constitution of the salts or of the alcohols. The salting out efficiency of a salt seems rather to be a function of its solubility in the water and in the alcohol, of the amount of water with which it unites to form its lowest hydrate, and of the ability of the alcohol to replace the water of hydration.

MINNEAPOLIS, MINN.

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF HARVARD UNIVERSITY.]

PHENYL ESTERS OF OXALIC ACID.

BY ROGER ADAMS AND H. GILMAN.

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Introduction.

In the course of a research in this laboratory, we desired to use one of the substituted phenyl esters of oxalic acid. In reviewing the methods already available for the preparation of these substances, we found them to be few in number, limited in applicability and not suited to the preparation of the particular compound wanted. Nencki[1] first prepared the phenyl ester of oxalic acid by boiling phosphorus oxychloride with anhydrous oxalic acid and phenol. This method was extended by Bischoff[2] to the preparation of substituted phenyl esters of oxalic acid, and was shown by him to work well with certain types of substituted phenols. With many phenyl derivatives, however, only small yields of esters could be thus produced, and in several cases the esters, if they were formed at all, could not be isolated from the reaction mixtures. Thus, *e. g.*, the cresols, xylenols and carvacrol gave good results, thymol, *p*- and *m*-nitrophenols gave very poor yields, while the desired products from the *o*-nitrophenol, α- and β-naphthols, could not be obtained. Moreover, this method cannot be applied to any phenol containing a substituting group which is sensitive to hot phosphorus oxychloride.

A second method was used by Bischoff[3] for the preparation of this class of compounds. It consisted in heating the phenyl ester of oxalic acid with the substituted phenol, when replacement occurred and the substituted phenyl ester resulted. This gave poor results, but was applicable to a number of esters which could not be made by the first process. The α- and β-naphthyl esters are examples.

In the manufacture of aurin, from phenol, oxalic acid and sulfuric acid, a by-product was obtained which Claparède and Smith believed to be the phenyl ester of ortho-oxalic acid.[4] This they also synthesized by distilling a mixture of oxalic acid and phenol, or by simply dissolving phenol

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[1] *J. prakt. Chem.*, [2] **25**, 283 (1882).

[2] *Ber.*, **35**, 3440 (1902).

[3] *Ibid.*, **35**, 3441, 3448 (1902).

[4] *J. Chem. Soc.*, **43**, 358 (1883).

and anhydrous oxalic acid in glacial acetic acid and heating.[1] The corresponding α- and β-naphthyl compounds were also prepared. This method, however, is very limited in application, as shown by Bischoff,[2] and has no importance in the synthesis of the compounds in question, since water could not be removed to give the phenyl esters of oxalic acid. In fact, Hailer[3] has given some evidence that these supposedly ortho-oxalic acid esters are nothing but oxalic acid with two molecules of phenol of crystallization.

This comprises all the work on the synthesis of the phenyl esters of oxalic acid. We have, therefore, looked for a more suitable method of preparation than the one mentioned, and have studied the action of oxalyl chloride on phenols under different conditions. We found that treatment of phenols with oxalyl chloride alone gave poor results, due chiefly to the volatility of the chloride. In the presence of pyridine, however, the reaction ran smoothly, and we were able so to adjust the experimental conditions that it was possible to produce any type of substituted phenyl ester in practically quantitative yields. The general procedure is as follows:

About 25 cc. of pyridine are cooled well in ice and to this 5 g. of pure oxalyl chloride are added slowly. The yellow addition product of the two substances separates instantly in the form of yellow lumps. These are now crushed carefully with a spatula before proceeding further. Two molecules of phenol are dissolved in a few cc. of pyridine, and the solution is added gradually to the oxalyl chloride pyridine compound, then the whole mixture is allowed to stand about two hours, or more, at 0°. To obtain the ester, the reaction product is poured into a mixture of concentrated hydrochloric acid and ice. The pyridine thus goes into solution, and the ester precipitates. It is filtered, washed with water, then (except in the cases when polyphenols and oxyacids have been used) is treated with a cold dilute sodium hydroxide solution to extract any traces of unchanged phenol which may be present. Finally, the ester is filtered again, washed with water, dried, and crystallized.

To get the best results, it is essential to crush well the lumps of the oxalyl chloride pyridine compound, and to keep the reaction mixture at 0° or below. In one or two of the experiments carried out, after putting the substances together, we heated the mixture for a few hours under a reflux condenser. This proved unsatisfactory, however, for, in the first place, blackening and charring took place, as well as the formation of colored by-products, and, secondly, the oxalyl chloride at the high temperature had a greater tendency to act as a dehydrating agent. This

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[1] *Ber.*, **17**, 1740 (1884).

[2] *Ibid.*, **35**, 3444 (1902).

[3] *Chem. Zentr.*, **1910**, I, 1039.

latter happened in the case of salicyl aldehyde, no ester being produced. We made a number of experiments also at room temperature, allowing the mixture to stand overnight. Most of the reactions went smoothly, but in one or two instances there was some difficulty. Thus, the salicyl aldehyde gave only a tarry-like mass, and hydroquinone gave a considerable amount of a dehydration product. Besides, small amounts of colored products sometimes formed, which were not too easily removed. Keeping the reaction at 0°, however, gave very satisfactory results, clean, pure compounds, and in all except one or two cases practically quantitative yields of the esters.

We chose for experimentation different types of substituted phenols, not only such as had already been used, but also others, more particularly some containing substituting groups sensitive to phosphorus oxychloride.

Experimental.

Of the following compounds prepared, the di-*p*-cresyl, diguaiacyl, di-α-naphthyl, and di-β-naphthyl esters of oxalic acid had already been synthesized by Bischoff, using other methods. In every case, our compounds agreed with his in solubility, and when crystallized from the same solvent agreed also in crystalline form. We found the melting point of the di-*p*-cresyl ester to be 147°, and of the di-β-naphthyl ester to be 188° as compared with Bischoff's 149° for the former and 191° for the latter. The other two had the same melting point.

I. Monatomic Phenols.

(*a*) *Hydrocarbon Substituting Groups.*

1. **Di-*p*-cresyl Ester of Oxalic Acid,**[1] $(CH_3\text{-}C_6H_4)_2C_2O_4$.—Shiny white plates from a mixture of equal parts of alcohol and ether. M. p. 147°.

Calc. for $C_{16}H_{14}O_4$: C, 71.1; H, 5.2. Found: C, 71.0; H, 5.3.

2. **Di-α-naphthyl Ester of Oxalic Acid,**[1] $(C_{10}H_7)_2C_2O_4$.—Silky needles from benzene or glacial acetic acid. M. p. 161–162°.

Calc. for $C_{22}H_{14}O_4$: C, 77.2; H, 4.1. Found: C, 77.1; H, 4.3.

3. **Di-β-naphthyl Ester of Oxalic Acid,**[2] $(C_{10}H_7)_2C_2O_4$.—If the material obtained by following the general directions given was crystallized from benzene, it formed tiny, white lumps. M. p. 146–147°. On analysis this substance proved to be a molecular compound of the di-β-naphthyl ester and one molecule of benzene. It was extremely stable, for heating at 80–90° for several hours did not decompose it.

Calc. for $C_{22}H_{14}O_4\text{-}C_6H_6$: C, 80.0; H, 4.8. Found: C. 79.4; H, 5.0.

By crystallizing the above substance from glacial acetic acid, however, the benzene was driven out, and the free ester formed tiny, white needles M. p. 188–189°.

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[1] *Ber.*, 35, 3443 (1902).

[2] *Ibid.*

Calc. for $C_{22}H_{14}O_4$: C, 77.2; H, 4.1. Found: C, 77.3; H, 4.3.

(*b*) *Other Substituting Groups.*

1. **Di-*o*-nitrophenyl Ester of Oxalic Acid,** $(NO_2\text{-}C_6H_4)_2C_2O_4$.—Long, flat, yellow needles from benzol. M. p. 185°. Soluble in chloroform, glacial acetic acid; very slightly soluble in ethyl alcohol and methyl alcohol; insoluble in ether.

Calc. for $C_{14}H_8O_8N_2$: C, 50.6; H, 2.4. Found: C, 50.9; H, 2.6.

2. **Di-salicyl Aldehyde Ester of Oxalic Acid,** $(CHO\text{-}C_6H_4)_2C_2O_4$.—Shiny, white plates from benzene. M. p. 153–154°. Soluble in chloroform and glacial acetic acid; slightly soluble in ethyl alcohol, methyl alcohol; insoluble in ether.

Calc. for $C_{16}H_{10}O_6$: C, 64.4; H, 3.4. Found: C, 64.5; H, 3.5.

If the reaction of oxalyl chloride, pyridine, and salicyl aldehyde was carried on at the boiling temperature of the pyridine, none of the above ester formed, but a considerable amount of a white solid was isolated from the black reaction mass. This crystallized from ether, melted at 129°, and on analysis proved to be the well-known di-salicyl aldehyde.

Calc. for $C_{14}H_{10}O_3$: C, 74.3; H, 4.4. Found: C, 74.1 and 74.4; H, 4.8 and 4.6.

At room temperature the salicyl aldehyde gave no ester, just a reddish, sticky product.

3. **Di-vanillin Ester of Oxalic Acid,** $[(CH_3O)(CHO)C_6H_3]_2C_2O_4$.—Very small, white crystals from glacial acetic acid. Melting point 203–204°. Soluble in chloroform and benzene. Very slightly soluble in ethyl alcohol and methyl alcohol. Insoluble in ether.

Calc. for $C_{18}H_{14}O_8$: C, 60.3; H, 3.9. Found: C, 59.9; H, 3.9.

4. **Di-β-aceto-α-naphthyl Ester of Oxalic Acid,** $(CH_3CO\text{-}C_{10}H_6)_2C_2O_4$.—Small, white, leaf-like crystals from benzene. M. p. 197°. Readily soluble in glacial acetic acid, chloroform and acetone. Slightly soluble in ethyl alcohol, methyl alcohol, and ether.

Calc. for $C_{26}H_{18}O_6$: C, 73.2; H, 4.2. Found: C, 73.0; H, 4.4.

5. When we attempted to prepare the salicylic acid ester of oxalic acid, the reaction apparently ran smoothly, and a good yield of a white solid resulted. However, we were unable to find a solvent for the substance, and on testing we found nitrogen. This was undoubtedly the pyridine salt of the di-salicylic acid ester of oxalic acid which had not decomposed on treatment with strong hydrochloric acid. By the action of hot concentrated hydrochloric acid or sodium hydroxide, the pyridine was set free, but the ester hydrolyzed at the same time, so that only complete decomposition products resulted.

6. **Di-methyl Salicylate Ester of Oxalic Acid,** $(CH_3OOC\text{-}C_6H_4)_2C_2O_4$.—White needles from benzene. M. p. 158°. Readily soluble in ethyl

alcohol, chloroform, benzene, glacial acetic acid; slightly soluble in methyl alcohol.

Calc. for $C_{18}H_{14}O_8$: C, 60.3; H, 3.9. Found: C, 60.0; H, 3.9.

7. **Di-guaiacyl Ester of Oxalic Acid,**[1] $(CH_3O\text{-}C_6H_4)_2C_2O_4$.—Shiny, white plates from a mixture of alcohol and ether. M. p. 127°.

Calc. for $C_{16}H_{14}O_6$: C, 63.6; H, 4.6. Found: C, 63.8; H, 4.9.

II. Diatomic Phenols.

(*a*) **Di-*p*-hydroxyphenyl Ester of Oxalic Acid,** $(HO\text{-}C_6H_4)_2C_2O_4$.—As precipitated from the reaction mixture, this substance formed a white powder, only very slightly soluble in all the common solvents, or even heavier solvents, such as glacial acetic acid, anisol or benzyl alcohol. It started to shrink at 192° and melted at 212°. The compound was prepared for analysis by washing well with cold water, then several times with hot benzene. It was soluble with a yellow color in dilute sodium hydroxide.

Calc. for $C_{14}H_{10}O_6$: C, 61.3; H, 3.6. Found: C, 60.9; H, 3.8.

If the hydroquinone was added to the oxalyl chloride pyridine compound at room temperature, and the mixture allowed to warm up from the heat of reaction, then a mixture of compounds resulted from which one could be obtained by the action of glacial acetic acid. This crystallized in white needles from glacial acetic acid and melted at 226°. The analysis agreed well for the monoacetate of di-*p*-oxyphenyl ether. As the production of this compound was rather uncertain, and as we obtained but poor yields of it, we have not studied it further. Slightly soluble in ethyl and methyl alcohol, chloroform, ether, benzene.

Calc. for $C_{14}H_{12}O_4$: C, 68.8; H, 4.9. Found: C, 68.9; H, 4.7.

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[CONTRIBUTION FROM THE RESEARCH LABORATORY OF PARKE, DAVIS & CO.]

MONO-ACETYL-TRI-CHLOROTERTIARY-BUTYL-ALCOHOL. (ACETYL CHLORETONE.)

BY T. B. ALDRICH.

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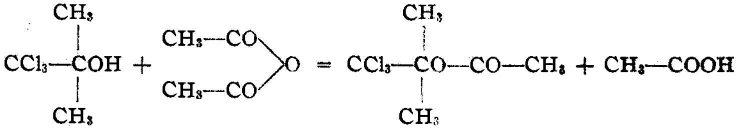
When trichlorotertiary-butyl-alcohol (presumably tri-bromotertiary-butyl-alcohol acts in the same way) is acetylated in the usual manner with acetic anhydride and anhydrous sodium acetate, an acetyl compound is formed according to the following equation:



$$CCl_3\text{—}\underset{CH_3}{\overset{CH_3}{C}}OH + \begin{array}{l}CH_3\text{—}CO\\CH_3\text{—}CO\end{array}\!\!>O = CCl_3\text{—}\underset{CH_3}{\overset{CH_3}{C}}O\text{—}CO\text{—}CH_3 + CH_3\text{—}COOH$$

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[1] *Ber.*, **35**, 3443 (1902).