# The Chemistry of Sultones. III. Formation of Six- in Preference to Five-Membered Ring Sultones[1]

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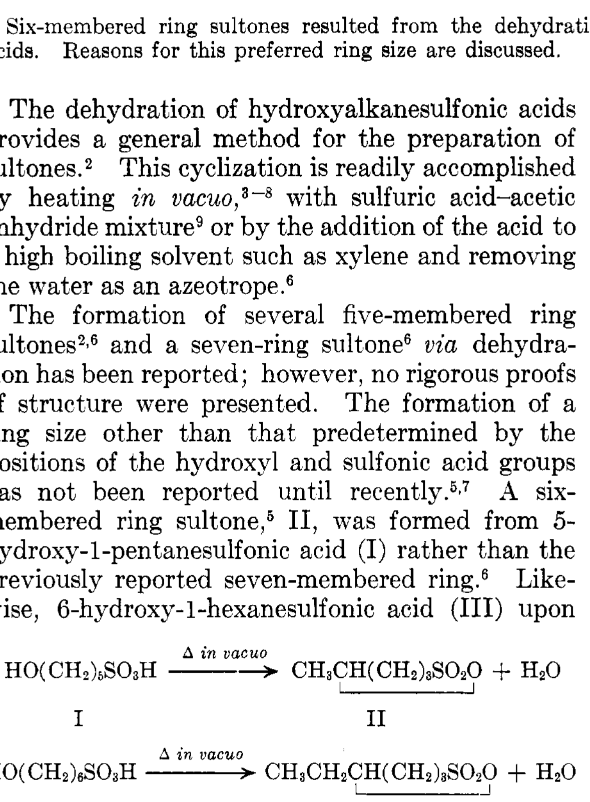
Six-membered ring sultones resulted from the dehydration of 3-hydroxy-1-pentane- and 3-hydroxy-1-hexanesulfonic acids. Reasons for this preferred ring size are discussed.

The dehydration of hydroxyalkanesulfonic acids provides a general method for the preparation of sultones.[2] This cyclization is readily accomplished by heating *in vacuo*,[3–8] with sulfuric acid–acetic anhydride mixture[9] or by the addition of the acid to a high boiling solvent such as xylene and removing the water as an azeotrope.[6]

The formation of several five-membered ring sultones[2,6] and a seven-ring sultone[6] *via* dehydration has been reported; however, no rigorous proofs of structure were presented. The formation of a ring size other than that predetermined by the positions of the hydroxyl and sulfonic acid groups has not been reported until recently.[5,7] A six-membered ring sultone,[5] II, was formed from 5-hydroxy-1-pentanesulfonic acid (I) rather than the previously reported seven-membered ring.[6] Likewise, 6-hydroxy-1-hexanesulfonic acid (III) upon vacuum distillation did not yield the eight-membered ring, but gave 4-hydroxy-1-hexanesulfonic acid sultone (IV).[7] Analogous rearrangements have been demonstrated in the sulfonation of $\gamma$-branched olefins forming tertiary five-ring sultones.[10a] Although similar ring contractions involving lactones[10b] are known, these were the first reported cases of isomerization on sultone formation.



$$HO(CH_2)_5SO_3H \xrightarrow{\Delta\ in\ vacuo} CH_3\underline{CH(CH_2)_3SO_2O} + H_2O$$

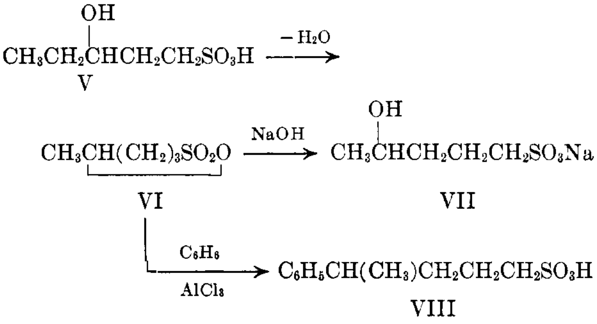
I II

$$HO(CH_2)_6SO_3H \xrightarrow{\Delta\ in\ vacuo} CH_3CH_2\underline{CH(CH_2)_3SO_2O} + H_2O$$

III IV

This paper concerns six-membered ring formation where a five-membered ring might be expected from the position of the hydroxyl group relative to the sulfonic acid group Both 3-hydroxy-1-pentanesulfonic acid (V) and 3-hydroxy-1-hexanesulfonic acid (IX) were heated *in vacuo* forming in each case the six-membered ring sultone.

The structure of 4-hydroxy-1-pentanesulfonic acid sultone (VI) was established by hydrolysis with aqueous sodium hydroxide giving sodium 4-hydroxy-1-pentanesulfonate (VII).



$$CH_3CH_2\overset{OH}{C}HCH_2CH_2SO_3H \xrightarrow{-H_2O}$$

V

$$CH_3\underline{CH(CH_2)_3SO_2O} \xrightarrow{NaOH} CH_3\overset{OH}{C}HCH_2CH_2CH_2SO_3Na$$

VI VII

$$\xrightarrow[AlCl_3]{C_6H_6} C_6H_5CH(CH_3)CH_2CH_2CH_2SO_3H$$

VIII

It has been well established that sultones undergo various nucleophilic displacements without rearrangement.[3,11] The resulting sulfonate, VII, gave iodoform when treated with basic iodine–potassium iodide solution. Further evidence was provided by the Friedel–Crafts reaction of the sultone with benzene[5] to give 4-phenyl-1-pentanesulfonic acid (VIII) whose benzylthiuronium salt was identical with that of an independently synthesized sample.

The structure of 4-hydroxy-1-hexanesulfonic acid sultone (X) was established by an independent synthesis from 4-hydroxy-1-hexanesulfonic acid (XII), prepared by the addition of sodium bisulfite to 4-hydroxyhexene-1 (XI). Hydrolysis of the sultone gave 4-hydroxy-1-hexanesulfonic acid (XII). Comparison of both the sodium and the benzylthiuronium salts indicated that these acids were identical.

The sultone was converted by a Friedel-Crafts reaction to 4-pheny-1-hexanesulfonic acid (XIII), which was identical to the independently synthesized material. Nearly all of the sultone obtained from the 3-hydroxy-1-hexanesulfonic acid (IX) was

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[1] Abstracted from the Ph.D. theses of David N. Burdge, Purdue University, 1959, and Robert J. Steltenkamp, Purdue University, 1962.

[2] A. Mustafa, *Chem. Rev.*, **54**, 195 (1954); A. Mustafa in N. Kharasch, "Organic Sulfur Compounds," Pergamon Press, New York, N. Y., 1961, p. 183.

[3] J. H. Helberger, *Chem. Abstr.*, **41**, 4101 (1947); J. H. Helberger, *et al.*, *Ann.*, **562**, 23 (1949); *ibid.*, **565**, 22 (1949); *ibid.*, **586**, 147 (1954).

[4] C. W. Smith, D. G. Norton, and S. A. Ballard, *J. Am. Chem. Soc.*, **75**, 748 (1953).

[5] W. E. Truce and F. D. Hoerger, *ibid.*, **76**, 5357 (1954).

[6] J. Willems, *Bull. soc. chim. Belges*, **64**, 747 (1955).

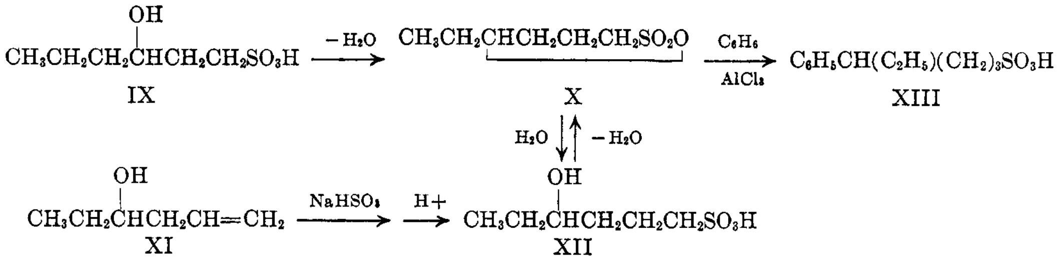
[7] B. Helferick and V. Bollert, *Ber.*, **94**, 505 (1961).

[8] E. Goethals and L. Jossom-Merckaert, *Bull. soc. chim. Belges*, **70**, 218 (1961).

[9] T. Morel and P. E. Verkade, *Rec. trav. chim.*, **67**, 539 1948); *ibid.*, **68**, 619 (1949).

[10] (a) F. G. Bordwell, R. D. Chapman, and C. E. Osborne, *J. Am. Chem. Soc.*, **81**, 2002 (1959). (b) E. E. Blaise and A. Koehler, *Compt. rend.*, **148**, 1772 (1909); C. S. Hornberger, *et al.*, *ibid.*, **75**, 1274 (1953).

[11] W. E. Truce and F. D. Hoerger, *J. Am. Chem. Soc.*, **77**, 2496 (1955). This has also been demonstrated with alkyl sulfonates, see G. W. Wheland, "Advanced Organic Chemistry," 3rd ed., John Wiley & Sons, New York, N. Y., 1960, p. 377.



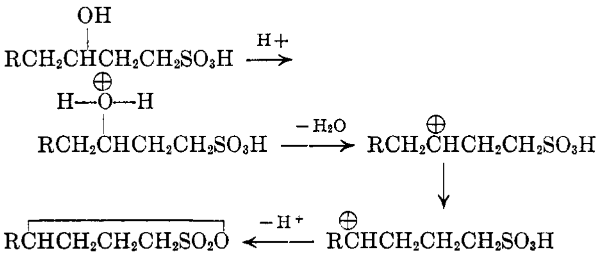
$$\underset{\text{IX}}{CH_3CH_2CH_2\overset{OH}{C}HCH_2CH_2SO_3H} \xrightarrow{-H_2O} \underset{\text{X}}{CH_3CH_2CHCH_2CH_2CH_2SO_2O} \xrightarrow[AlCl_3]{C_6H_6} \underset{\text{XIII}}{C_6H_5CH(C_2H_5)(CH_2)_3SO_3H}$$

$$\text{X} \underset{-H_2O}{\overset{H_2O}{\rightleftarrows}} \text{XII}$$

$$\underset{\text{XI}}{CH_3CH_2\overset{OH}{C}HCH_2CH{=}CH_2} \xrightarrow{NaHSO_3} \xrightarrow{H+} \underset{\text{XII}}{CH_3CH_2\overset{OH}{C}HCH_2CH_2CH_2SO_3H}$$

the six-membered ring; however, some of the five-membered ring sultone may have been present since a small amount of a sulfobetaine derivative was recovered having a wide melting point range.

The formation of a sultone from a hydroxysulfonic acid may be assumed to occur by a carbonium ion intermediate, since the reaction proceeds only at elevated temperatures (120–210° *in vacuo*) under *acidic* conditions, and with the aforementioned isomerizations. These carbonium ion shifts may be favored by (1) the formation of a more stable carbonium ion and (2) the formation of a more stable ring system. Although carbonium ion stability in the dehydration of 5-hydroxy-1-pentanesulfonic acid (I) to the six-membered ring, II, is a very important factor (primary carbonium ion to a secondary carbonium ion), this factor cannot explain the isomerization observed with 3-hydroxy-1-hexanesulfonic acid nor the entire isomerization of 6-hydroxy-1-hexanesulfonic acid. It seems unlikely that such a relatively small difference in carbonium ion stabilization involved in the hydride transfer of 3-hydroxy-1-pentanesulfonic acid (hyperconjugative stabilization of five as opposed to four possible forms) should result in the formation of one product exclusively. Thus another driving force in addition to carbonium ion stabilization must be responsible for the rearrangement, namely, the formation of a more stable ring system in the final product.



$$RCH_2\overset{OH}{C}HCH_2CH_2SO_3H \xrightarrow{H+} RCH_2\overset{H-\overset{\oplus}{O}-H}{C}HCH_2CH_2SO_3H \xrightarrow{-H_2O} RCH_2\overset{\oplus}{C}HCH_2CH_2SO_3H$$

$$\downarrow$$

$$RCHCH_2CH_2CH_2SO_2O \xleftarrow{-H^+} R\overset{\oplus}{C}HCH_2CH_2CH_2SO_3H$$

The greater stability of six-membered ring sultones as opposed to the five-membered ring compounds can be explained by assuming a staggered "chair" conformation for the six-membered ring similar to cyclohexane as opposed to a nearly planar five-membered ring sultone, with the subsequent bond oppositions as in cyclopentane.[12] Several relevant facts support this assumption. First, the valence angle of tetravalent sulfur approximates the valence angle of tetrahedral carbon.[13] Second, an oxygen atom (and presumably the same would be true for a sulfur group) may replace a methylene group without markedly influencing the conformational effects.[14] Finally the same differences in the stability of five- and six-membered ring compounds are observed when a hydroxyl group is substituted for a hydrogen[14] and, by analogy, the two oxygen atoms linked by coordinate covalences to the sulfur atom should have little effect. Since the difference in the heats of formation of cyclohexanol and cyclopentanol is −11.3 kcal. per mole[15] and that of cyclohexane and cyclopentane is −11.0 kcal. per mole,[16,17] the difference in the heats of formation of six- and five-membered ring sultones would be expected to be similar.

This order of ring stability is supported by a study of the relative reactivities of several sultones on methanolyis.[18] The five-membered ring sultones, 3-hydroxy-1-propanesulfonic acid sultone, 4-hydroxy-2-butanesulfonic acid sultone, and tolyl sultone reacted with methanol much more rapidly than the six-membered ring sultone, 4-hydroxy-1-butanesulfonic acid sultone. Furthermore, on treating a mixture of 4-hydroxy-2-butanesulfonic acid sultone and 4-hydroxy-1-butanesulfonic acid sultone with methanol, the former was almost completely converted to the methoxyalkanesulfonic acid before the latter had reacted appreciably. This same order of reactivity was also reported with other nucleophilic reagents such as pyridine, sodium thiophenoxide, etc.

This order of reactivity is exactly opposite in the lactone series, δ-valerolactone hydrolyzing in basic solution at a rate which is twenty-two times that of γ-valerolactone.[19] The greater stabilization of five-

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[12] W. G. Dauben and K. S. Pitzer in M. S. Newman, "Steric Effects in Organic Chemistry," John Wiley & Sons, New York, N. Y., 1956.

[13] C. M. Suter, "The Organic Chemistry of Sulfur," John Wiley & Sons, New York, N. Y., 1944, p. 658.

[14] H. C. Brown, J. H. Brewster and H. Shechter, *J. Am. Chem. Soc.*, **76**, 467 (1954).

[15] G. S. Parks, J. R. Mosley, and P. V. Peterson, Jr., *J. Chem. Phys.*, **18**, 152 (1950).

[16] R. Spitzer and H. M. Huffman, *J. Am. Chem. Soc.*, **69**, 211 (1947).

[17] "Selected Values of Properties of Hydrocarbons," Circular of the National Bureau of Standards, C461, U. S. Govt. Printing Office, Washington, D. C., 1947.

[18] J. H. Helberger, J. R. Heyden, and H. Winter, *Ann.*, **586**, 147 (1954); J. H. Helberger and H. Lantermann, *ibid.*, **586**, 158 (1954).

[19] W. Huckel, "Theoretische Grundlagen der Organischen Chemie," Vol. II, 3rd ed., Akademische Verlagsgesellschaft Gust und Portig K-G, Leipsig, 1943, p. 562.

membered ring lactones as compared to six-membered ring lactones has been discussed already.[14]

## Experimental[20]

**Potassium 3-Hydroxy-1-hexanesulfonate.**—1-Chloro-3-hexanol[21] (50.2 g., 0.37 mole) was added to a saturated aqueous solution of potassium sulfite (158.0 g., 1.0 mole) and refluxed with stirring for 15 hr. After partial evaporation of the water and subsequent cooling, a solid crystallized which was filtered and dried. Several extractions with hot methanol and a recrystallization from methanol gave the crystalline potassium sulfonate, yield 42.2 g. (52%), m.p. above 310°.

The potassium sulfonate (0.33 g., 1.47 mmoles) was dissolved in a minimum of ethanol and added to a hot ethanolic solution of S-benzylthiuronium chloride (0.30 g., 1.47 mmoles). An immediate formation of potassium chloride occurred which was filtered after digesting. After partial evaporation of the alcohol, the thiuronium salt was precipitated with the addition of ether. The derivative was recrystallized from dioxane, m.p. 120–122°, yield 0.44 g. (89%).

*Anal.* Calcd. for $C_{14}H_{24}S_2O_4N_2$: C, 48.25; H, 6.94; S, 18.40. Found: C, 48.05; H, 7.15; S, 18.53.

**4-Hydroxy-1-hexanesulfonic Acid Sultone (X).**—Potassium 3-hydroxy-1-hexanesulfonate (38.30 g., 0.174 mole) was dissolved in methanol and passed through a cation exchange resin (Amerlite 1R-120). The methanol was removed under vacuum to give the hydroxysulfonic acid as a viscous, yellow-brown oil, yield 31.51 g. (99.5%).

The hydroxysulfonic acid, upon heating to 130° at 2.4 mm., began to dehydrate. The resulting sultone was obtained as a colorless liquid by distillation, b.p. 127° (2.3 to 2.5 mm.) or 105–107° (0.7 mm.), $n^{25}D$ 1.4586, yield 21.63 g. (76%). Gas chromatographic analysis[22] using silicon rubber and silicon grease columns gave one peak. The same sultone was also obtained by the addition of an alcoholic solution of the acid to boiling xylene and removing the water as a ternary azeotrope.[6]

*Anal.* Calcd. for $C_6H_{12}SO_3$: C, 43.90; H, 7.32; S, 19.51. Found: C, 44.03; H, 7.53; S, 19.40.

The above sultone (1.42 g., 8.05 mmoles) was refluxed in dry pyridine (13.0 g.) for 18 hr. After cooling the reaction mixture, the sulfobetaine derivative was filtered and washed with ether, yield of crude tan material 2.05 g. (98%), m.p. 216–242°. This sulfobetaine derivative was recrystallized from absolute ethanol several times and the mother liquor evaporated to give 1.38 g. (66%), m.p. 250.5–251.5°, and 0.33 g. (16%), m.p. 204–221°. The material with m.p. 250.5–251.5° was identical (no depression on a mixed melting point) with the sulfobetaine obtained from the independently synthesized material and accounts for 81% of the total amount of solid isolated. An infrared spectrum of the material with m.p. 204–221° shows that this still consists largely of the derivative isolated above.

**Hydrolysis of Sultone Obtained from 3-Hydroxy-1-hexanesulfonic Acid.**—The sultone X (2.56 g. 15.5 mmoles), prepared from 3-hydroxy-1-hexanesulfonic acid (IX), was treated with 15 ml. of water and heated until all the sultone had dissolved. Potassium hydroxide (0.87 g., 15.5 mmoles) dissolved in water was added to neutralize the reaction mixture. The potassium salt of the hydroxysulfonic acid was obtained by evaporation of the water and then recrystallized from methanol, m.p. above 310°, yield 2.13 g. (62%). The infrared spectrum indicated a different salt from the hydroxysulfonate from which the sultone was made.

An S-benzylthiuronium salt, obtained by adding the potassium hydroxysulfonate (0.65 g., 2.96 mmoles) dissolved in hot ethanol to an ethanolic solution of S-benzylthiuronium chloride (0.60 g., 2.96 mmoles), was collected and recrystallized from dioxane, yield 0.41 g. (41%), m.p. 121.5–123.5° (reported for the S-benzylthiuronium derivative of 4-hydroxy-1-hexanesulfonate,[7] m.p. 121–122°). A depression was obtained (107–116°) in a mixed melting point with the thiuronium salt of 3-hydroxy-1-hexanesulfonate. Evaporation of the mother liquor gave an oil.

**4-Hydroxy-1-pentanesulfonic Acid Sultone (VI).**—1-Chloro-3-pentanol[21] (40 g., 0.326 mole) was refluxed with stirring for 10 hr. with a solution of potassium sulfite (80.0 g., 0.5 mole) in the minimum amount of water. There was no organic layer remaining at the end of this. Most of the water was removed on a rotary evaporator and the resulting paste dissolved in 300 ml. of methanol. The stirred and refluxed methanolic solution was treated for 4 hr. with a moderate stream of hydrogen chloride. The precipitated potassium chloride was filtered and the methanol removed. The resulting oil was vacuum distilled to remove first the water and then the sultone, b.p. 111–113° (1 mm.), $n^{25}D$ 1.4581 (lit.,[5] b.p. 121–123° (2 mm.), $n^{25}D$ 1.4586); yield 34.5 g. (72.5% based on 1-chloro-3-pentanol).

The sultone was heated with excess pyridine and the precipitated sulfobetaine filtered and dried. After one recrystallization from ethanol–ether, it melted at 245–247°. No depression of melting point was observed in a mixture melting point (245–247°) with the sulfobetaine obtained by Truce and Hoerger[5] from 4-hydroxy-1-pentanesulfonic acid sultone.

**Hydrolysis of 4-Hydroxy-1-pentanesulfonic Acid Sultone.**—The sultone, VI, was refluxed with vigorous stirring in a concentrated, aqueous solution of two equivalents of sodium hydroxide. There was no organic layer remaining after 15 min. of refluxing. The reaction mixture was allowed to cool to room temperature and was treated dropwise with iodine–potassium iodide solution. The resulting iodoform was filtered and dried, m.p. 119° (lit.,[23] 119°).

**Sodium-4-hydroxy-1-hexanesulfonate.**—4-Hydroxy-1-hexene[24] (49.7 g., 0.50 mole) was refluxed with stirring with sodium bisulfite (72.8 g., 0.70 mole) and benzoyl peroxide (1.43 g.) in a solution of 225 ml. water and 225 ml. methanol. After refluxing for 20 hr. the mixture was evaporated to dryness and the hydroxysulfonic acid salt was extracted with methanol. Several recrystallizations from methanol gave the pure salt, yield 21.0 g. (21%).

The S-benzylthiuronium salt was prepared from this sodium salt (1.20 g., 5.9 mmoles) and S-benzylthiuronium chloride (1.20 g., 5.9 mmoles) in absolute ethanol, yield 0.56 g. (28%), m.p. 120–122° (lit.,[7] m.p. 121–122°) after two recrystallizations from dioxane.

A depression of 20° was observed in a mixed melting point with the same derivative from potassium 3-hydroxy-1-hexanesulfonate. No depression was observed on a mixed melting point with the same derivative from 4-hydroxy-1-hexanesulfonic acid.

**4-Hydroxy-1-hexane-sulfonic Acid Sultone.**—The sodium 4-hydroxy-1-hexanesulfonate (19.5 g., 0.095 mole) was dissolved in methanol and passed through a cation exchange resin (Amberlite 1R-120). After removing the methanol, the free acid was dehydrated by heating *in vacuo* and then distilled, b.p. 97–98° (0.5 mm.) [lit.,[7] 153–154° (12 mm.)] yield 6.12 g. (39.2%), $n^{25}D$ 1.4599 (98% pure by gas chromatographic analysis).

The sulfobetaine derivative obtained from the above sultone and refluxing pyridine, m.p. 250–251° (68%) after recrystallization from ethanol, was identical to the sulfobe-

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[20] All boiling and melting points are uncorrected.

[21] E. Fourneau and P. Ramart-Lucas, *Bull. soc. chim. France*, [4] **25**, 366 (1919); H. J. Backer and C. C. Bolt, *Rec. trav. chim.*, **54**, 70 (1935).

[22] Analyses were performed using the Perkin-Elmer Model 154-C and the F and M, temperature programmed, Model 500 vapor fractometers.

[23] R. L. Datta and N. Proasad, *J. Am. Chem. Soc.*, **39**, 453 (1917).

[24] R. W. Freedman and E. I. Becker, *J. Org. Chem.*, **16**, 1701–1711 (1951).

TABLE I

INTERMEDIATES IN THE INDEPENDENT SYNTHESIS OF $ArCHR(CH_2)_3SO_3Na$

| Compound | Yield, % | B.p. °C. | B.p. Mm. | $n_D$ (t, °C.) |
|---|---|---|---|---|
| $C_6H_5CH(C_2H_5)(CH_2)_2COOH$[a] | 56.5 | 136–139 | 3.0 | |
| $C_6H_5CH(CH_3)(CH_2)_2COOH$[b] | 72.5 | 133 | 0.7 | |
| $C_6H_5CH(C_2H_5)(CH_2)_3OH$[c] | 91.2 | 135–139 | 7.5 | 1.5140 (20) |
| $C_6H_5CH(CH_3)(CH_2)_3OH$[d] | 64.5 | 106 | 2.0 | 1.5210 (21) |
| $C_6H_5CH(C_2H_5)(CH_2)_3Br$[e] | 72.5 | 115–119 | 5.0 | 1.5306 (20) |
| $C_6H_5CH(CH_3)(CH_2)_3Br$[f] | 77.5 | 105 | 2.2 | 1.5382 (18) |

[a] Lit.,[27] b.p. 160–163° (5 mm.) and 185° (22 mm.). [b] Lit.,[28,29] b.p. 147° (1 mm.). [c] Lit.,[29] b.p. 125° (5 mm.). [d] Lit.,[29] b.p. 109° (1 mm.). [e] Lit.,[29] b.p. 125° (3 mm.). [f] Lit.,[29] b.p. 125° (15 mm.).

taine derivative of the sultone prepared from 3-hydroxy-1-hexanesulfonic acid. On evaporation of the mother liquor more of the same sulfobetaine was obtained, m.p. 248–251°.

*Anal.* Calcd. for $C_{11}H_{17}O_3SN$: C, 54.21; H, 7.04; N, 5.76; S, 13.15. Found: C, 54.57; H, 7.28; N, 5.59; S, 13.00.

**Hydrolysis of 4-Hydroxy-1-hexanesulfonic Acid Sultone.**—The above sultone prepared from the 4-hydroxy-1-hexanesulfonic acid was hydrolyzed back to the original acid.[7] The infrared spectra of the two salts were identical and the S-benzylthiuronium salt, m.p. 121–123° (lit.,[7] 121–122°) of the hydrolyzed material was identical to the derivative of 4-hydroxy-1-hexanesulfonic acid. A depression was observed in a mixed melting point of the thiuronium salt of 3-hydroxy-1-hexanesulfonic acid.

**Friedel-Crafts Reaction of the Sultone with Benzene.**—The six-membered ring sultones prepared from 3-hydroxy-1 pentane- and 3-hydroxy-1-hexanesulfonic acids were dissolved in excess benzene and an equal molar amount of aluminum chloride added according to the method of Truce and Hoerger.[5] After refluxing, the reaction mixture, cooled to room temperature, was poured with stirring over a slurry of ice and hydrochloric acid. The aqueous layers were neutralized and the water removed. After the residue was extracted three times with hot absolute ethanol, the ethanol was evaporated and the resulting potassium sulfonate dried.

| | Yield, % | S-benzylthiuronium salt,[25] m.p., °C. |
|---|---|---|
| Sodium 4-phenyl-1-pentanesulfonate | 45 | 142.5–143.5 |
| Sodium 4-phenyl-1-hexanesulfonate | 61 | 100–103 |

**Independent Synthesis of 4-Arylalkanesulfonates.**—The properties of the intermediates utilized in the independent synthesis of the sulfonates are shown in Table I. Both 4-arylalkanoic acids were prepared by Friedel-Crafts reaction of benzene with γ-valerolactone and γ-caprolactone.[26] The alcohols reported in Table I were prepared by reducing the corresponding acid with lithium aluminum hydride. The bromides were prepared by the action of phosphorus tribromide on the alcohols.

The sulfonates were obtained from the bromides by refluxing with excess potassium sulfite in water and ethylene glycol. After removing the water, the mixture was acidified and heated to remove all sulfur dioxide. The sulfonate was isolated in the form of the barium salt and then converted to the sodium salt with sodium sulfate. The sodium sulfonate was recrystallized from hot aqueous ethanol.

| | Yield, % | S-benzylthiuronium salt,[25] m.p., °C. |
|---|---|---|
| Sodium 4-pheny-1-pentane sulfonate[a] | 86 | 142.5–143.5 |
| Sodium 4-phenyl-1-hexanesulfonate[b] | 53 | 102–104 |

[a] S-benzylthiuronium salt: *Anal.* Calcd. for $C_{19}H_{26}O_3N_2S_2$: C, 57.8; H, 6.65; N, 7.1. Found: C, 57.79; H, 6.90; N, 6.90. The *p*-toluidine salt crystallized slowly over a period of 1 week, and after one recrystallization from 50% ethanol, m.p. 117–117.5°. [b] S-benzythiuronium salt: *Anal.* Calcd. for $C_{20}H_{28}O_3N_2S_2$: C, 58.79; H, 6.91; N, 6.87. Found: C, 59.10; H, 6.97; N, 6.63.

The sodium and the S-benzylthiuronium salts were identical with those derived from the Friedel-Crafts reaction of the sultones.

**Acknowledgment.**—The authors are indebted to the National Science Foundation (Grant G-9929) and the National Cancer Institute, National Institutes of Health (Grant CY-4536), for financial support of this work.

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(25) R. L. Shriner, R. C. Fuson, and D. Y. Curtin, "The Systematic Identification of Organic Compounds," 4th ed., John Wiley & Sons, New York, N. Y., 1956, p. 269.

(26) R. V. Christian, Jr., *J. Am. Chem. Soc.*, **74**, 1591 (1952); W. L. Mosby, *ibid.*, **74**, 2564 (1952); W. E. Truce and C. E. Olson, *ibid.*, **74**, 4721 (1952).

(27) M. C. Kloetzel and H. L. Herzog, *J. Org. Chem.*, **15**, 370–373 (1950); Levy, *Compt. rend.*, **197**, 772 (1933).

(28) J. F. Eijkman, *Chem. Zentr.*, **75**, 1416 (1904).

(29) P. A. Levene and R. E. Marker, *J. Biol. Chem.*, **110**, 329 (1935).