long to the same botanical family. Such was found to be the case with the oil from yellow mustard seed; but the oil from the black mustard seed yielded less erucic acid. The quantitative results were as follows.

TABLE XI

VALUES FOR MUSTARD-SEED OILS

Seed	Erucic acid product, %	Iodine no.	M. p., °C.	Mol. wt.
Yellow	40.9	71.9	26	331
Black	34.4	79.0	26–27	328

Summary and Conclusions

1. The solubility of magnesium erucate in mixtures of ethyl alcohol and water has been determined and it has been shown that a satisfactory separation from other unsaturated magnesium soaps can be effected.
2. The solubility of lead erucate in anhydrous ether has been measured and the unreliability of anhydrous ether as a solvent demonstrated.
3. The solubilities of behenic, stearic and erucic acids at 10° and 0° have been determined.
4. A new direct criterion of purity of rapeseed oil is proposed based on the separation of magnesium erucate along with the small amounts of saturated soaps present, in 90% alcohol and the subsequent isolation of erucic acid in almost pure form from which behenic acid is obtained by hydrogenation in presence of a catalyst.
5. A semi-quantitative method for olive-rapeseed, olive-cottonseed oil mixtures is suggested.
6. The method does not distinguish rapeseed oil from mustard seed oil, since the latter like the former yields a large proportion of erucic acid.

NEW YORK, N. Y.

[CONTRIBUTION FROM THE BAKER LABORATORY OF CHEMISTRY, CORNELL UNIVERSITY]

THYMOLSULFONEPHTHALEIN, THE INTERMEDIATE ACID, 4'-HYDROXY - 3' - ISOPROPYL - 6' - METHYL - BENZOYLBENZENE-2-SULFONIC ACID AND SOME OF THEIR DERIVATIVES

BY W. R. ORNDORFF AND RALPH T. K. CORNWELL[1]

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Thymolsulfonephthalein was first made by Lubs and Clark[2] from the chlorides of *o*-sulfobenzoic acid and thymol. They also prepared its di-

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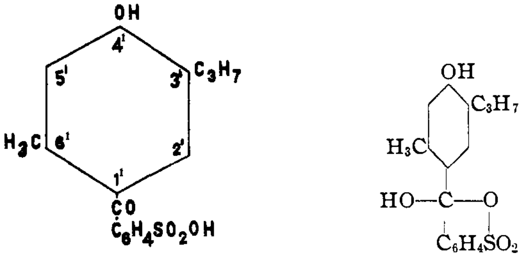
[1] From a dissertation presented by Ralph T. K. Cornwell in partial fulfilment of the requirements for the degree of Doctor of Philosophy. An abstract of this paper was read before the Organic Division of the American Chemical Society at the meeting in Ithaca, N. Y., Sept. 8–13, 1924.

We wish here to express our appreciation to the Monsanto Chemical Works, St. Louis, Mo., who very kindly furnished gratis the saccharin used in this work.

[2] Lubs and Clark, *J. Washington Acad. Sci.*, **5**, 614 (1915); **6**, 481 (1916).

bromo derivative. These indicators are known as *Thymol Blue* and *Dibromothymol Blue.* Thymolnitrosulfonephthalein is described by Lubs and Acree.[3] Although investigations[3] have been made regarding the use of these substances as indicators, very little is known about the chemistry of thymolsulfonephthalein. Therefore, this investigation was undertaken to study the methods for the preparation of thymolsulfonephthalein and to see whether derivatives of it characteristic of the other sulfonephthaleins could be made.

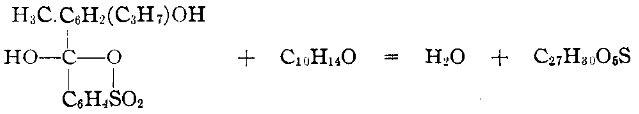
Using the method of Lubs and Clark[2] both thymolsulfonephthalein and the isomeric dithymyl *o*-sulfobenzoate were obtained from the isomeric dichlorides of *o*-sulfobenzoic acid. Because of the small yields of the pure thymolsulfonephthalein this method was abandoned and the condensation of thymol with the anhydride of *o*-sulfobenzoic acid was studied; 55% yields of thymolsulfonephthalein were obtained by the latter method. In accordance with other investigations[4] carried out in this Laboratory on the sulfonephthaleins, it was found that the formation of thymolsulfonephthalein in this way takes place in two stages. First, a molecule of the anhydride combines with a molecule of thymol to form an addition compound, a tautomeric substance called the *intermediate acid* (I),



(Ketone form) (Lactone form)

(I) 4'-Hydroxy-3'-*iso*propyl-6'-methyl-benzoyl-benzene-2-sulfonic acid.

and then the intermediate acid reacts with another molecule of thymol as follows.



$$\begin{array}{c} H_3C.C_6H_2(C_3H_7)OH \\ | \\ HO-C-O \\ |\quad\;\;| \\ C_6H_4SO_2 \end{array} + C_{10}H_{14}O = H_2O + C_{27}H_{30}O_5S$$

Intermediate acid Thymol Water Thymolsulfonephthalein

That the intermediate acid is a tautomeric, γ-ketone acid was proved by making derivatives of both the ketone form and the lactone form. Its

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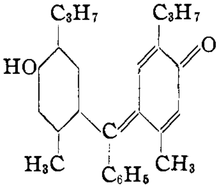
[3] Lubs and Acree, THIS JOURNAL, **38**, 2772 (1916). Clark and Lubs, *ibid.*, **40**, 1443 (1918). Gillespie, *ibid.*, **42**, 742 (1920). Scales, *Science*, **51**, 215 (1920). Evers, *Analyst*, **46**, 392 (1921). Lizius and Evers, *ibid.*, **47**, 331 (1922). Kolthoff, *Rec. trav. chim.*, **40**, 755 (1921); **43**, 144 (1924). Simpson, *Ind. Eng. Chem.*, **16**, 709 (1924).

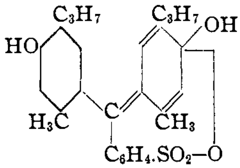
[4] Orndorff and Sherwood, THIS JOURNAL, **45**, 486 (1923). Orndorff and Vose, *ibid.*, **46**, 1896 (1924).

structure was proved by fusing it with potassium hydroxide and identifying the *p*-thymotic acid[5] thus formed.

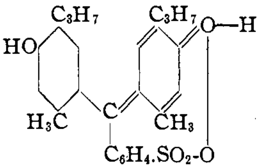
Since thymolsulfonephthalein is a highly *colored* substance it is given the *quinoid* structure. Mr. H. T. Lacey, working in this Laboratory, has found that thymolbenzein (II), the mother substance of thymolsulfonephthalein, has basic properties. Therefore, the *anhydrous* thymolsulfonephthalein is represented as an inner carbonium (III) or inner oxonium (IV) salt. That it is an inner salt is also indicated by the fact that the anhydrous material combines with dry ammonia gas, but not with dry hydrogen chloride (like taurine).



(II) Thymolbenzein



(III) Thymolsulfonephthalein (inner carbonium salt)



(IV) Thymolsulfonephthalein (inner oxonium salt)

The crystalline material always contains about one molecule of water per molecule of substance and is probably a solid solution of the inner carbonium or inner oxonium salt and the quinoid hydrate.[4] Thymolsulfonephthalein reacts as a tautomeric substance and *colorless* derivatives of the *lactoid* form and *colored* derivatives of the *quinoid* form were made. It has not been isolated in the *colorless*, *lactoid* form, although dibromothymolsulfonephthalein has.

Two forms of the dimethyl ether of thymolsulfonephthalein were obtained, a *colorless*, stable derivative of the *lactoid* form and a *colored*, unstable derivative of the *quinoid* form of the inner carbonium or oxonium salt.[6]

The magenta color of a strong acid solution (*P*H 1.2–2.8) of thymolsulfonephthalein is probably caused by the formation of a salt of the quinoid form with the acid. Weaker acid solutions, neutral solutions and alkaline solutions (*P*H 2.8–8.0) are yellow and stronger alkaline solutions (*P*H 8.0–9.6) are blue. Dilute aqueous solutions of the monosodium salt of thymolsulfonephthalein are yellow; those of the disodium salt, blue.

Thymolsulfonephthalein combines with one molecular proportion of aniline to form a salt and it reacts with two molecular proportions of aniline with the loss of water to form a green dianilino compound, which is a dimethyl-di-*iso*propyl derivative of the diphenylaminesulfonephthalein described by Orndorff and Sherwood.[4]

Dibromothymolsulfonephthalein was isolated in the *colorless*, *lactoid*

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[5] Kobek, *Ber.*, **16**, 2102 (1883).

[6] Orndorff and Shapiro, THIS JOURNAL, **46**, 2856 (1924).

form. It forms a *colored, quinoid* hydrate from which water may be driven off leaving the colorless dibromo compound.

It was found that one molecule of sodium hydroxide could be added to a solution of thymolsulfonephthalein and to a solution of dibromothymolsulfonephthalein before a permanent blue color was formed.

Thymolsulfonephthal*ein* forms a stable, colorless reduction product, thymolsulfonephthal*in*. The reduction product and its zinc salt were made.

Experimental Part

The sulfur and halogen determinations were made by means of the Parr bomb. De Roode's method was used for the combustion analyses. The melting points recorded are uncorrected. They were determined in an electrically heated Thiele-Dennis apparatus[7] using a thermometer that had been standardized by the Bureau of Standards. To determine the loss in weight of a substance on heating, a platinum boat containing the substance was suspended in an electrically heated tube[8] on an asbestos support, to prevent contact with the hot glass. A slow current of dry air or carbon dioxide was passed through the tube during the heating. International Atomic Weights for 1925[9] were used in the computations.

Reaction of Thymol with the Chlorides of *o*-Sulfobenzoic Acid.—A modification of the method of Remsen and Dohme[10] was used to prepare the chlorides. One hundred g. (1 mole) of the pure acid ammonium salt of *o*-sulfobenzoic acid, made by the hydrolysis of saccharin,[11] and 238 g. (about 2.5 moles) of phosphorus pentachloride were heated in a boiling water-bath for three or four hours until the evolution of hydrogen chloride ceased. Then the phosphorus oxychloride was completely removed by distillation under reduced pressure at 98°. The sulfonechlorides were then extracted with dry ether or were distilled under reduced pressure. The first method is the better one; 98% yields of the pure, dry sulfonechlorides may be quickly and easily obtained in this way.

Condensations of thymol with the sulfonechlorides were tried both without condensing agents and with zinc chloride and aluminum chloride. At 100–110° the main product of the reaction proved to be the dithymyl *o*-sulfobenzoate (Orndorff and Sherwood[4]) and only small yields (10–15%) of pure thymolsulfonephthalein were obtained. At higher temperatures large amounts of tar resulted.

Dithymyl *o*-Sulfobenzoate.—The material obtained by the condensa-

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[7] Dennis, *J. Ind. Eng. Chem.*, **12**, 366 (1920).

[8] Chamot and Pratt, THIS JOURNAL, **32**, 635 (1910). Orndorff and Nichols, *Am. Chem. J.*, **48**, 477 (1912).

[9] THIS JOURNAL, **47**, 600 (1925).

[10] Remsen and Dohme, *Am. Chem. J.*, **2**, 340 (1889).

[11] Blackshear, *Am. Chem. J.*, **14**, 455 (1892).

tion of the chlorides of *o*-sulfobenzoic acid with thymol which was insoluble in cold, 5% aqueous sodium hydroxide solution was dissolved in methanol and the solution boiled with Norit until colorless. On concentration of this solution colorless, transparent crystals separated. After recrystallization from petroleum ether, the dry material (m. p., 102–103°) was analyzed.

Anal. Subs., 0.7464, 0.6610: $BaSO_4$, 0.3714, 0.3324. Calcd. for $C_{27}H_{30}O_5S$: S, 6.88. Found: 6.84, 6.91.

The ester is insoluble in cold, aqueous solutions of sodium hydroxide. It is slowly saponified by boiling aqueous and by cold alcoholic solutions of sodium hydroxide. It dissolves in concd. sulfuric acid with development of a red color. It is fairly soluble in benzene and easily soluble in ether. We were unable to transform dithymyl *o*-sulfobenzoate into the isomeric thymolsulfonephthalein by warming with an equivalent amount of either aluminum chloride or stannic chloride.[12]

Preparation of Thymolsulfonephthalein from the Anhydride of *o*-Sulfobenzoic Acid and Thymol.—Eighty-six g. of the anhydride,[13] 140 g. of thymol and 10 g. of freshly fused zinc chloride were heated at 105–110° for 30 hours. Water was then added to the dark purple mass thus formed and the unchanged thymol removed by distillation in steam. Small green crystals of *pure* thymolsulfonephthalein separated, which were filtered off, treated with ether to remove the last traces of thymol, and air dried; yield, 120 g., or 55%. The intermediate acid was isolated from the filtrate (see below). At lower temperatures and at 120–125°, 30–35% yields of the sulfonephthalein were obtained. Above 125° a green tar was formed, which was not further investigated. Without the zinc chloride the yield of thymolsulfonephthalein was about 4%.

The Intermediate Acid, 4′-Hydroxy-3′-*iso*propyl-6′-methyl-benzoyl-benzene-2-sulfonic Acid.—The filtrate mentioned above was concentrated under reduced pressure at 98°. The intermediate acid separated when the hot solution was saturated with hydrogen chloride and was purified by recrystallization from concd. hydrochloric acid. It contained two molecules of water of crystallization per molecule of substance and no hydrogen chloride.

Anal. Subs., 1.1467, 1.2135: loss at 100–105°, 0.1127, 0.1188. Subs., 0.5824, 0.4201: $BaSO_4$, 0.3672, 0.2614. Subs.,[14] 1.1999: cc. of 0.1 *N* NaOH, 32.41. Calcd. for $C_{17}H_{18}O_5S + 2H_2O$: H_2O, 9.73; S, 8.66; mol. wt., 370.24. Found: H_2O, 9.83, 9.79; S, 8.66, 8.55; mol. wt., 370.2.

Subs. (dry), 0.4895, 0.5517: $BaSO_4$, 0.3421, 0.3915. Subs. (dry), 0.1930, 0.1748: CO_2, 0.4351, 0.3916; H_2O, 0.0950, 0.0866. Subs., 0.5295: 15.87 cc. of 0.1 *N* NaOH.

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[12] Csányi, *Ber.*, **52**, 1792 (1919).

[13] Cobb, *Am. Chem. J.*, **35**, 502 (1906). White and Acree, THIS JOURNAL, **41**, 1197 (1919).

[14] The molecular weight was determined by titration with 0.1 *N* sodium hydroxide solution using methyl red as the indicator.

Calcd. for $C_{17}H_{18}O_6S$: C, 61.04; H, 5.43; S, 9.59; mol. wt., 334.208. Found: C, 61.48, 61.10; H, 5.51, 5.54; S, 9.60, 9.77; mol. wt., 333.65.

An aqueous solution of the acid gives a blue color with aqueous ferric chloride solution, which is destroyed by acids. The intermediate acid is slightly soluble in benzene, toluene and petroleum ether at room temperature but readily soluble in the hot solvents. It is very soluble in methanol, ethanol, acetone and glacial acetic acid but insoluble in chloroform and carbon tetrachloride.

Above 150° the acid slowly decomposes to form thymolsulfonephthalein, the anhydride of *o*-sulfobenzoic acid and water. In the presence of zinc chloride this decomposition takes place at 135°. The acid reacts with thymol in the presence of zinc chloride at 85° to form thymolsulfonephthalein and water.

To prove its structure, 2 g. of the intermediate acid was dissolved in 10 cc. of water in a nickel crucible and fused with 10 g. of potassium hydroxide at 200–220° for two hours. When cool the fused mass was dissolved in water and acidified with hydrochloric acid. A substance separated, which on recrystallization from ethanol proved to be *p*-thymotic acid.[5] Therefore, the hydroxyl group in the intermediate acid is in the *para* position to the ketone carbon atom.

The following derivatives of the tautomeric forms of the intermediate acid were made.

AMMONIUM SALT.—The pure, anhydrous intermediate acid (0.9801 g.) was saturated with dry ammonia gas. A stable mono-ammonium salt was formed by removing the excess of ammonia in a desiccator over sulfuric acid.

Anal. Subs., 0.9801: gain, 0.0499. Calcd. for $C_{17}H_{18}O_6S + NH_3$: NH_3, 4.85. Found: 4.85.

BARIUM SALT.—An aqueous solution of the pure intermediate acid was boiled with an excess of barium carbonate for 30 minutes. After the hot solution had been filtered, the barium salt of the intermediate acid crystallized from the concentrated filtrate with six molecules of water. It was purified by recrystallization from water.

Anal. Subs., 1.7054, 1.1106: loss at 150°, 0.2072, 0.1348. Subs., 2.1388: $BaSO_4$ 0.5485. Calcd. for $(C_{17}H_{17}O_6S)_2Ba + 6H_2O$: H_2O, 11.85; Ba, 15.06. Found: H_2O, 12.15, 12.14; Ba, 15.09.

Subs. (dry), 0.1335: $BaSO_4$, 0.0386. Calcd. for $(C_{17}H_{17}O_6S)_2Ba$: Ba, 17.09. Found: 17.02.

Professor Vieweg of the Department of Geology describes the crystals as follows. "The crystals have a tabular habitus, and are rectangular in shape. The crystallization is orthorhombic. Considering the large faces on which most of the crystals lie as the basal pinacoid, (001), the other forms seen in most cases are the macro-dome, (101), the brachy-dome and the prism (110). The prism angle, 110 to $1\bar{1}0$, is 28°, as measured with the microscope."

THE DIBENZOATE.—Five g. of the pure, dry intermediate acid was dissolved in 10 cc. of benzoyl chloride. The excess of benzoyl chloride was evaporated in a water-oven through which a current of dry air passed. The colorless residue was crystallized first from dry ether and then from dry benzene. Long, colorless, transparent needles, m. p. 119–120°, which did not lose any weight at 110°, were obtained.

Anal. Subs., 0.2203, 0.2554: $BaSO_4$, 0.0945, 0.1101. Calcd. for $C_{17}H_{16}O_5S(COC_6H_5)_2$: S, 5.91. Found: 5.89, 5.92.

The dibenzoate is insoluble in cold water. It is hydrolyzed by boiling water and aqueous sodium hydroxide solutions. It reacts with boiling ethanol to form the intermediate acid and ethyl benzoate. It is very soluble in acetone; less soluble in toluene, xylene and petroleum ether.

Thymolsulfonephthalein.—Analyses of the sulfonephthalein made from the anhydride of *o*-sulfobenzoic acid show that it contains about 1 molecule of water per molecule of substance.

Anal. Subs., 0.6670, 0.6803, 0.4068, 1.0945: loss at 150°, 0.0220, 0.0215, 0.0129 0.0359. Calcd. for $C_{27}H_{30}O_5S + H_2O$: H_2O, 3.72. Found: 3.30, 3.16, 3.17, 3.28.

Subs. (dry), 0.3930, 0.4963: $BaSO_4$, 0.1961, 0.2462. Subs., 0.0738, 0.1100: CO_2, 0.1875, 0.2799; H_2O, 0.0427, 0.0649. Calcd. for $C_{27}H_{30}O_5S$: C, 69.48; H, 6.49; S, 6.88. Found: C, 69.29, 69.40; H, 6.48, 6.62; S, 6.85, 6.81.

Thymolsulfonephthalein dissolves in a saturated aqueous solution of sodium bicarbonate with development of a red color, which changes to yellow on dilution. It dissolves in a 10% aqueous sodium carbonate solution and in ammonium hydroxide with development of a blue color. Solutions in 10% aqueous sodium hydroxide are purple and the color changes to blue when the solutions are diluted. When the alkaline solutions of thymolsulfonephthalein are acidified at room temperature, the sulfonephthalein is precipitated as an amorphous red powder. When the alkaline solutions are acidified at their boiling points, green crystals of the sulfonephthalein separate. Thymolsulfonephthalein is slightly soluble in dilute acids forming yellow solutions and the color changes to magenta upon the addition of strong acids. It dissolves in concd. sulfuric acid with development of a bright red color. It is slightly soluble in cold water forming a yellow solution and more soluble in boiling water with development of a red color. It can be crystallized from ether and glacial acetic acid. It is slightly soluble in acetone, chloroform, benzene, toluene, xylene, ethyl acetate and carbon tetrachloride. It dissolves in aniline, monomethylaniline and dimethylaniline forming red solutions. The color of the aniline solution changes to green on boiling; the color of the monomethylaniline and dimethylaniline solutions does not change on boiling.

The crystalline thymolsulfonephthalein when ground forms a chocolate-brown powder, which begins to lose water at 59°. At 195° it turns red and slowly shrivels. Between 200° and 220° slight carbonization takes place and it melts to form a crimson, opaque liquid.

Professor Vieweg of the Department of Geology describes the crystals of thymolsulfonephthalein as follows.

They are "very small crystals requiring the use of the highest power to see them. They are green by reflected light and red by transmitted light. Under the polarizing microscope they are seen to be strongly pleochroic. The crystals, which are elongated.

absorb light very strongly in the direction of elongation, the crystals appearing practically black. At right angles, light varying from yellowish-orange to orange-red, depending on the thickness, is transmitted. The crystals showed parallel extinction, and are therefore not monoclinic or triclinic."

Titration of Thymolsulfonephthalein.—Carefully measured portions (50 cc., 75 cc., 100 cc., 150 cc.) of a red solution of 0.1658 g. of pure, dry thymolsulfonephthalein in 500 cc. of absolute ethanol were diluted with distilled water until the color changed to a bright yellow. The resulting solutions were titrated with 0.01 *N* sodium hydroxide solution, using a small 10cc. buret graduated in 0.05 cc. The first appearance of a faint, permanent absorption band in the yellow part of the spectrum, determined by means of a small direct vision pocket spectroscope, was taken as the end-point. The results of the titration, listed in Table I, show that one molecular equivalent of sodium hydroxide can be added to a solution of thymolsulfonephthalein before the color change from yellow to blue takes place.

TABLE I

TITRATION OF THYMOLSULFONEPHTHALEIN

Thymolsulfonephthalein, g.	0.01 *N* NaOH, cc. Calcd.	Found	One molecular equivalent NaOH, %
0.01658	3.56	3.57	100.3
.02487	5.33	5.35	100.4
.03316	7.11	7.15	100.5
.04974	10.67	10.71	100.4

This agrees with the work of Lubs and Acree.[3]

The following derivatives of the tautomeric forms of thymolsulfonephthalein were made.

AMMONIUM SALT.—A sample of the pure, dry thymolsulfonephthalein absorbed about 3 molecules of dry ammonia gas. The resulting material was purple, and aqueous solutions of it were blue. On standing in an evacuated desiccator over concd. sulfuric acid the excess of ammonia was lost and a stable, red mono-ammonium salt resulted. Dilute aqueous solutions of the mono-ammonium salt are yellow.

Anal. Subs., 1.0340: gain, 0.0394. Calcd. for $C_{27}H_{30}O_5S + NH_3$: NH_3. 3.52. Found: 3.67.

ZINC SALT.—An aqueous suspension of thymolsulfonephthalein was boiled with an excess of zinc carbonate until all of the thymolsulfonephthalein had dissolved. After filtration, orange-red plates of the zinc salt of the sulfonephthalein with 5 molecules of water crystallized from the concentrated filtrate.

Anal. Subs., 0.8838: loss at 110°, 0.0734. Calcd. for $(C_{27}H_{29}O_5S)_2Zn + 5H_2O$: H_2O, 8.29. Found: 8.31.

Subs. (dry), 0.3065, 0.5061: $ZnNH_4PO_4$, 0.0552, 0.0920. Calcd. for $(C_{27}H_{29}O_5S)_2Zn$: Zn, 6.56. Found: 6.60, 6.66.

The zinc salt is very soluble in water with development of a red color which changes to yellow on dilution. The zinc salt is soluble in ether, acetone, methanol and ethanol.

MONOSODIUM SALT.—On allowing a filtered solution of 5 g. of pure thymolsulfonephthalein in 2 liters of a saturated aqueous sodium bicarbonate solution to stand for several hours, a brick-red salt separated which was filtered off, air-dried and extracted with acetone. The acetone extracts were evaporated to dryness and the residue was crystallized from ethyl acetate. Orange-red crystals of the monosodium salt of thymolsulfonephthalein containing about 1 molecule of ethyl acetate per molecule of substance were obtained.

Anal. Subs., 0.1415, 0.8755, 1.0069: loss at 150°, 0.0166, 0.1131, 0.1133. Calcd. for $C_{27}H_{29}O_5SNa + CH_3.COOC_2H_5$: $CH_3CO_2C_2H_5$, 15.27. Found: 11.71, 12.91, 11.25.

Subs. (dry), 0.2830, 0.4621: $BaSO_4$, 0.1360, 0.2233. Subs., 0.1245: Na_2SO_4, 0.0187. Calcd. for $C_{27}H_{29}O_5SNa$: S, 6.57; Na, 4.71. Found: S, 6.60, 6.64; Na, 4.86.

The anhydrous salt is brown and is hygroscopic. It becomes red as water is taken up. It is very soluble in cold water, methanol, ethanol and ethyl acetate, slightly soluble in ether and carbon tetrachloride, and insoluble in benzene, toluene and petroleum ether. It dissolves in aniline with development of a red color that does not change when the solution is boiled. Concd. aqueous solutions of the salt are red; dilute solutions are yellow.

DISODIUM SALT.—Two g. of pure thymolsulfonephthalein was added to a solution of 1 g. of sodium in 100 cc. of absolute ethyl alcohol. After the mixture had been boiled for two hours and then concentrated to crystallization, very small, dark blue crystals of the disodium salt with 2 molecules of alcohol were obtained.

Anal. Subs., 0.1065: loss at 165°, 0.0154. Calcd. for $C_{27}H_{28}O_5SNa_2 + 2C_2H_5OH$: C_2H_5OH, 15.28. Found: 14.46.

Subs. (dry), 0.1046: Na_2SO_4, 0.0292. Calcd. for $C_{27}H_{28}O_5SNa_2$: Na, 9.01. Found: 9.04.

The disodium salt is soluble in water, methanol and acetone. The solutions are blue. It dissolves in ethyl acetate with development of a red color. It is slightly soluble in ether and insoluble in chloroform, carbon tetrachloride, benzene, toluene, xylene and aniline.

DIACETATE.—A solution of 5 g. of pure thymolsulfonephthalein in 100 cc. of acetic anhydride was boiled for ten minutes. On pouring the solution into ice water the diacetate solidified. It was filtered off, air-dried and crystallized from ether. Colorless, transparent crystals melting at 171–172° were thus obtained.

Anal. Subs., 0.6281, 0.5890: $BaSO_4$, 0.2626, 0.2518. Calcd. for $C_{27}H_{28}O_5S(COCH_3)_2$: S, 5.84. Found: 5.74, 5.87.

The diacetate is soluble in methanol, ethanol, petroleum ether, glacial acetic acid, benzene, toluene, xylene, chloroform and carbon tetrachloride. It is insoluble in cold water. It is slowly hydrolyzed by boiling water and slowly saponified by hot aqueous solutions of sodium hydroxide. An alcoholic solution of sodium hydroxide saponifies the acetate in the cold. It dissolves in concd. sulfuric acid with development of a red color, undergoing hydrolysis.

DIBENZOATE.—This was made from the pure thymolsulfonephthalein in the same way that the dibenzoate of the intermediate acid was prepared. It can also be made by the Schotten-Baumann reaction. Colorless prisms, m. p. 194–195°, were obtained by crystallization from petroleum ether.

Anal. Subs., 0.6443, 0.5560, 0.8866: $BaSO_4$, 0.2268, 0.1933, 0.3012. Calcd. for $C_{27}H_{28}O_5S(CO.C_6H_5)_2$: S, 4.75. Found: 4.84, 4.78, 4.67.

It is soluble in ether, methanol, ethanol, benzene, toluene and xylene, insoluble in water, and slowly hydrolyzed by boiling water. It is slowly saponified by an alcoholic solution of sodium hydroxide. It dissolves in conc. sulfuric acid with development of a red color, undergoing hydrolysis.

The dibenzoate is more stable than the diacetate. The latter turns pink on standing in a glass vial for some time.

DIMETHYL ETHER. *A. Colorless Form.*—A solution of 25 g. of pure thymolsulfonephthalein in 1 liter of methyl alcohol containing 3% of hydrogen chloride was boiled for 25 hours. On concentrating to crystallization the colorless dimethyl ether of thymolsulfonephthalein crystallized with some of the unchanged sulfonephthalein. The mixture was filtered off, dried and the dimethyl ether separated from the sulfonephthalein by extraction with cold, dry ether. The dimethyl ether of thymolsulfonephthalein crystallized from the concentrated ethereal extracts and a colorless product was obtained by recrystallization from either acetic anhydride or glacial acetic acid. On standing in a glass vial for several months the dimethyl ether slowly assumes a light flesh color.

The dimethyl ether may also be made by boiling some of the sulfonephthalein for a longer time with methyl alcohol alone.

The dimethyl ether turns red at 195° and the colored product melts sharply at 201–202°.

Anal. Subs., 0.4352, 0.4119: $BaSO_4$, 0.2067, 0.1950. Subs., 0.2793: AgI, 0.2668. Calcd. for $C_{27}H_{28}O_3S(OCH_3)_2$: S, 6.49; OCH_3, 12.55. Found: S, 6.52, 6.50; OCH_3. 12.62.

The dimethyl ether is insoluble in cold water and is not changed by boiling water. It is insoluble in a 10% aqueous sodium hydroxide solution. On standing in contact with the aqueous sodium hydroxide solution for several months the crystals of the dimethyl ether slowly disintegrate and become yellow and the solution assumes a greenish-yellow color. At the same time colorless plates, which are probably crystals of the sodium salt of the carbinol acid of the dimethyl ether of thymolsulfonephthalein, separate from the solution.

The dimethyl ether is slowly saponified by boiling with an aqueous solution of sodium hydroxide and more quickly saponified by an alcoholic solution of sodium hydroxide. It dissolves in concd. sulfuric acid forming a red solution and is slowly hydrolyzed by boiling with dil. hydrochloric acid. When it is heated with aniline it reacts to form the green dianilino derivative of thymolsulfonephthalein. The dimethyl ether does not take up either dry hydrogen chloride or dry ammonia at room temperature or at 100–105°.

The dimethyl ether dissolves in methanol and in ethanol forming a red solution. It is soluble in ether, acetone, chloroform, ethyl acetate, hot benzene and hot toluene without development of color. The dimethyl ether is soluble in boiling acetophenone and in boiling phenyl iodide and the solutions are brilliant red. From these highly colored solutions the colorless dimethyl ether crystallizes on cooling.

B. Colored Form.—A sample (0.3621 g.) of the pure, dry, colorless dimethyl ether was heated in the electrically heated tube[8] in a platinum boat for two minutes at 180°. The whole mass turned a deep purple color and partially melted. There was no appreciable change in weight. The *colored* form of the dimethyl ether absorbs neither dry hydrogen chloride nor dry ammonia gas. It changes back to the colorless form either on recrystallization from or on standing in contact with methanol.

ANILINE SALT.—Five g. of pure thymolsulfonephthalein was dissolved in 150 cc. of aniline at the temperature of the steam-bath. The resulting red solution was heated for 12 hours at 115–120°. The color changed to green and small, brown needles separated. After cooling, the crystals were filtered off and washed with ether. The air-dried material, which did not have a definite melting point, lost no weight at 100-105°.

Anal. Subs., 0.5213, 0.2600: $BaSO_4$, 0.2194, 0.1090. Calcd. for $C_{27}H_{30}O_5S$.-$C_6H_5NH_2$: S, 5.73. Found: 5.78, 5.76.

The aniline salt is insoluble in cold water, ether, benzene, toluene and petroleum ether. It is slightly soluble in hot water and is soluble in methanol, ethanol, acetone and glacial acetic acid. The solutions are red. It dissolves readily in 10% aqueous sodium hydroxide solution, the aniline being liberated.

DIANILINO DERIVATIVE.—After the aniline salt had been filtered off as described above, water was added to the filtrate and the excess of aniline removed by steam distillation. A green tar settled to the bottom. The supernatant liquid was poured off and the tar was dissolved in ethanol. Water was then added to the solution until it became cloudy. On standing for several hours the dianilino derivative of thymolsulfonephthalein crystallized in small, dark green, almost black needles, which did not have a definite melting point.

Anal. Subs., 0.1414, 0.3825: $BaSO_4$, 0.0513, 0.1454. Calcd. for $C_{39}H_{40}O_3N_2S$: S, 5.21. Found: 4.98, 5.22.

It is insoluble in cold and boiling 10% aqueous sodium hydroxide solution. It is very soluble in ether, acetone, methanol, ethanol, chloroform, carbon tetrachloride and glacial acetic acid. The solutions are green. It is only slightly soluble in benzene, toluene and xylene.

Dibromothymolsulfonephthalein.—A solution of 15 g. of bromine in 200 cc. of glacial acetic acid was added to a suspension of 20 g. of pure thymolsulfonephthalein in 200 cc. of glacial acetic acid. The mixture was stirred mechanically until all of the sulfonephthalein had dissolved after which the dibromo compound slowly crystallized.[2] The colorless dibromo compound decomposes at 130–135°.

Anal. Subs., 0.5240, 0.5375: $BaSO_4$, 0.1986, 0.2047. Subs., 0.2714, 0.4434: AgBr, 0.1638, 0.2648. Calcd. for $C_{27}H_{28}O_5SBr_2$: S, 5.14; Br, 25.61. Found: S, 5.21, 5.23; Br, 25.68, 25.42.

It is very soluble in ether, methanol and ethanol; less soluble in benzene, toluene and xylene and insoluble in petroleum ether. It dissolves in water with development of an orange-red color due to the formation of the hydrate. It dissolves in 10% aqueous sodium hydroxide solutions giving purple solutions, the color of which changes to a pure blue upon dilution.

HYDRATE.—The hydrate of dibromothymolsulfonephthalein is precipitated from alkaline solutions of the dibromo compound at room temperature as a red flocculent mass, whereas it separates from the boiling alkaline solutions in the form of small purple, almost black crystals. The crystalline hydrate, which contains 2 molecules of water of crystallization, forms a red powder when ground.

Anal. Subs., 0.3517: loss at 100–105°, 0.0284. Calcd. for $C_{27}H_{28}O_5SBr_2.H_2O + 2H_2O$: H_2O, 7.97. Found: 8.07.

When the hydrate is carefully heated in a stream of carbon dioxide the water is driven off and the colorless dibromothymolsulfonephthalein results.

Titration of Dibromothymolsulfonephthalein.—A solution of 0.1791 g. of pure, dry dibromothymolsulfonephthalein in 25 cc. of absolute ethanol was diluted to 500 cc. with distilled water. Portions (5 cc., 30 cc., 70 cc.) of this solution were diluted to 150 cc. with distilled water and titrated with 0.01 *N* sodium hydroxide solution as described under the titration of thymolsulfonephthalein. The results listed in Table II show that one molecular equivalent of sodium hydroxide may be added to a solution of dibromothymolsulfonephthalein before the end-point is reached. This does not agree with the work of Lubs and Acree[3] who state that less than one molecule of sodium hydroxide (0.91–0.85) will cause a permanent color change.

TABLE II

TITRATION OF DIBROMOTHYMOLSULFONEPHTHALEIN

Dibromothymol-sulfonephthalein, g.	0.01 N NaOH, cc. Calcd.	Found	One molecular equivalent NaOH, %
0.001797	0.29	0.29	100.00
.010782	1.73	1.74	100.52
.025158	4.03	4.03	100.00

DIACETATE.—The diacetate of dibromothymolsulfonephthalein was prepared in the same way that the diacetate of thymolsulfonephthalein was made. The substance was purified by recrystallization from ether; m. p., 222–223°.

Anal. Subs., 0.3740: $BaSO_4$, 0.1232. Subs., 0.3407, 0.3373: AgBr, 0.1798, 0.1791. Calcd. for $C_{27}H_{26}O_5SBr_2(COCH_3)_2$: S, 4.53; Br, 22.57. Found: S, 4.52; Br, 22.46, 22.60.

The diacetate is insoluble in water and in 10% aqueous sodium hydroxide solution at room temperature. It is slowly saponified when boiled with the latter and quickly saponified by an alcoholic solution of sodium hydroxide. It dissolves in concd. sulfuric acid with development of a red color, undergoing hydrolysis. It is very soluble in methanol, ethanol, ether and acetone, less soluble in benzene, toluene, xylene, chloroform and carbon tetrachloride and insoluble in petroleum ether.

ZINC SALT OF THYMOLSULFONEPHTHALIN.—Five g. of pure thymolsulfonephthalein and 5 g. of zinc dust were boiled with 150 cc. of water until all of the thymolsulfonephthalein had dissolved and the solution had become colorless. The solution was then filtered and the filtrate evaporated to dryness in a water-oven in an atmosphere of carbon dioxide. The colorless residue was crystallized from ether, the zinc salt of the reduction product crystallizing with 8 molecules of water.

Anal. Subs., 0.5906, 0.5460: loss at 125–130°, 0.0753, 0.0705. Calcd. for $(C_{27}H_{31}O_5S)_2Zn + 8\ H_2O$: H_2O, 12.60. Found: 12.75, 12.91.

Subs. (dry), 0.5146, 0.4742: $ZnNH_4PO_4$, 0.0919, 0.0851. Calcd. for $(C_{27}H_{31}O_5S)_2Zn$: Zn, 6.54. Found: 6.54, 6.57.

The zinc salt of thymolsulfonephthal*in* is quite stable. It is slowly oxidized to the zinc salt of the sulfonephthal*ein* on standing in the sunlight for a short time or on bubbling air through aqueous solutions. The zinc salt of the sulfonephtha*lin* is very soluble in ether, acetone, methanol and ethanol, slightly soluble in benzene, toluene, xylene, chloroform and carbon tetrachloride and insoluble in petroleum ether.

Thymolsulfonephthal*in*.—Concd. hydrochloric acid was added to an aqueous solution of the zinc salt of thymolsulfonephtha*lin* until a permanent cloudiness was formed. On allowing this solution to stand for several hours very long, fine, colorless, hair-like crystals of thymolsulfonephthal*in* separated, closely interwoven and resembling a mass of cotton. The crystals were filtered off and dried in an atmosphere of carbon dioxide. They contained about 3.5 molecules of water. At 134–135° they melted forming a dark red liquid.

Anal. Subs., 0.4515: loss at 100–110°, 0.0560. Calcd, for $C_{27}H_{32}O_5 + 3.5\ H_2O$: H_2O, 11.9. Found: 12.40.

Subs. (dry), 0.5435, 0.2700: $BaSO_4$, 0.2725, 0.1348. Calcd. for $C_{27}H_{32}O_5S$: S, 6.85. Found: 6.89, 6.86.

Thymolsulfonephthal*in* is less stable than its zinc salt. . It oxidizes very quickly in the sunlight to the colored sulfonephthal*ein*. Unlike thymolsulfonephthal*ein*, which is only slightly soluble in water, thymolsulfonephthal*in* is extremely soluble in water. Colorless aqueous or alkaline solutions of thymolsulfonephthal*in* are easily oxidized by bubbling air through them. Thymolsulfonephthal*in* is very soluble in methanol, ethanol, ether, acetone, glacial acetic acid, less soluble in benzene, toluene, xylene and insoluble in chloroform and petroleum ether.

Summary

1. It has been proved that the formation of thymolsulfonephthalein from the anhydride of *o*-sulfobenzoic acid and thymol, which is the best method of preparing this substance, takes place in two stages. First, a molecule of the anhydride combines with a molecule of thymol to form an addition compound, called the intermediate acid, and this then reacts with another molecule of thymol to form thymolsulfonephthalein and water.

2. The tautomeric nature of the intermediate acid, a γ-ketone acid, has been proved by making derivatives of the *ketone* form (salts) and the *lactone* form (dibenzoate).

3. Thymolsulfonephthalein is a tautomeric substance and *colored* derivatives of the *quinoid* form (salts) and *colorless* derivatives of the *lactoid* form (diacetate, dibenzoate and dimethyl ether) have been made.

4. The *colorless* dimethyl ether of thymolsulfonephthalein was converted into the *colored*, *quinoid* form at 180°.

5. Thymolsulfonephthalein and its dimethyl ether react with aniline to form a dimethyl di-*iso*propyl derivative of diphenylaminesulfonephthalein, which is *colored* and hence has the *quinoid* structure.

6. Dibromothymolsulfonephthalein and its diacetate have been made. Both are *colorless* and, therefore, have the *lactoid* structure. Dibromothymolsulfonephthalein forms a *colored*, *quinoid* hydrate.

7. Thymolsulfonephthalein and dibromothymolsulfonephthalein are used as indicators and it has been shown that one molecular equivalent of sodium hydroxide can be added to a solution of either before the color change in the alkaline range from yellow to blue takes place.

8. Thymolsulfonephthal*in* and its zinc salt have been made.

9. Dithymyl *o*-sulfobenzoate, as well as the isomeric thymolsulfonephthalein, was obtained by the reaction of thymol with the isomeric chlorides of *o*-sulfobenzoic acid.

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