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## STUDIES IN THE DIPHENIC ACID SERIES. III

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When the dichloride, diamide, diethyl ester, dimethyl ester, monoethyl ester, monomethyl ester, mono-amide and imide of diphenic acid are heated with concentrated sulfuric acid, each compound is transformed into a member of the diphenyleneketone-4-carboxylic acid series; evidently sulfuric acid causes a rotation of the rings in the biphenyl nucleus.<sup>2</sup> By means of acetic anhydride diphenic acid can be transformed into its anhydride and diphenimide secured from the mono-amide of diphenic acid;<sup>2</sup> these reactions are dehydrations and involve a joining of the side-chains attached to the rings. A part of this paper deals with an investigation of the action of acetic anhydride on the four esters of diphenic acid mentioned above, as well as the diamide; diphenamic acid has also been studied again.

*p,p'*-Dinitrodiphenic acid is unique in that it does not form an anhydride or a ketone acid; a plausible explanation of the behavior of this compound may be found by postulating that the meta orienting nitro group in each ring loosens the hydroxyl groups in the carboxyl and strengthens the bond which holds the hydrogen atom in the latter as well as the force holding the ring hydrogen which is meta to the nitro group. This idea would lead one to expect that a compound, such as *p,p'*-dibromodiphenic acid, in which the substituents are not meta orienting would form an anhydride. We have secured evidence regarding this point.

In a previous paper<sup>3</sup> it was pointed out that the results obtained by Bischoff and Adkins<sup>4</sup> regarding the condensation of diphenic anhydride and resorcinol were somewhat different from those which one of us described. Later Adkins, Steinbring and Pickering<sup>5</sup> questioned the validity of the criticisms. We are now ready to reaffirm the latter and to describe additional experimental evidence which supports our point of view.

### Discussion of Experiments and Interpretation of Results

All of the temperatures given below are uncorrected.

**Esters of Diphenic Acid.**—The preparation of the monomethyl, mono-ethyl, dimethyl and diethyl esters of diphenic acid has been previously described.<sup>2</sup> Six g. of

<sup>1</sup> Some of the experimental results described in this paper are taken from a thesis submitted to the Faculty of the Massachusetts Institute of Technology by L. A. Clough in partial fulfilment of the requirements for the degree of Master of Science.

<sup>2</sup> Underwood and Kochmann, *THIS JOURNAL*, **46**, 2069 (1924).

<sup>3</sup> Underwood and Kochmann, *ibid.*, **45**, 3071 (1923).

<sup>4</sup> Bischoff and Adkins, *ibid.*, **45**, 1030 (1923).

<sup>5</sup> Adkins, Steinbring and Pickering, *ibid.*, **46**, 1917 (1924).

each of these compounds was heated with 12 g. of glacial acetic acid and 18 g. of acetic anhydride for sixteen hours at 145°. The major part of the liquid was then removed by distillation and the residue kept in an ice chest until crystallization took place. In every case practically all of the ester was recovered unchanged. The results of these experiments indicate that the hydroxyl and alkoxyl groups in these esters are very firmly held.

**Diphenamic Acid.**—A mixture of 80 g. of diphenamic acid (the mono-amide of diphenic acid), 60 g. of glacial acetic acid and 60 g. of acetic anhydride was heated at 145° for one hour. The solid which formed upon cooling was collected on a filter, thoroughly washed with cold sodium carbonate solution and water and subsequently dried at 110°. This product, m. p. 219°, was identified as diphenimide. Acidification of the sodium carbonate extract yielded a precipitate which melted at 168° after washing with water and drying at 110°. The compound gave a qualitative test for nitrogen; heating with concd. ammonium hydroxide did not produce the diamide of diphenic acid and the melting point was not changed by recrystallization from ethyl alcohol and from water. It was thought that this substance might be 1-cyanobiphenyl-10-carboxylic acid. In order to check our hypothesis, analyses and hydrolyses were carried out. Approximately 0.5 g. of the compound melting at 168° was heated on a water-bath for four hours with a mixture of 2 cc. of 95% sulfuric acid and 3 cc. of water; the solid gradually dissolved. The cold reaction liquid was poured into water and the precipitate collected on a filter, washed with water and finally crystallized from ethyl alcohol. By means of a mixed melting point the product of the hydrolysis was identified as diphenic acid. Upon dilution of the acetic acid-anhydride reaction mixture with water, more of the dissolved material was obtained; this was separated into its components by the procedure already described. The total yield of diphenimide was 18.2 g. and that of cyanobiphenylcarboxylic acid was 3.8 g.

*Anal.* Calcd. for  $C_{14}H_9O_2N$ : C, 75.31; H, 4.06; N, 6.28. Found: C, 74.70, 74.68; H, 4.35, 4.40; N, 6.60, 6.40.

**Diamide of Diphenic Acid.**—The solution obtained upon heating 10 g. of the diamide of diphenic acid, 25 g. of glacial acetic acid and 40 g. of acetic anhydride at 145° for eight hours was concentrated by distilling most of the liquid. When water was added to the residue a precipitate was formed. This was collected on a filter and dried at 110°. The solid, which was insoluble in cold sodium carbonate solution, did not melt sharply. By extraction with a large amount of hot methyl alcohol most of the product was dissolved. After about one-half of the solvent had been removed by distillation, the solution on standing deposited long, flat needles which melted at 172° when dry. Further concentration of the solution yielded a crystalline mass which apparently contained an impure acetyl derivative of the diamide; this material did not melt sharply. By careful treatment of the substance with dilute sodium hydroxide solution and subsequent recrystallizations from methyl alcohol, more of the compound melting at 172° was secured.

It was thought that the latter was 2,2'-dicyanobiphenyl produced by the removal of two molecules of water from one molecule of diphenic acid diamide. The compound was insoluble in solutions of sodium carbonate and sodium hydroxide; recrystallization from ether and from acetone did not change the melting point; qualitative tests showed the presence of nitrogen. Approximately 1 g. of the substance was heated on a water-bath for four hours with a mixture of 4 cc. of 95% sulfuric acid and 4 cc. of water; the solid gradually dissolved. The cold reaction liquid was poured into water, the precipitate collected on a filter, washed with water and finally crystallized from ethyl alcohol. By means of a mixed melting point the hydrolysis product was identified as diphenic acid. The use of more concentrated sulfuric acid and a shorter time of heating gave some diphenamic acid. These experiments as well as the neutral character of the substance

and the results of analyses indicated that the compound melting at  $172^{\circ}$  was 2,2'-dicyanobiphenyl. In one run 1.9 g. of the latter was obtained from 10 g. of the diamide; it was difficult to get check yields on account of the necessity for several crystallizations. A small amount of the so-called acetyl derivative of diphenic acid diamide was purified by several crystallizations from large amounts of ether; the material melted sharply at  $166$ – $167^{\circ}$ . It was not studied further since the isolation of it involved many troublesome steps and the compound did not appear to be important in our work. Treatment of the substance with dilute sodium hydroxide solution gave the diamide of diphenic acid.

*Anal.* (Crystals, m. p.  $172^{\circ}$ .) Calcd. for  $C_{14}H_8N_2$ : C, 82.32; H, 3.95; N, 13.72. Found: C, 81.80, 81.85; H, 4.17, 4.06; N, 14.05, 14.10.

*p,p'*-Dibromodiphenic Acid.—Schmidt and Junghans<sup>6</sup> made *p,p'*-dibromodiphenic acid by the oxidation of 2,7-dibromophenanthraquinone. The procedure which we used was based upon their work; details are similar to those given by one of us in describing the preparation of *p,p'*-dinitrodiphenic acid,<sup>2</sup> except that glacial acetic acid was employed as a solvent. The oxidation proceeded very slowly and it was frequently necessary to remove the dibromodiphenic acid by treatment of the solid reaction product with sodium carbonate solution. Unchanged dibromophenanthraquinone was then heated with more oxidizing agent. This process was repeated several times. It was not possible to estimate yields accurately. The 2,7-dibromophenanthraquinone used in this experiment was prepared by another investigator; details of the procedure employed in making it are not available.

Approximately 1 g. of *p,p'*-dibromodiphenic acid (m. p.  $277$ – $278^{\circ}$ ), 10 g. of glacial acetic acid (solvent) and 20 g. of acetic anhydride were heated at  $145^{\circ}$  for eleven hours. After some of the liquid had been distilled, the reaction mixture upon cooling deposited crystals; these were collected on a filter, washed and dried. The white solid melted at  $304$ – $305^{\circ}$ . It was insoluble in sodium carbonate solution; when heated with 20% aqueous sodium hydroxide it slowly dissolved; acidification of the liquid yielded *p,p'*-dibromodiphenic acid.

*Anal.* Calcd. for  $C_{14}H_8O_3Br_2$ : Br, 41.84. Found: Br, 41.50, 41.61.

This experiment shows that *p,p'*-dibromodiphenic acid readily forms an anhydride; the results support the ideas stated in the introductory part of the paper. However, it is necessary to consider the possibilities regarding stereoisomerism as well as the influence of ring substituents upon carboxyl groups in order to get a complete account of the reasons for the unique behavior of *p,p'*-dinitrodiphenic acid.

**Condensation of Diphenic Anhydride with Resorcinol. Work of Bischoff and Adkins.**—In commenting upon the investigation<sup>3</sup> by one of us, Adkins and his associates<sup>5</sup> declared (without stating detailed experimental evidence) that the use of a temperature ( $175^{\circ}$ ) higher than  $135$ – $150^{\circ}$  for condensing diphenic anhydride and resorcinol caused fundamental changes in structure which were avoided by Bischoff and Adkins. It was also said that Bischoff early in his work learned that when the anhydride was condensed with resorcinol at temperatures in the vicinity of  $175^{\circ}$ , a non-fluorescent compound was formed, sometimes with the evolution of carbon dioxide. We believe this observation has an important bearing on the results which Bischoff and Adkins reported and that they should have mentioned it.

<sup>6</sup> Schmidt and Junghans, *Ber.*, **37**, 3567 (1904).

In order to answer the question regarding the influence of temperature on this reaction, we carried out the experiment described by Bischoff and Adkins, using the proportions of reagents, temperature, time of heating and extraction procedure which they gave. We readily obtained crystals by dissolving the reaction product in alcohol and gradually diluting the solution with water. The carefully purified crystalline material (resorcinoldiphenic) dissolved in aqueous sodium hydroxide, forming a greenish-yellow liquid, but did not produce marked fluorescence. On the other hand, the amorphous residue (ketone acid derivative) gave a strongly fluorescent liquid when added to sodium hydroxide solution. We repeated the condensation three times; in every case the results were practically the same. By the use of a very small amount of the crystalline substance a melting point of 178–179° was found; these figures were previously given by one<sup>3</sup> of us. A mixture of the crystals obtained by the Bischoff and Adkins method and those prepared some time ago in this Laboratory melted at 247–249°. We also found that the melting point of our resorcinoldiphenic (secured from a condensation product made at 175°) had changed from 178–179° to 247–249° upon standing in a stoppered test-tube. When a large amount of the crystals obtained by the Bischoff and Adkins method was heated in a capillary tube, it was observed that as soon as the temperature reached 175–178° liquefaction began; this was soon followed by solidification; it was necessary to heat the solid to 247–249° before it melted again. The compound now remained liquid or pasty even after cooling. These results indicate that the crystalline substance obtained through the condensation of diphenic anhydride and resorcinol at 135–150° is apparently the same as that which one of us made by the use of a higher temperature, 175°. Also it is obvious that the melting point of resorcinoldiphenic changes when the material is heated or allowed to stand for a long time. This may be due to isomerization, loss of water or other causes. We intend to study this matter further.

Bischoff and Adkins stated that acetylation of their resorcinol-diphenic anhydride condensation product (by heating with acetic anhydride) yielded a substance which was insoluble in alkalis and that the analogous ketone acid derivative was soluble in alkali. Later Adkins and his associates<sup>5</sup> repeated these statements and implied that one of us had overlooked them when criticizing the work. This differentiation procedure might be valid if one were dealing with homogeneous substances, but it is necessary to remember that the material obtained from the diphenic anhydride condensation is a mixture.

We have treated with acetic anhydride the amorphous reaction mass which we obtained by working at 175°, the material secured by the use of Bischoff and Adkins' procedure, and a mixture containing about 70% of crystalline resorcinoldiphenic and 30% of amorphous ketone acid-resor-

cinol condensation product. In each case 10 cc. of acetic anhydride was used for 1 g. of solid; heating was continued for four hours at 140°; then the mass was cooled, poured on ice and allowed to stand, with occasional stirring, scratching of the walls of the container and additions of cold water, until a pasty solid appeared. The latter was collected, washed with a small amount of sodium carbonate solution and with water; then the solid was pressed on a porous plate. In every case when the material was stirred with *N* sodium hydroxide solution the latter became yellowish-green; some of the solid remained undissolved. Acidification of the filtered liquid gave a considerable amount of precipitate. These experiments show clearly that the material obtained by acetylating Bischoff and Adkins' reaction product is not entirely insoluble in alkali; the results support the criticisms of the work of these investigators.

### Summary

When monomethyl diphenate, mono-ethyl diphenate, dimethyl diphenate and diethyl diphenate were heated with acetic anhydride, each ester remained unchanged. Under similar conditions diphenamic acid was dehydrated in two different ways, giving diphenimide and 1-cyanobiphenyl-10-carboxylic acid; the diamide of diphenic acid was transformed into 2,2'-dicyanobiphenyl, through the loss of two molecules of water. *p,p'*-Dibromodiphenic acid formed an anhydride upon treatment with acetic anhydride; the behavior of this acid is different from that of *p,p'*-dinitrodiphenic acid.

Bischoff and Adkins obtained an amorphous substance by condensing diphenic anhydride with resorcinol at 135–150° in the presence of anhydrous zinc chloride and discussed the product as though it were practically homogeneous. This work has been repeated; it was found that the material is apparently identical with that which one of us secured by working at 175°. It contains two substances, resorcinoldiphenin, which can be obtained in crystalline form, and an amorphous condensation product derived from diphenyleneketone-4-carboxylic acid. Incidentally it was learned that the melting point of resorcinoldiphenin apparently changes when the compound is heated or allowed to stand for a long time. Solutions of pure resorcinoldiphenin in aqueous sodium hydroxide do not show marked fluorescence.

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