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

THE DIMETHYL AND DIETHYL ETHERS OF PHENOLSULFONEPHTHALEIN AND OF ORTHO-CRESOLSULFONEPHTHALEIN

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Recent investigations in this Laboratory on the *colored* sulfonephthaleins have shown that they form *colorless* dimethyl ethers or diethyl ethers when boiled with methyl or ethyl alcohol containing hydrochloric (or sulfuric) acid, or *colorless* dimethyl ethers even when boiled for a long time with methyl alcohol alone. In 1923, Orndorff and Sherwood[2] made colorless methyl and ethyl ethers of phenolsulfonephthalein by the catalytic method of esterification, and from the analyses and properties of these ethers thought they were monomethyl and mono-ethyl ethers. Mr. N. Fuchs, who analyzed the methyl ether, obtained 8.54% and 8.58% of sulfur. The calculated percentage of sulfur for the monomethyl ether is 8.71, while for the dimethyl ether it is 8.39%. It will be seen from these results that it is impossible to determine by the sulfur analyses alone whether this ether is a monomethyl or a dimethyl ether. As it was not found possible to prepare an acetate or benzoate of this ether and as it was only slightly soluble in solutions of the caustic alkalies, it seemed likely that it was a dimethyl ether. This was proved by making determinations of the number of methoxyl groups.

Dimethyl Ether of Phenolsulfonephthalein.—Six and a half grams of pure phenolsulfonephthalein was boiled for eight hours with 200 cc. of pure methyl alcohol containing 8 g. of dry hydrogen chloride. The sulfonephthalein had then completely dissolved and the solution was a deep red. On allowing this solution to stand overnight a large crop of needle-shaped crystals having a bright pink color separated. These were recrystallized from methyl alcohol and then from ether. In this way 4.5 g. of a colorless product melting at 178° was obtained. The same dimethyl ether was also obtained by boiling 7 g. of phenolsulfonephthalein with 750 cc. of methyl alcohol for four hours and concentrating the solution; yield, 6 g. of the pure ether; m. p., 178°. The number of methoxyl groups present was determined by a modification of the Zeisel method.[3]

Anal. Subs., 0.2933, 0.1394: AgI, 0.3567, 0.1728. Calc. for $C_{19}H_{12}O_3S(OCH_3)_2$: CH_3O, 16.23. Found: 16.07, 16.38.

The pure, colorless dimethyl ether of phenolsulfonephthalein is soluble in methyl alcohol or ethyl alcohol, forming a red solution. It dissolves in acetone, benzene, chloroform or ethyl acetate without development of color. It is difficultly soluble without color in ether and slightly soluble in water and insoluble in petroleum ether. It crystallizes very well, without color, from xylene. It dissolves in glacial acetic acid giving a red solution, but from this the colorless ether crystallizes. When heated for half an hour at 180° in a current of dry carbon dioxide, 0.5 g. of the colorless ether melted to

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[2] Orndorff and Sherwood, THIS JOURNAL, **45**, 486 (1923).

[3] Hewitt and Moore, *J. Chem. Soc.*, **81**, 318 (1902).

a dark red liquid and lost but 0.5 mg. Neither this red ether nor the original colorless ether absorbed any ammonia when exposed to the dry gas. On standing with methyl alcohol this red ether gradually changed back to the colorless dimethyl ether and on recrystallization from methyl alcohol it melted at 174°. One gram of the dimethyl ether was boiled for four hours with 25 cc. of a 5% sodium hydroxide solution until it all dissolved, forming a deep red solution. No sodium salt[2] of a dimethyl or a monomethyl ether could be isolated from this solution. On acidification with hydrochloric acid a red precipitate was obtained, which proved to be phenolsulfonephthalein.

Anal. Subs., 0.3641: $BaSO_4$, 0.2383. Calc. for $C_{19}H_{14}SO_5$: S, 9.05. Found: 8.99.

The dimethyl ether is therefore completely hydrolyzed by boiling with solutions of the dil. alkalies.[2] Long continued boiling with distilled water alone also completely hydrolyzes the dimethyl ether. The solution first became yellow, then orange-red and glistening red plates of phenolsulfonephthalein separated. The same result was also obtained more readily on boiling the dimethyl ether with dil. hydrochloric acid. The dimethyl ether dissolves in concd. sulfuric acid in the cold giving a red solution and is precipitated unchanged by water. It dissolves somewhat in the cold in a 5% solution of sodium hydroxide forming a yellow solution. Cold aniline dissolves it and the solution is red. When this solution is boiled the color changes to blue and then to green and green crystals of diphenylamine-sulfonephthalein[2] crystallize from the solution. Cold dimethylaniline dissolves the ether giving a yellow solution, the color of which deepens somewhat when the solution is boiled, but no other change occurs. Pyridine also dissolves the ether giving a yellow solution, but does not react with it even when boiled. Professor Gill reports as follows on the colorless crystals of the dimethyl ether from xylene.

"This substance crystallizes in nearly rectangular tablets belonging to the monoclinic system. The large face is the clinopinacoid (010). The edges show the prism (110), the clinodome (011) and a very narrow basal pinacoid (001). The angle β is about 92°, as measured on the rotating stage of a microscope. Measurements on the goniometer were not sufficiently concordant to warrant calculation of the axial ratios, but the prism angle 110 to $1\bar{1}0$, is about 64° and the clinodome has an angle of near 50° (011 to $0\bar{1}1$). The crystals often have a cloudy zone across the middle and seem to develop a general cloudiness on standing; extinction, c to Z = 30°; on the edge, extinction is parallel; plane of optical axes (010), negative, small optical angle, strong double refraction."

Diethyl Ether of Phenolsulfonephthalein.—This ether was made by boiling for eight hours 6 g. of pure phenolsulfonephthalein with 300 cc. of absolute ethyl alcohol containing 5 cc. of concd. sulfuric acid. As no crystals were obtained when half of the solvent was distilled, the solution was poured onto crushed ice. After the ice had melted, the solution was filtered and the precipitate thoroughly washed with distilled water to remove all of the sulfuric acid. The dried, crude product was red and weighed 4 g. It was crystallized thrice from absolute ethyl alcohol without appreciably reducing the color, giving a product that melted at 108°. This product was then crystallized once from absolute methyl alcohol, after which it was found possible to recrystallize it from ether. Three recrystallizations from ether raised the melting point to 124–126° and gave a faintly pink product. A fourth crystallization did not change this melting point.

Anal. Subs., 0.4204, 0.2309: $BaSO_4$, 0.2381, 0.1284. Calc. for $C_{19}H_{12}O_3S(OC_2H_5)_2$: S, 7.81. Found: 7.78, 7.64.

Subs., 0.2986, 0.2693: AgI, 0.3363, 0.3074. Calc. for $C_{19}H_{12}O_3S(OC_2H_5)_2$: C_2H_5O, 21.96. Found: 21.61, 21.90.

From these results it will be seen that this is a diethyl, not a mono-ethyl ether.[2] The product analyzed by Orndorff and Sherwood melted at 171° and gave 8.35% and 8.26% of sulfur. As it was recrystallized from methyl alcohol several times, it is probable that alcoholysis took place (see below) and that the product analyzed was mostly the dimethyl ether. The dimethyl ether and the mono-ethyl ether both contain the same amount of sulfur, namely, 8.39%. The diethyl ether dissolves in the same solvents as the dimethyl ether and reacts in the same way with a sodium hydroxide solution and with aniline. It dissolves in dimethylaniline and in pyridine forming yellow solutions, but does not react with these solvents even when the solutions are heated to boiling. Like the dimethyl ether it does not combine with ammonia or with hydrogen chloride. On heating the diethyl ether to 155° until it just melted it turned red without loss of weight. This red ether, however, did not absorb any ammonia. When treated with methyl alcohol it gradually changed back to a light pink and this product recrystallized from methyl alcohol melted at 172–173° and an analysis showed that it was the dimethyl ether.

Anal. Subs., 0.2422: AgI, 0.2912. Calc. for $C_{19}H_{12}O_3S(OCH_3)_2$: CH_3O, 16.23. Found: 15.89.

This result proves that alcoholysis took place. On boiling 0.5 g. of the colorless diethyl ether with 25 cc. of distilled water for three hours it dissolved completely giving an orange-red solution and glistening red plates of phenolsulfonephthalein crystallized from the solution.

Anal. Subs., 0.2813: $BaSO_4$, 0.1841. Calc. for $C_{19}H_{14}O_5S$: S, 9.05. Found: 8.99.

Crystals of the diethyl ether from methyl alcohol were examined by Professor Gill who reports as follows.

"The crystals examined show a somewhat pinkish color, apparently due to specks of foreign matter on their surfaces. The crystallization is almost certainly *monoclinic*. Slender prisms of rhombic cross-section show about equal development of their four faces and similar etched-figures on them all. Two triangular end faces were observed repeatedly but could not be measured on the goniometer. They are considered as the base (001) and the ortho dome ($\bar{1}01$). The principal faces are those of the prism (110) which gave sufficiently good reflections to fix the prism angle at within a few minutes of 65° 20′. The plane of symmetry (010) appears to bisect the sharper angle of the prism. Optically the crystals are biaxial with high double refraction estimated at about 0.100. Extinction is symmetrical on cross-sections obtained by breaking and 32° to 34° on needles lying on a prism face."

Dimethyl Ether of *o*-Cresolsulfonephthalein.—Ten g. of pure *o*-cresolsulfonephthalein was boiled for five hours with 700 cc. of pure methyl alcohol. The phthalein had then completely dissolved, giving a dark red solution. Half of the solvent was distilled and when the solution was allowed to stand, a crop of bright pink crystals was obtained. These were recrystallized from ether, glacial acetic acid and again from ether. A yield of 7.5 g. of the dimethyl ether was thus obtained, in the form of colorless, needle-shaped crystals; m. p., 167°. Analyses for methoxyl groups and for sulfur showed that the product was a dimethyl ether.

Anal. Subs., 0.3925, 0.2356: AgI, 0.4472, 0.2673. Subs., 0.3233, 0.2065: $BaSO_4$, 0.1806, 0.1159. Calc. for $C_{21}H_{16}O_3S(OCH_3)_2$: CH_3O, 15.12; S, 7.81. Found: CH_3O, 15.06, 14.99; S, 7.67, 7.70.

The pure, colorless dimethyl ether is soluble in methyl and ethyl alcohols, glacial acetic acid, acetone and ethyl acetate forming red solutions, and in ether, benzene and xylene without development of color. It is slightly soluble in water and insoluble in

petroleum ether. When heated for ten minutes at 190°, it melted to a red liquid without loss of weight. Neither the colorless nor the colored ether, when ground and exposed to dry ammonia gas, gained in weight. On exposing the colorless dimethyl ether to dry hydrogen chloride, it did not absorb any of the gas, but the colored modification absorbed between one and two molecules after four hours' exposure.

Anal. Subs., 0.4083: gain, 0.0451. Calc. for $C_{21}H_{16}O_5S(OCH_3)_2.HCl$: HCl, 8.15. Found: 9.95.

The hydrochloride had a bright green surface color. On standing for 12 hours in a vacuum desiccator, it lost all of its hydrochloric acid. When the colored ether was allowed to stand under cold methyl alcohol, it gradually changed back to the original colorless ether. The colorless dimethyl ether dissolves in cold 10% aqueous sodium hydroxide forming a bright yellow solution and in cold dil. hydrochloric acid forming a reddish-pink solution. When these solutions are boiled, the dimethyl ether is gradually changed back to the original sulfonephthalein, more readily, however, in the acid solution. Crystals of the dimethyl ether from ether were examined by Professor Vieweg who reports as follows.

"The dimethyl ether of *o*-cresolsulfonephthalein forms slightly pink, tabular crystals. They are not sufficiently well crystallized to give consistent measurements with the goniometer. Under the microscope they are found to be *monoclinic*, the largest faces being the clinopinacoid (010), the forms (110) and (011) being present also. The angle β (measured with the microscope), is approximately 73°. The extinction angle, c to Z, is 25°. The crystals are not pleochroic."

Diethyl Ether of *o*-Cresolsulfonephthalein.—The diethyl ether could not be obtained by boiling the sulfonephthalein with absolute ethyl alcohol and so the following method was worked out for its preparation. Seven g. of pure *o*-cresolsulfonephthalein was boiled with 500 cc. of absolute ethyl alcohol containing 5 cc. of concd. sulfuric acid for four hours, when all had dissolved to give a dark red solution. Half of the solvent was distilled and the residual solution was then poured into a beaker containing ice and 25 cc. of 10% sodium bicarbonate solution while the mixture was vigorously stirred. The red precipitate was quickly separated on a Büchner funnel and thoroughly washed with cold water to remove the last trace of acid. It was thoroughly air-dried and then extracted several times with boiling petroleum ether (b. p., 65–70°). From this red solution, 3 g. of bright pink crystals were obtained and two further crystallizations from glacial acetic acid, gave a pure, colorless product which was shown on analysis, however, to contain a molecule of acetic acid of crystallization. This product melted at 99–101°. It was crystallized twice from petroleum ether and in this way was obtained as tabular crystals which melted at 131–132°. Analyses showed that this product was the pure diethyl ether of *o*-cresolsulfonephthalein.

Anal. Subs., 0.2665, 0.2243: $BaSO_4$, 0.1449, 0.1207. Subs., 0.1577: AgI, 0.1711. Calc. for $C_{21}H_{16}O_5S(OC_2H_5)_2$: S, 7.31; C_2H_5O, 20.55. Found: S, 7.47, 7.39; C_2H_5O, 20.81.

The pure, colorless diethyl ether is readily soluble in cold methyl alcohol, acetone, ethyl acetate, ether, benzene and xylene; it is less soluble in ethyl alcohol, glacial acetic acid, carbon tetrachloride, chloroform and petroleum ether and slightly soluble in water. It dissolves in cold, dil. hydrochloric acid forming a reddish-pink solution and in dilute aqueous alkali giving a bright yellow solution. Boiling the acid solution rapidly converts the ether into the original sulfonephthalein. It is more stable towards alkali and it was only by prolonged boiling in 20% sodium hydroxide solution that hydrolysis could be effected. The colorless ether did not absorb either hydrogen chloride or ammonia when exposed to these dry gases. The colored modification, obtained by melting the colorless form to a red liquid at 140° in an atmosphere of carbon dioxide, absorbed

two molecules of hydrogen chloride and three molecules of ammonia gas. By allowing these products to stand over solid potassium hydroxide and sulfuric acid, respectively, they reverted to the original, colored diethyl ether.

Anal. Subs., 0.1798: gain, HCl, 0.0301. Calc. for $C_{21}H_{16}O_3S(OC_2H_5)_2.2HCl$: HCl, 14.22. Found: 14.34.

Subs., 0.3305: gain, NH_3, 0.0375. Calc. for $3NH_3$: 10.44. Found: 10.19.

The diethyl ether is unique in that its red modification absorbs ammonia, the colored modifications of the ethers previously described not having shown this phenomenon. Crystals of the diethyl ether from petroleum ether are described by Professor Vieweg as follows.

"The crystals are slightly pink in color and have a columnar habitus. They are crystallized well enough to permit of goniometer measurement. This measurement indicates *monoclinic* crystallization and the optical properties confirm this. Elongation is parallel to the "b" axis. There is no noticeable pleochroism. The following angles were measured: $\beta = 78° 40'$, $\bar{1}01 : 001 = 56° 40'$, $010 : 110 = 70° 20'$."

All of these dimethyl and diethyl ethers have the lactoid structure, since they are *colorless* and do not absorb either ammonia or hydrogen-chloride. When heated until they melt they are converted into *colored*, quinoid ethers without loss of weight. The *colored* dimethyl ethers are unstable, however, and revert to the original *colorless* ethers when treated in the cold with methyl alcohol.

Summary

Phenolsulfonephthalein and *o*-cresolsulfonephthalein give *colorless* dimethyl and diethyl ethers when boiled with methyl or ethyl alcohol containing hydrochloric or sulfuric acid. They give the same *colorless* dimethyl ethers when boiled for a long time with methyl alcohol alone. These ethers have the lactoid structure. When heated above their melting points they are converted into *colored*, quinoid compounds without loss of weight. The *colored* dimethyl ethers are unstable, however, and revert to the original *colorless* ethers when treated with methyl alcohol.

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