_{10}H_{21}$	22	105	54	41.4	trace		trace		80	30.4
2.	*oxo*-$C_{13}H_{27}$	138	137	141	15.6	6.4	6.0	3.8	3.9	20	33.5
3.	*oxo*-$C_{16}H_{33}$	132	132	122	......	....	....	....	....	20	......
4.	2-$(C_4H_9)C_8H_{16}$	113	116	73	......	....	....	....	....	40	......
5.	*n*-$C_{13}H_{27}$	132	141	149	58.6	9.2	7.7	7.7	7.0	60	37.8
6.	*oxo*-$C_{13}H_{27}OCH_2$—	50	137	125	......	2.0	1.0	1.7	trace	40	31.5
B.	Alkylbenzyl- and allylsucroses										
7.	*t*-$C_{12}H_{25}C_6H_4CH_2$—	113	95	120	......	....	....	....	....	40	......
8.	*t*-$C_{12}H_{25}C_6H_4CH_2$—	116	86	104	......	11.9	11.2	11.9	10.3	10	......
9.	*t*-$C_{12}H_{25}C_6H_4CH_2$—	62	70	90	180+	2.8	2.8	2.7	2.3	10	34.1
10.	*t*-$C_{18}H_{37}C_6H_4CH_2$—	33	42	38	......	Insoluble				......	Insol.
11.	$(CH_3)_3CCH_2C(CH_3)_2CH_2CH{=}CHCH_2$—	16	53	18	15.5	3.3	3.1	trace		40	30.6
C.	Alkoxyhydroxypropylsucroses, etc.: $\underset{\displaystyle OH}{\underset{\vert}{Z\overset{}{C}H}}CH_2OC_{12}H_{21}O_{10}$										
12.	*n*-$C_{10}H_{21}$	79	85	90	79.1	13.9	13.9	13.5	13.2	80	35.1
13.	*n*-$C_{14}H_{29}$-$C_{16}H_{33}$	93	112	119	180+	2.6	2.6	2.5	2.5	>80	37.3
14.	*oxo*-$C_{10}H_{21}OCH_2$	74	88	79	6.7	3.1	2.4	2.3	1.9	40	28.9
15.	*oxo*-$C_{10}H_{21}OCH_2$	37	....	....	7.4	21.4	21.4	13.1	11.7	>80	28.9
16.	2-$(C_4H_9)C_8H_{16}OCH_2$	100	94	86	7.3	11.6	11.4	6.6	6.6	40	30.9
17.	*n*-$C_{12}H_{25}OCH_2$	84	75	86	88.4	14.8	14.8	15.1	14.7	>80	......
18.	*oxo*-$C_{13}H_{27}OCH_2$	85	96	95	10.3	16.5	16.5	17.0	16.6	40	35.5
19.	*oxo*-$C_{13}H_{27}OCH_2$	129	106	113	11.6	18.7	18.7	7.0	6.8	......	31.0
20.	*oxo*-$C_{13}H_{27}OCH_2$	111	121	115	<21.0	16.5	15.4	10.8	9.8	......	34.8
21.	*oxo*-$C_{16}H_{33}OCH_2$	14	....	....	150.2	2.2	1.1	2.5	1.9	>80	......
22.	(*n*-$C_{16}H_{33}$-$C_{18}H_{37}$)OCH_2	82	87	97	180+	2.6	2.6	1.9	1.9	80	38.5
23.	Hydroabietoxymethyl	93	107	97	180+	4.3	3.7	1.9	1.2	>80	......
24.	$C_9H_{19}C_6H_4OCH_2$	51	58	47	180+	3.3	2.8	2.9	2.8	......	35.0
25.	$C_{12}H_{25}C_6H_4OCH_2$	110	102	87	180+	3.3	3.3	3.4	3.3	40	33.7
26.	*t*-$C_{12}H_{25}SCH_2$	88	77	52	11.9	11.4	11.0	5.6	5.2	40	33.0
D.	Monosucrose alkenylsuccinates: $R{-}\overset{\displaystyle CO_2H}{\overset{\vert}{C}}H{-}CH_2CO_2C_{12}H_{21}O_{10}$										
27.	$(C_3H_6)_4$—	0	106	88	35.7	4.8	4.2	4.9	4.7	>80	31.6
28.	$(C_3H_6)_4$—	83	104	91	49.5	10.6	10.6	3.3	2.9	>80	34.8
29.	$(C_3H_6)_4$—	2	72	72	47.0	....	....	....	....	......	30.6
30.	$(C_4H_8)_3$—	0	74	....	59.2	3.9	3.1	5.3	5.3	80	29.8
31.	$C_3H_6)_6$—	15	....	....	27.8	1.8	1.6	1.9	trace	>80	33.2
32.	*n*-$C_{18}H_{35}$—	34	82	76	180+	trace	trace	0	0	>80	42.0

[a] Ref. 10, pp. 94–97; 0.2% concentration of sample, 60°C. wash temperature. A, as received in 50 p.p.m. hardness water; B, "built" in 50 p.p.m. water; C, built in 300 p.p.m. water. The built composition contained 15% "active," 20% sodium tripolyphosphate, 20% tetrasodium pyrophosphate, 20% sodium carbonate, 24% "N-brand" sodium silicate, and 1% carboxymethylcellulose. The data are reported as percentages of reflectances of swatches washed identically in commercial sodium n-dodecylsulfate (Duponol WA Dry, du Pont Company). The cotton soil was described in Ref. 10, pp. 69–76.

[b] Ref. 10, pp. 40–41.

[c] Ref. 10, pp. 47–49; A, in 50 p.p.m. hardness water, at once and after 5 min.; B, in 300 p.p.m. hardness water, at once and after 5 min.

[d] Ref. 10, pp. 35–36; in most cases no attempt was made to obtain ratings below 20 ml. (excellent); however 10's were observed in few instances.

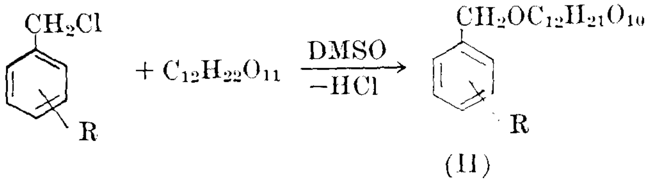
[e] Ref. 10, pp. 31–33.

The evaluation data for these products are quite conservative since test concentrations were based on 100% "active." The data indicated that *oxo-* and *n*-tridecylsucroses (Runs 2 and 5) are among the best available cloth detergents either alone or in the presence of a standard inorganic builder composition in hard or soft water. To the author's knowledge they surpass, in this respect, other sugar-based detergents. 2-Butyloctylsucrose (Run 4) was also a good detergent but failed when "built" in hard water. Branched *(oxo)* hexadecyl was somewhat less excellent as a hydrophobe than the C_{13} alkyls. Decyl *(oxo)* radicals were too small to be effective hydrophobes. *oxo*-Tridecoxymethyl sucrose was effective "built," but not alone. It is noteworthy that the products were poor wetters and gave very moderate lathers, but several were good lime-soap dispersants.

Previous work on the etherification of potassio or sodio derivatives of sucrose bears on the question of the major products obtained in this work. Sodium in liquid ammonia was used to prepare "monosodio sucrose," which was methylated with methyl tosylate (6); substitution occurred principally on the glucose 2 hydroxyl and fructose 1 hydroxyl, with minor 3 and 6 substitution in both hexose portions. Various small halogen compounds also produced undefined substitution (5), but no higher alkyl ethers appear to have been reported in the literature. Similar investigations on other carbohydrates, though voluminous, were not very pertinent to the present work.

Dimethyl sulfoxide was first used in the preparation of a sugar surfactant by Huber and Tucker (12); its use greatly accelerated this transesterification. The effect of DMSO on the substitution pattern in the present work is unknown.

Alkylbenzyl- and Allylsucroses. Attempts to use unactivated alkyl chlorides, even with catalytic amounts of sodium iodide, in the above ether synthesis gave poor conversions (6–12%). However, when highly reactive chlorides, such as tridecoxymethyl, alkylbenzyl, or long-chain allyl-type chlorides, were used, excellent apparent conversions were observed.



(II)

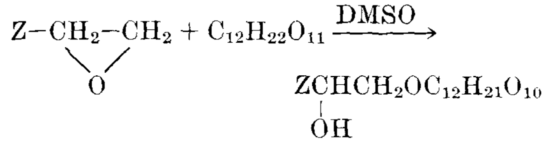
$$RCH = CHCH_2Cl + C_{12}H_{22}O_{11} \xrightarrow[-HCl]{DMSO} RCH = CHCH_2OC_{12}H_{21}O_{10}$$

(III)

Alkylbenzylsucroses are illustrated by dodecylbenzylsucrose (II, $R = t - C_{12}H_{25}$), obtained from chloromethylated commercial tetrapropylene-based dodecylbenzene (DDB). This product was obtained in as high as 80% conversions, using the sodium sucrate reagent in DMSO (Run 9). However the best products were prepared at 27–34% conversions, using aqueous alkali as the condensing agent in DMSO (Runs 7 and 8). Conversions could not be raised in this system without loss of activity. As shown in Table I, Section B, products of Runs 7 and 8 had good soft and hard water "built" detergency but differed in lime-soap dispersion. A poor detergent (Run 9), prepared *via* the sodium sucrate reagent, was still an excellent dispersant. The reasons for these differences are uncertain, but degradation of the products by alkali was indicated, and this may have been suppressed by the unconverted hydrophobe. An octadecylbenzylsucrose was prepared (Run 10), but this hydrophobe was too large for solubilization by sucrose. Use of an allyl-type dodecenyl chloride in Run 11 gave 70–86% conversion of an ineffective surfactant. A somewhat larger or less-branched unsaturated group might well have produced a more active ether.

(3-Alkoxy-2-hydroxy-1-propyl) Sucroses and Related Types. Modification of carbohydrates by condensation with alkylene oxides has produced such well-known useful products as polyhydroxyethyl-substituted starches and celluloses. Sucrose has been condensed similarly; for instance, *octakis*(2-hydroxypropyl)sucrose from propylene oxide (1) has been partially esterified (2) to give emulsifiers and various workers have condensed sucrose or its derivatives with ethylene oxide [a crystalline *bis*(hydroxyethyl) derivative has been isolated (15)], but reactions of sucrose with higher epoxides have not been described.

In this work hydrophobic epoxides, including glycidyl derivatives of alcohols, phenols, and mercaptans, have been condensed with sucrose, as shown:



$$Z{-}CH_2{-}\underset{O}{CH_2} + C_{12}H_{22}O_{11} \xrightarrow{DMSO} Z\underset{OH}{CH}CH_2OC_{12}H_{21}O_{10}$$

(IV)

As shown in Table I, Section C, this class included very good detergents (110–130%), which are surpassed among sugar-based products only by the alkylsucroses of Section A. Both higher olefin oxides and alkyl glycidyl ethers yielded excellent detergents and fair lime-soap dispersants under mild conditions and exceptional nonionic lathering agents under somewhat more vigorous ones. The change in properties was actually a gradual one, and insufficient work was done to determine all of the variables involved although more than two dozen runs were made on tridecyl glycidyl ether alone. It appeared however that an "optimum" degree of degradation exists in this case for a combination of good detergency and high lather. Runs 18 and 19 represented the closest approaches to this suggested "optimum" with this ether.

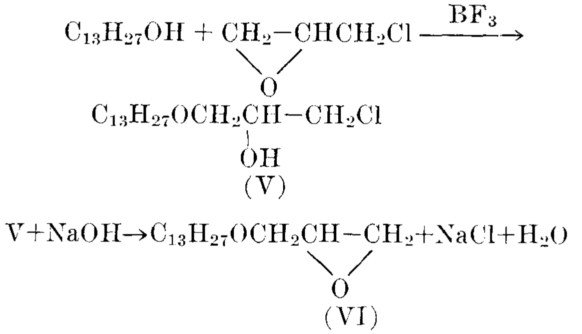
Again DMSO was not only the solvent of choice, but no other was found which gave equivalent products. The epoxides were not completely soluble in the reaction mixture, but this may have provided a desirably low effective concentration of reactant and limited disubstitution by improving the selectivity of the reaction. The nature of the catalyst was also very important for optimum activity of the product. Aqueous alkali alone was effective but was improved further by anhydrous potassium carbonate. Strangely anhydrous alkali or sodium sucrate did not produce satisfactory products, and again it is believed that the initially-formed sucrose ethers were more rapidly degraded by stronger bases. Sodamide in liquid ammonia was unsatisfactory, as was triethylenediamine in DMF, dimethylacetamide, or DMSO. Boron trifluoride etherate in DMF was investigated unsuccessfully.

Detergency was the principal criterion in this screening of solvents and catalysts. Evaluation data have not been included in Table I for many such runs since they represented completely different and highly degraded products. Similar poor results were obtained from runs made at temperatures above the preferred 85–90°C. temperature range, as expected on the basis of degradation of the sucrose moiety. Although excess carbohydrate did not usually contaminate the products, removal of DMSO was difficult to accomplish without damage to surfactivity.

The above points may be illustrated by reference to the evaluation data. The highest contents of sucrose surfactants are believed to be found in Runs 13, 14, 16, 19, and 20, for example. As more extensive degradation occurred (Runs 15, 18, and probably 17), lower detergencies and improved lathers were observed. It is clear then that the data in Table I do not necessarily represent the best possible product from any given starting material. In some cases, such as *oxo*-hexadecyl glycidyl ether (Run 21), this hypothesis suggests that the product was too highly degraded. Higher alkyl groups (Runs 22, 23) were again too large to be effectively solubilized by this hydrophile. Products derived from phenols and mercaptans (24, 25, 26) were not exceptional and were studied only briefly.

It should be mentioned that all of these sucrose derivatives are optically active. Data were not obtained for most of the products because of their lack of purity, but an unsuccessful attempt was made in the case of the surfactant based on *oxo*-tridecyl glycidyl ether to correlate specific rotation with reaction conditions and surface activity. Samples were purified carefully to remove solvents and sucrose, but the measured values of $[\alpha]_{\mathrm{D}}^{25^\circ\mathrm{C.}}$ (aqueous) varied from −37.4° to −48.6°. It was soon found that the solutions were undergoing a change in rotation with time, the initial value, $[\alpha]$ −37.4°, changing in 24 hrs. to −42.3° and in 70–100 hrs. to −45.8°. This change, usually called mutarotation, is always associated with the shifting hemiacetal equilibrium in sugars with a free carbonyl group; for example, α-*D*-glucose, $[\alpha]$ + 113°, mutarotates to an equilibrium mixture in solution, $[\alpha]$ + 52°, containing β-*D*-glucose, $[\alpha]$ + 19°. Sucrose $[\alpha]_{\mathrm{D}}^{25^\circ}$ + 66.5, does not exhibit mutarotation (although it does invert by hydrolysis, which requires acidic or enzymatic catalysis). That our product mutarotated is considered good evidence that degradation had converted a part of the product to hexoses (substituted and free).

It should be mentioned here that procedures have not been described in the literature which are completely satisfactory for the preparation of higher alkyl glycidyl derivatives of branched-chain alcohols and mercaptans especially. In this and other work which will be described subsequently, improved procedures have been developed; the synthesis of *oxo*-tridecyl glycidyl ether is described in the experimental section. For the usual acid-catalyzed addition of alcohols to epichlorohydrin, BF_3 was preferred as the catalyst and 100% excess alcohol was used to suppress the formation of high-boiling adducts. The alkoxychloropropanol (V) was separated easily from alcohol and high boilers by distillation.



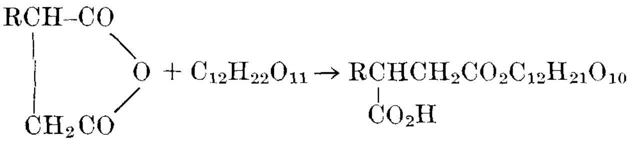
$$C_{13}H_{27}OH + \underset{\diagdown O \diagup}{CH_2{-}CHCH_2Cl} \xrightarrow{BF_3} C_{13}H_{27}OCH_2\underset{OH}{CH}{-}CH_2Cl \quad (V)$$

$$V + NaOH \rightarrow C_{13}H_{27}OCH_2\underset{\diagdown O \diagup}{CH{-}CH_2} + NaCl + H_2O \quad (VI)$$

Although it has been stated that "the over-all reaction of a halohydrin with alkali to produce the oxide is rapid and quantitative at room temperature" (21) and this is doubtless kinetically correct in homogeneous dilute solution, the reaction under practical synthetic conditions may be quite sluggish and incomplete, especially when higher-branched alkyl groups are present. For instance, when V was treated with excess concentrated sodium hydroxide and agitated 24 hrs., only a 60–71% yield of VI was obtained; heating and stirring V at 90° for 2 hrs. with alkali gave a similar result. The unchanged V was recovered. This appeared to be a salting-out effect since it was less noticeable with dilute alkali. Although such solvents as ether, tetrahydrofuran, and 1,2-dimethoxyethane actually retarded the reaction, it has been found that a rapid and quantitative reaction at room temperature occurred with concentrated alkali when DMSO was added. From V, VI was obtained in better than 90% yields in a few minutes. Although straight-chain alkylphenoxy-, alkylmercapto-, and alkoxy-substituted chloropropanols were less sluggish than the branched-chain compounds, the use of DMSO also assured rapid high conversions in these cases. The method has recently been patented (8).

Monosucrose Alkenylsuccinates. Another new type of sucrose-based surfactant is related both to the simple sugar esters and to the disucrose alkenylsuccinates prepared similarly by transesterification (9). Two disadvantages of the Snell process are that methanol generated in the reaction must be removed by azeotropic distillation at reduced pressures and that excess sugar and sucrose di-esters must be separated from the desired mono-ester.

In this study a method of esterifying sucrose with a higher alkyl cyclic anhydride has been developed; no by-product was formed, and the nearly pure half ester of sucrose was the product (VII).



$$RCH{-}CO{-}O{-}COCH_2 \text{ (cyclic)} + C_{12}H_{22}O_{11} \rightarrow RCH\underset{CO_2H}{}CH_2CO_2C_{12}H_{21}O_{10}$$

(VII)

Higher fatty anhydrides (actually the mixed anhydrides with chloroacetic acid) have been used to esterify sucrose (16). Hydrophobic cyclic anhydrides have been condensed with starch (7) and cellulose (4) at low degrees of substitution.

Selected examples of this type are listed in Section D of Table I. It is apparent that these products did not approach the other types in any respect. They were at best fair built detergents and mediocre lathering agents but notably were not sensitive to hard water, as the presence of a free carboxyl group might portend. The structure VII is assumed as written; the more acidic and less hindered carboxyl was esterified and the weakly acidic hindered carboxyl was free.

Excess sucrose (up to 100%) was used in a solvent such as DMF, dimethylacetamide, or DMSO. The reaction was very slow in DMF at 80–90° without a catalyst. Pyridine was an effective catalyst, and with it small runs proceeded to completion in 1–3 hrs. if the anhydride was added slowly to the solvent-catalyst-sucrose mixture so that precipitation of the sugar by unreacted anhydride was avoided. The work-up consisted of the distillation of solvent and the precipitation of sucrose with isopropanol. According to the evaluation data, a small (10%) excess of sucrose (Run 27) with tetrapropenylsuccinic anhydride gave a product which was not effective alone but as a built composition was as good as one (Run 28) prepared with 100% excess sugar. The former procedure, in which 95% of the excess sucrose precipitated from the cooled product solution, is probably the simplest yet described for a sugar-based surfactant. Since lather data were also better for the product prepared from a larger excess of sugar, it seems probable that a small amount of sucrose di-ester in the first product accounts for its lowered effectiveness. A similar explanation serves to rationalize the inferiority of Run 29 in which triethylenediamine was the catalyst. Although this strongly basic amine was a powerful catalyst (in DMF at 85–90° the reaction was complete in a few minutes), its use probably led to lower selectivity and formation of some di-ester. Triisobutenylsuccinic anhydride gave a less effective product (Run 30) as did hexapropenylsuccinic anhydride (Run 31). Sucrose *n*-octadecenylsuccinate (Run 32) was also less effective than the tetrapropenylsuccinate, another indication that this group is too hydrophobic for effective solubilization by sucrose alone. The products were patented recently (9a).

Experimental

Typical procedures are given by Run numbers to avoid confusion when the same product was made by various methods. Although many more runs and different products were prepared than are reported, this description has been restricted to those for which reasonable assessment could be made of the synthetic variables and the effect on evaluation data. These included most of the more effective materials, except those based on crude (not distilled) intermediates. Most of these products were analyzed but usually gave low carbon and hydrogen results; only a few such data are included for illustration since at best they represent mixtures.

Alkylsucroses

Sodium Sucrate in DMSO. A solution of 257 g. (0.75 mole) of anhydrous reagent sucrose in 1,250 ml.

dimethyl sulfoxide (DMSO, Crown-Zellerbach Company) was prepared by warming and stirring to 90° C.; the solution was hygroscopic and was protected by Drierite-filled drying tubes. Then the solution was maintained at 70–80° as 108 g. (0.50 mole) of a 25% commercial solution of sodium methoxide in methanol was added rapidly drop by drop with vigorous stirring to disperse and redissolve the gelatinous precipitate which formed initially. If a less concentrated reagent is desired, the methoxide solution can be diluted with additional DMSO prior to this step to facilitate the formation of an homogeneous reagent. Methanol was removed by distillation to 80° at the aspirator, then at the cold-trapped oil pump (2–5 mm.), distilling about 200 ml. DMSO to ensure complete removal of methanol. The nearly homogeneous light amber reagent solution was not heated above 80°C. at any time nor was it stored, but the reactions with alkyl halides were started immediately when the solution had been cooled to ambient temperature.

The finished reagent weighed 1,449 g. and was assumed to contain 0.50 mole of sodium sucrate and 0.25 mole of excess sucrose.

Alkyl Bromides. These were prepared from commercial alcohols and anhydrous hydrogen bromide (19). Since most of the products were mixtures, a wide boiling range was accepted as most representative of the alcohols. The following bromides were used in this work: *oxo*-decyl, b.p. 93–103°/13 mm., n_D^{25} 1.4550–61, 73.5% conv.; *oxo*-tridecyl, b.p. 132–143°/13 mm., n_D^{25} 1.4604, 68.8% conv.; *oxo*-hexadecyl, b.p. 147–165°/13 mm., n_D^{25} 1.4650, 69.5% conv.; 2-butyloctyl, b.p. 83–85°/0.6 mm., 60% conv.; *n*-tridecyl (from an experimental Fischer-Tropsch process alcohol), b.p. 105–109°/0.6 mm., 66.5% conv. These conversions may not be optimum; lower boiling cuts contained olefinic impurities.

Run 2. oxo-Tridecylsucrose. To 319 g. of the reagent (0.11 mole of sodium sucrate) was added at once 26.3 g. (0.10 mole) of *oxo*-tridecyl bromide. The 500-ml. r.b. flask was immediately sealed with a polyethylene stopper and shaken vigorously on a reciprocating shaker for 42 hrs. (Later it was shown that 2–4 hrs. were adequate with efficient agitation.) The reaction was not noticeably exothermic on this scale, but some cooling should be provided in large batches to maintain the mixture below 30–35°.

An oil was still present and was extracted into hexane; 12.0 g. (46% as bromide, n_D^{25} 1.4564) was recovered after washing, drying and distilling the hexane.

The DMSO layer (lower) should not have a pH above 8 as measured on moist narrow-range pH paper. (pHydrion, pH 6–8, was used.) If necessary, the pH may be adjusted carefully to 7–8 with a mixture (prepared by cautious mixing with cooling) of DMSO and orthophosphoric acid. Then the mixture was concentrated below 80° down to 1 mm. with efficient stirring to a syrupy residue which was poured slowly while hot into 600 ml. of anhydrous ethanol at 25–30° being agitated in a Waring Blendor. The slurry was filtered to remove sucrose and inorganic salts, and the filtrate was concentrated again to a syrup, which was triturated with 300 ml. of isopropyl alcohol to precipitate additional sucrose and filtered. The filtrate was finally concentrated to 80°/1 mm.; nitrogen sparging was used to remove a small further amount of DMSO. The residue was a clear amber resinous gum, 35.8 g., brittle when cold, and soluble in hot or cold water.

Since the conversion was not above 54%, based on recovered bromide, the apparent conversion (68%) leads to 54/68 = 79%, maximum active content. Very low carbon and somewhat low hydrogen contents (redried at 56°/1 mm. for two days) and other data in some cases led to the conclusion that these "active contents" may be 10–20% high and several per cent of DMSO was present also, which could not be removed completely without causing caramelization of the sample.

Unchanged sucrose may be left in the product as an inert diluent and the solvent purification steps eliminated. However this led to a much more viscous product mixture, and the sugar also retained DMSO even more tenaciously than the sucrose-free product. All of the products reported are believed to contain no more than 1–2% free sucrose. Ethanol or even methanol should be used in the initial separation of unchanged sucrose since it was found that use of isopropyl alcohol in this step resulted in loss of "active" by absorption on the sucrose. It is desirable to remove DMSO again as efficiently as feasible below 80° since its presence interfered with the complete separation of sucrose. Isopropyl alcohol then precipitated small remaining amounts of sucrose without significant product loss.

In Table II the apparent conversion is the crude weight conversion based on the halide charged. The maximum conversion is based on the halide recovered. The maximum active is the maximum conversion divided by the apparent conversion, as percentage.

TABLE II

Alkylsucrose Synthesis

Run	RBr	Oil recovered, as RBr	Apparent conv., %	Max. conv., %	Max. active, %
1	*oxo*-$C_{10}H_{21}$	37	70	62	89
2	*oxo*-$C_{13}H_{27}$	46	68	54	79
3	*oxo*-$C_{16}H_{33}$	64	49	36	73
4	2-(C_4H_9)C_8H_{16}	59	24	24	100
5	*n*-$C_{13}H_{27}$	54	59	46	78
6	*oxo*-$C_{13}H_{27}OCH_2Cl$	32	37	37	100

The other reported runs in this series (1,3,4,5,6) were carried out similarly except for Run 6, involving *oxo*-tridecoxymethyl chloride. This intermediate from tridecanol, paraformaldehyde, and hydrogen chloride was redistilled immediately before use (b.p. 90–96° 0.2–0.4 mm.), and the sodium sucrate (0.133 moles) in DMSO was cooled rapidly until at about 18°C. much DMSO had crystallized. Then the chloride, 24.9 g., 0.10 mole, was added all at once, and the flask was sealed. Despite external ice-bath cooling the temperature of the mixture rose to 35°, and the color darkened to red-brown. Isolated as described above, the product was a brittle red-brown resin.

A similar procedure, using *n*-tetradecyl chloride, resulted after seven days in the recovery of 94% of the chloride and isolation of an uncharacterized but soluble and "active" gum in 6% conversion. When sodium iodide (1.0 g. with 0.11 mole sucrate) was added, the conversion increased only to 12% after 18 hrs. at 25°, followed by 8 hrs. at 55–70°.

DMF was not a satisfactory solvent for sodium sucrate; it appeared to react with the alkoxide and gave mixtures with poor activities.

Higher Alkylbenzyl- and Allylsucroses

Run 9. Chloromethylated tetrapropylene dodecylbenzene (DBCL, Continental Oil Company) was redistilled before use; 29.5 g. (0.10 mole) was added drop by drop to sodium sucrate (0.15 mole) in DMSO (prepared as described above) during 20 min. as the temperature was increased from 41° to 61°C. Heating and stirring were continued an additional hour. The cooled mixture was stirred with excess $NaHCO_3$, filtered, extracted with hexane, and concentrated below 70°/0.5 mm., then freed of sugar in isopropyl alcohol as usual, leaving 48.2 g. of amber gum (80% apparent conversion). In other similar runs it was possible to isolate 20–30% of oils, corresponding to within a few per cent of the expected recovery for 100% yield.

Run 7. Dodecylbenzyl chloride was etherified in lower conversions but to give better detergents in a partially aqueous system. A solution of 68.4 g. (0.20 mole) sucrose in 200 ml. of DMSO, cooled to 30°, was treated with 3.0 g. of 50% aqueous NaOH with stirring, then with 29.5 g. of the chloride at once. After 10 min. at 30° the alkali lower layer formed an unstirrable mass; 25 ml. of water were added, and heating was begun. After 90 min. at 50° up to 70° no further improvement was noted in the activity of a few drops of the mixture in water.

The hot mixture was shaken with 200 ml. of hexane and allowed to stand in a separatory funnel overnight. Three "layers" formed: upper, hexane-oil; middle, semi-gel; lower, DMSO-active. The lower layer was separated and concentrated below 80°/1 mm. and freed of sugar in isopropyl alcohol as usual. A hard off-white gum, 16.1 g. (27% conv.), was isolated. From another similar run, using 50% KOH, 31% of oils based on the chloride was recovered, and the "active" was further purified by precipitation of impurities from an acetone solution of the crude product by ether from which 18.7 g. (62% conv.) of waxy gum were isolated. A sample was redried at 100°/1 mm. without noticeable decomposition and gave an indicative analysis, typically low in carbon.

Anal. Calc'd. for $C_{21}H_{52}O_{11}$: C, 62.0; H, 8.73.
Found: C, 59.6; H, 8.83.

The sodium sucrate-DMSO method was used (Run 10) with propylene-based octadecylbenzyl chloride to give 29% conversion of a brittle amber product.

Run 11. A dodecenyl chloride (5,5,7,7-tetramethyl-2-octen-1-yl chloride, Rohm and Haas Company) was condensed with sucrose by the aqueous alkali (10% NaOH) method at 72–73° for 90 min. to give 86% crude conversion to an unusually impure hard amber product. Redried at 56°/1 mm., it was very low in carbon content.

Anal. Calc'd. for $C_{24}H_{44}O_{11}$: C, 56.6; H, 8.70.
Found: C, 50.63; H, 8.45.

In another run with sodium sucrate in DMSO, a 70% conversion to viscous amber product resulted with 19% recovered chloride.

(Alkoxyhydroxypropyl) Sucroses

Run 19. This preparation of the *oxo*-tridecoxy compound illustrates the results obtainable on a larger laboratory scale with efficient agitation as provided by a "Vibro-mixer." The reaction was carried out in a cylindrical glass vessel 23½ in. high and 4⅞ in. in diameter, equipped with a stainless steel agitator extending through a rubber stopper, and carrying a metal bearing to about half the depth of the vessel, on which three discs with tapered perforations were mounted. In operation the entire contents were rapidly circulated by the vibrating discs; suspended solids and immiscible liquids were agitated much more effectively than by a conventional paddle type of stirrer.

The reactor was charged with 3,900 ml. of DMSO and heated to 85–90°C.; the stopper and bearing were raised with the agitator operating slowly, and 889 g. (2.6 moles) of sucrose was added. When dissolution was complete, 78 g. of anhydrous K_2CO_3 and 333 g. (1.3 moles) of *oxo*-tridecyl glycidyl ether was added; the stopper was replaced and secured with contact tape. The mixture was agitated efficiently at 85–90° while 39 ml. of 50% aqueous KOH was added in 2–3-ml. portions every 15 min. during 3 hrs. and for an additional 2 hrs. The reaction mixture was discharged into a 12-liter flask, cooled to room temperature, stirred, and treated (bubbler) with CO_2 gas until the pH dropped to 8.5.

The mixture was filtered with a filter-aid and extracted with three 650-ml. portions of hexane. From the hexane by water washing, drying, and distilling were isolated 176.3 g. of unchanged glycidyl ether (53% recovery; n_D^{25} 1.4461).

The combined DMSO layers were stirred and concentrated, finally to 100° at the oil pump, leaving a syrup which was poured hot into a total of 4 liters of isopropyl alcohol and agitated in the Waring Blendor. The slurry was filtered to remove the sucrose.

The filtrate was concentrated to a syrup at 70–80° C./0.5 mm., cooled, and washed with reagent ether by stirring and decanting the ether. The remaining ether and some DMSO were removed from the residual gum by stirring and purging with N_2 at 90–95°C. and about 2 mm. for 10 hrs.; stirring was not feasible after 5 hrs. The light amber gum weighed 277 g. (76% yield at 47% conversion).

On a smaller scale (0.20 mole sucrose, 0.1 mole glycidyl ether) a similar product was prepared in 98% yield at 78% conversion in 6.5 hrs. at 85–90°, using a blade stirrer; lather and detergency data were not as good as that of the above material however. This product was further purified by four ether washings; a sample that was dried without darkening at 100°/1 mm. for 24 hrs. still retained 4.5% DMSO as shown by the sulfur analysis.

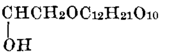
Anal. Calc'd. for $C_{28}H_{54}O_{13}$: C, 56.1; H, 9.08.
Found: C, 52.95; H, 8.86; S, 1.84.

Run 20. Better products were obtained on the smaller scale at lower conversions, using the intermediate 3-*oxo*-tridecoxy-1,2-chloropropanol without isolation of glycidyl ether. The lower conversion was probably a result of the salting-out of the glycidyl ether.

The chloropropanol (29.3 g., 0.10 mole) was stirred 30 min. at 25–30°C. with 11 g. of 40% NaOH solution and 50 ml. of DMSO. A solution of 37.6 g. (0.11 mole) of sucrose in 50 ml. of DMSO was then added, and heating and vigorous stirring at 90–95° continued for 3 hrs. After the usual isolation, 13.3 g. (22% conv.) of brittle, nearly colorless, ether-washed product was obtained; the yield was not determined.

This product from *oxo*-tridecanol was studied more thoroughly than any other. Many other products were made before the above conditions had been determined. Despite the fact that further improvement is considered possible, the runs of Table I-C are tabulated to illustrate some of the conditions and products which have been investigated preliminarily. Processing and isolation methods were similar to those described above. In all cases 50–100% excess sucrose was used.

TABLE I-C

Alkoxyhydroxypropylsucroses: 
$Z\underset{\substack{|\\ OH}}{C}HCH_2OC_{12}H_{21}O_{10}$

Run	Z	Catalyst	Hrs.–°C.	Conv. %	Yield %
12	*n*-$C_{10}H_{21}$[a]	KOH-K_2CO_3	13.5–90	74	88
13	*n*-$C_{14}H_{29}$-$C_{16}H_{33}$[a]	KOH-K_2CO_3	25–90	59	81
14	*oxo*-$C_{10}H_{21}OCH_2$[b]	NaOH	10–100	53	....
15	*oxo*-$C_{10}H_{21}OCH_2$[c]	K_2CO_3	3–100	54	....
16	2-(C_4H_9)$C_8H_{16}OCH_2$[d]	KOH-K_2CO_3	9–90	84	91
17	*n*-$C_{12}H_{25}OCH_2$[e]	KOH-K_2CO_3	11–90	22	40
21	*oxo*-$C_{16}H_{33}OCH_2$	NaOH	12–95	82	....
22	(*n*-$C_{16}H_{33}$-$C_{18}H_{37}$)OCH_2[f]	KOH-K_2CO_3	11–90	60	75
23	Hydroabietoxymethyl[g]	NaOH	11.5–90	36	....
24	$C_9H_{19}C_6H_4OCH_2$	NaOH	11–90	68	....
25	$C_{12}H_{25}C_6H_4OCH_2$	KOH-K_2CO_3	12–90	45	63
26	*t*-$C_{12}H_{25}SCH_2$	KOH-K_2CO_3	6–90	65	81

[a] Sources: Olefins, oxides, Food Machinery and Chemical Corporation. Alcohols, alkylphenols, and mercaptans were standard products of commerce.

[b] Anal. Calc'd. for $C_{25}H_{48}O_{13}$: C, 53.9; H, 8.70. Found: C, 52.7; H, 8.87.

[c] Reaction conducted in DMF.

[d] Another sample obtained with NaOH catalyst in 83% conv. in 13 hrs. at 90°C. was analyzed. Cal'd. for $C_{27}H_{52}O_{13}$: C, 55.3; H, 8.97. Found: C, 55.40; H, 9.31. However the surface-activity was quite mediocre despite the excellent agreement.

[e] Crude glycidyl ether used wihout distillation.

[f] From Adol 65, Archer-Daniels-Midland Company.

[g] Anal. Calc'd. for $C_{35}H_{60}O_{13}$: C, 60.8; H, 8.77. Found: C, 56.2; H, 8.68; S, 0.964.

Oxo-Tridecyl Glycidyl Ether. *oxo*-Tridecanol (Enjay Company) was condensed with epichlorohydrin by adding the latter (142 g., 1.53 mole) drop by drop to the former (601.2 g., 3.0 moles), which contained 1.0 ml. BF_3-etherate (45% BF_3), being heated and stirred at 75–80° at a rate sufficient to maintain this temperature. After being heated another hour after the addition had been completed, the catalyst was neutralized by stirring with 10–15 g. of activated alumina or by washing with water, and the excess tridecanol was recovered by distillation through a 2-ft. "zigzag" column. Then, at 0.3–0.6 mm., 371.7 g. of 1-chloro-3-tridecoxy-2-propanol (mixed isomers) was collected at 129–157° n_D^{25} 1.4577–1.4587. A residue of 15.4 g. did not distill. The yields were 93.3%, based on tridecanol, and 82.9% on epichlorohydrin.

The chloropropanol (97.6 g., 0.33 mole) was treated with 46.6 ml. of 14.3 *N* NaOH and 50 ml. of DMSO, and the mixture was stirred. Immediate precipitation of salt occurred. Back-titration (stirring) of the excess alkali with hydrochloric acid, using phenolphthalein indicator, proved in other runs that the reaction was at least 95% complete within 5 min., but agitation was continued 2 hrs. in this case. After water washing and drying, the organic layer was fractionated, giving water-white *oxo*-tridecyl glycidyl ether, 78.4 g., 93% yield, b.p. 106–120°/0.2 mm., n_D^{25} 1.4463–1.4470. A cut, b.p. 110–118°/0.4 mm., was analyzed.

Anal. Calc'd. for $C_{16}H_{32}O_2$: C, 74.9; H, 12.6.
Found: C, 75.54; H, 12.64.

A fraction, 6.1 g., b.p. 120–140°/0.2 mm., n_D^{25} 1.4535, still contained chlorine as well as an estimated 2.4 g. of glycidyl ether. The residue should not be overheated since above 200° it evolved HCl, which reconverted the product to chloropropanol.

This general procedure was useful for the preparation of glycidyl ethers from alcohols and alkylphenols. In practice, the salt may be filtered out of the lower DMSO layer, which can be fortified with more alkali and used again. Higher glycidyl derivatives had negligible solubility in this alkali-DMSO-salt layer. Removal of excess alcohol, phenols, or mercaptan before treatment with alkali was essential since disubstituted 2-propanols were otherwise obtained. However this can be done after catalyst removal, in a stripping operation; the residual crude chloropropanol then gave as good an over-all yield as did purified material upon dehydrohalogenation.

Other glycidyl derivatives will be described elsewhere.

Monosucrose Alkenylsuccinates

Run 27. This procedure illustrates the use of a 10% excess of sucrose, which readily precipitated when a limited amount of solvent was employed. A solution of vacuum oven-dried reagent sucrose, 38.0 g. (0.11 mole), in 94 g. of dry DMF was prepared by stirring and heating briefly to 105°, protected against moisture with Drierite tubes. The solution was then quickly cooled to 85°, 5.0 ml. of pyridine was added rapidly from a pipet, and drop-by-drop addition of freshly distilled tetrapropenylsuccinic anhydride,[1] 26.6 g. (0.10 mole), was carried out in 6 min. at 80–85°. The addition should be as rapid as possible without causing the sucrose to precipitate. Heating and stirring were continued for 70 min., when a sample in water was active and entirely clear. The light amber solution was cooled to 25° until the sucrose crystallized completely. Filtration and drying gave 3.6 g. of sucrose (95% of the 10% excess). The filtrate was stirred (high-torque blade type), and DMF distilled at the aspirator below 90° and finally at 90–95°/1.0 mm. with nitrogen sparging, leaving 65.3 g. of very light amber resinous gum, which became so viscous that stirring was no longer possible. The product was easily crushed to a glassy powder after being cooled in Dry Ice (drying tubes) to cause embrittlement. It contained about 6.7% DMF, which could be removed only by 24-hr. heating of the powder at 56°; it fused and darkened above 100°C. A carefully desugared sample, prepared in 101% "yield," using 50% excess sucrose, was analyzed.

Anal. Calc'd. for $C_{28}H_{48}O_{14}$: C, 55.2; H, 7.83.
Found: C, 54.99; H, 8.08.

Other runs were carried out similarly. A 100% excess of sucrose (Run 28) gave better "as received" detergency and lather, but the use of more DMF (250 ml./0.2 mole sucrose) necessitated a separate step to precipitate excess sugar with isopropyl alcohol. Triethylenediamine (Run 29) gave a less effective product although it was an extremely active catalyst. DMSO as the solvent also promoted the reaction (Run 30, using triisobutenylsuccinic anhydride) but was even more difficult to remove than DMF and strongly

---

[1] TPSA, Monsanto Chemical Company.

retained sugar in the presence of the product.

The sucrose octadecenylsuccinates were prepared from an experimental polypropylene-derived anhydride (Neut. Equiv.: Calc'd. for $C_{22}H_{38}O_3$: 175.3. Found: 175.5; b.p. 162–220°/0.5–1.0 mm.) and from *n*-octadecenylsuccinic anhydride[2] in 85 and 91% conversions, respectively (Runs 31 and 32).

Acknowledgments

The coöperation of E.L. Doerr, D.N. VanEenam, and J.M. Schuck in the preparation of intermediates and of G.F. Deebel, R.E. Dolle, and J.D. Downing in larger-scale preparations is gratefully acknowledged, as is the coöperation of members of the Analytical, Physical Chemistry, and Surfactant Evaluation sections. The evaluations, under the supervision of J.C. Harris, were done by L.E. Weeks, M.E. Ginn, E.L. Brown, R.L. Evers, and Miss Frances B. Kinney.

REFERENCES

1. Anderson, A.W., U.S. 2,902,478, to Dow Chemical Company (1959).
2. Anderson, A.W., and Melstad, J.L., U.S. 2,908,681, to Dow Chemical Company (1960).
3. Ames, G.R., Chem. Rev., *60*, 541 (1960).
4. Berls, R.J., U.S. 2,903,382, to Armour and Company (1959).
5. Black,W.A.P., Dewar, E.T., Paterson, J.C., and Rutherford, D., J. Appl. Chem., *9*, 256 (1959).
6. Black,W.A.P., Dewar, E.T., and Rutherford, D., J. Chem. Soc., 3073 (1959).
7. Caldwell, C.G., and Wurzburg, O.B., U.S. 2,661,349, to National Starch Products Inc. (1953)
8. Gaertner, V.R., U.S. 2,965,652, to Monsanto Chemical Company (1960).
9. Gaertner, V.R., and Doerr, E.L., U.S. 2,868,731, to Monsanto Chemical Company (1959).
9a. Gaertner, V.R., U.S. 2,973,632, to Monsanto Chemical Company (1961).
10. Harris, J.C., "Detergency Evaluation and Testing," Interscience Publishers Inc., New York, 1954.
11. Hass, H.B., Mfg. Chemist, *29*, 152 (1958).
12. Huber, W.F., and Tucker, N.B., U.S. 2,812,324, to Procter and Gamble Company (1957).
13. Komori, S., Okahara, M., and Okamoto, K., J. Am. Oil Chem. Soc., *37*, 468 (1960).
14. Kononenko, O.K., and Herstein, K.M., Chem. and Eng. Data Series, *1*, 87 (1956).
15. LeMaistre, J.W., and Seymour, R.B., J. Org. Chem., *13*, 782 (1948).
16. Lorand, E. J., U.S. 1,959,590, to Hercules Powder Company (1934).
17. Osipow, L.I., Snell, F.D., Marra, D., York, W.C., Finchler, A., Ind. Eng. Chem., *48*, 1456 (1956); Hass, H.B., Snell, F.D., York, W.C., and Osipow, L.I., U.S. 2,893,990, to Sugar Research Foundation Inc. (1959).
18. Pilpel, N., Research (London), *12*, 68 (1959).
19. Reid, E.E., Ruhoff, J.R., and Burnett, R.E., in Blatt, A.H., "Organic Syntheses," Coll. Vol. II, John Wiley and Sons Inc., New York, 1943, pp. 246–248.
20. Rhodes, C.A. Chem. Prod., *21*, 320 (1958).
21. Winstein, S., and Henderson, R.B., in Elderfield, R.C., "Heterocyclic Compounds," Vol. I, John Wiley and Sons Inc., New York, 1950, p. 8.
22. Chem. Week, *88*, 45 (1961).

[Received March 1, 1961]

---

[2] Dynacolor Corporation, "acid-free."

The Examination of Fats and Fatty Acids for Toxic Substances

DAVID FIRESTONE, WILLIAM HORWITZ, LEO FRIEDMAN, and GLEN M. SHUE,
Food and Drug Administration, Bureau of Biological and Physical Sciences, U.S. Department of Health, Education and Welfare, Washington, D.C.

The chick edema disease factor was found to be present in a number of distillates and residues that were obtained during the production of commercial fatty acids. The raw materials from which the toxic samples were produced included inedible animal tallows, acidulated vegetable oil foots, and oils recovered from tin plate manufacture. The chick edema factor was found to be present in several oleic acids and in a triolein. Twenty stearic acid samples which were examined were nontoxic.

The nonurea adduct-forming fatty acids that were isolated from commercial oleic acids and various distillates and residues from the manufacture of commercial fatty acids were found to be toxic to weanling rats even after hydrogenation. Analysis of the nonurea-adducting monomers that were isolated from a fatty acid by-product distillate indicated the presence of cyclic structures.

THE OCCURRENCE of the chick edema disease factor in a by-product of the manufacture of commercial oleic and stearic acid (1-3) led to the examination of commercial fats and fatty acids for this factor. The chick edema disease is characterized by excessive fluid in the pericardial sac, in the abdominal cavity, and less often by subcutaneous edema. The causative agent in sufficient concentration brings about high mortality, beginning approximately on the third week after addition to the diet. The toxic factor was first found in the unsaponifiable fraction of a fatty acid by-product distillate added to certain lots of feed-grade fat. Purified fractions were physiologically active in fractions of a part per million of the diet. Subsequent investigation of fatty acid production showed that the chick edema factor was often present in the first distillates and residues and in the commercial fatty acids themselves. In addition, these fractions were also found to contain small amounts of fatty acids not forming adducts with urea that were toxic to weanling rats. The occurrence of the chick edema factor in oleic acids and derivatives has been reported by Ames *et al.* (4).[1] It has been isolated in

---

[1] The Food and Drug Administration's food additive regulations of April 22, 1960 (CFR Title 21, Section 121.86), requires that oleic and stearic acids be "prepared from edible fats and oils, free from chick edema factor."