

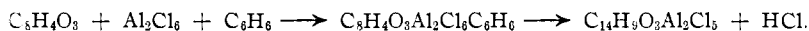
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THE FRIEDEL AND CRAFTS REACTION WITH PHTHALIC ANHYDRIDE

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Heller¹ pointed out that in the preparation of *o*-benzoylbenzoic acid from phthalic anhydride, benzene, and aluminum chloride, the aluminum chloride was a catalytic agent. Later, Heller and Schülke² observed that the phthalic anhydride and aluminum chloride first went into solution in the benzene and that afterwards a viscous precipitate was formed with the evolution of hydrogen chloride. This precipitate, on hydrolysis, gives *o*-benzoylbenzoic acid. They suggest, therefore, that there are two intermediate compounds which they represent thus,



Halla³ found that, using benzene containing various proportions of toluene and phthalic anhydride equivalent to the toluene used, toluylbenzoic acid was obtained almost exclusively. He also found that when the toluene was added after the phthalic anhydride, benzene, and aluminum chloride had reacted no toluylbenzoic acid was obtained and concluded that the toluene reacted directly with the phthalic anhydride and aluminum chloride and not on the intermediate compound as had been suggested by Heller and Schülke.

Heller⁴ pointed out that Halla's experiment showed only that the toluene did not react with the second intermediate compound and that he had represented it as reacting with the first intermediate compound. He also suggested that when toluene or naphthalene was used in benzene solution the toluene or naphthalene displaced the benzene in the first intermediate compound.

Rubidge and Qua⁵ showed that the insoluble intermediate compound could be acted on by acid anhydrides with benzene to produce diphenylphthalide and Stephens,⁶ McMullen,⁷ and Lawrance and Oddy⁸ have found that this reaction is quite general.

The stages of this reaction may be described thus: $\text{C}_6\text{H}_4\text{O}_3 + \text{C}_6\text{H}_6 + \text{Al}_2\text{Cl}_6 \longrightarrow$ clear solution \longrightarrow viscous precipitate \longrightarrow *o*-benzoylbenzoic acid. Various experiments have been carried out with these different products.

¹ Heller, *Z. angew. Chem.*, **19**, 669 (1906).

² Heller and Schülke, *Ber.*, **41**, 3627 (1908).

³ Halla, *Monatsh.*, **32**, 637 (1911).

⁴ Heller, *Ber.*, **45**, 665 (1912).

⁵ Rubidge and Qua, *THIS JOURNAL*, **36**, 732 (1914).

⁶ Stephens, *ibid.*, **43**, 1950 (1921).

⁷ McMullen, *ibid.*, **43**, 1965 (1921).

⁸ Lawrance and Oddy, *ibid.*, **44**, 329 (1922).

Experiments with the Clear Solution

Five g. of freshly sublimed phthalic anhydride and 9 g. of finely powdered aluminum chloride were treated with 20 cc. of benzene at about 10° with vigorous shaking. The solids slowly dissolved giving a clear light-brown liquid, and after 30 minutes only a small amount of aluminum chloride remained undissolved and there had been little evolution of hydrogen chloride. When aluminum chloride is not present 20 cc. of benzene will dissolve only 1 g. of phthalic anhydride at that temperature. This clear solution was heated for 2 hours with naphthalene and the product, after separation of a little phthalic acid, was found to be 60% benzoylbenzoic acid, 35% naphthoylbenzoic acids and 5% naphthyl-phenylphthalide.

To the clear solution prepared as above an equal volume of anhydrous ether was added and it was allowed to stand for 30 minutes. A heavy oil, light-brown in color, was precipitated. This oil was washed with ether to free it from phthalic anhydride and when treated with dil. hydrochloric acid gave only *o*-benzoylbenzoic acid. Placed in a vacuum desiccator over sulfuric acid, the oil gave off benzene, ether and hydrogen chloride and changed to a solid which seemed to be identical with the second intermediate compound. When the oil was heated on the water-bath for 6 hours with naphthalene dissolved in benzene no naphthoylbenzoic acid was produced. On analysis the ratio of aluminum to chlorine in the oil was found to be 2:4.75 expressed in atomic weights.

It is to be noted that the oil precipitated by ether would give no naphthoylbenzoic acid when heated with naphthalene in benzene solution but the clear solution before precipitation gave a mixture of naphthoylbenzoic acids and benzoylbenzoic acid. This suggests that the clear solution may represent two stages of the reaction and that the first product only will react with naphthalene to give naphthoylbenzoic acids while the second product only is precipitated by ether.

Experiments with the Insoluble Intermediate Compound

Five g. of phthalic anhydride, 9 g. of aluminum chloride and 80 cc. of benzene were shaken for 30 minutes at room temperature. The temperature was then raised to about 35° and the solution became cloudy while some undissolved aluminum chloride went into solution. After boiling for 2 hours the evolution of hydrogen chloride had ceased and the flask was then protected with a calcium chloride tube and placed in a vacuum oven at 75° . About 3 days' heating was necessary to reach constant weight.

Calc. for $C_{14}H_9O_3Al_2Cl_5$: benzoylbenzoic acid, 49.3; Al, 11.8; Cl, 38.8. Found: benzoylbenzoic acid, 49.5; Al, 12.0; Cl, 34.2.

As it seemed probable that there had been some hydrolysis during the long drying, the experiment was repeated with only 1 hour's drying.

Calc. for $C_{14}H_9O_3Al_2Cl_5$: Al/Cl, 0.304. Found: 0.322.

This intermediate compound was also prepared by slowly heating the phthalic anhydride, aluminum chloride, and benzene to 50° when the precipitate is quite light and can easily be poured off with the benzene from the undissolved aluminum chloride. After being filtered from the benzene, washed with petroleum ether and dried, this precipitate as well as that obtained by evaporation of the oil from the clear solution appeared to be identical with the precipitate previously analyzed.

Insoluble Intermediate Compound from Benzene with Toluene.—Five g. of phthalic anhydride, 9 g. of aluminum chloride, and 20 cc. of benzene were heated for 2 hours, the excess of benzene was then poured off and the precipitate washed with toluene. Then 20 cc. of toluene and 3.75 cc. of acetic anhydride were added and the temperature was raised to 100° for 20 minutes. After cooling, the product was decomposed with dil. hydrochloric acid, the toluene distilled with steam and the residue treated with hot 10% sodium hydroxide solution. The solution gave 0.14 g. of benzoylbenzoic acid and the residue after crystallization from alcohol gave 7.3 g. of *p*-tolylphenylphthalide, m. p. 106° , previously described by Limpricht.⁹

Intermediate Compound from Toluene with Benzene.—The intermediate compound was prepared as above using toluene instead of benzene and then treated with benzene and acetic anhydride. The product was nearly all *p*-toluylbenzoic acid, and only 0.2 g. of *p*-tolylphenylphthalide was obtained. The intermediate compound from benzene reacts much better with toluene than the intermediate compound from toluene reacts with benzene. A similar experiment in which the same amount of the intermediate compound from benzene was treated with benzene gave 2.5 g. of diphenylphthalide.

Intermediate Compound from Benzene with Naphthalene.—The intermediate compound was prepared using quantities 4 times as great as previously used and without removing the benzene, 20 g. of naphthalene was added and 13 cc. of acetic anhydride. After boiling for 5 hours and treating with sodium hydroxide solution, the soluble part yielded 5 g. of benzoylbenzoic acid. The insoluble part was dissolved in 75 cc. of hot alcoholic sodium hydroxide solution, 1.5 liters of water was added and the solution quickly filtered. On standing, the phthalide slowly precipitated from the filtrate and was filtered off in several fractions. The first precipitate on recrystallization from benzene melted at $227-8^{\circ}$ and the later precipitates melted at $153-4^{\circ}$. Repeated precipitation from alcoholic sodium hydroxide solution was necessary to effect a complete separation, and the total yield was 3.5 g. of the substance having the higher melting point and 20 g. of the other.

On fusion with potassium hydroxide, the phthalide melting at $227-228^{\circ}$ gave α -naphthoic acid, and the phthalide melting at $153-4^{\circ}$ gave β -

⁹ Limpricht, *Ann.*, **299**, 308 (1897).

naphthoic acid, thus indicating that the first is α -naphthyl-phenylphthalide and the second β -naphthyl-phenylphthalide. The α -naphthyl-phenylphthalide is nearly insoluble in alcohol and slightly soluble in ether and carbon disulfide; it is soluble in acetone, chloroform, benzene and ethyl acetate. The β -naphthyl-phenylphthalide is nearly insoluble in alcohol and is soluble in carbon disulfide, ether, acetone, chloroform, benzene and ethyl acetate.

Other Preparations of the Naphthyl-phenylthalides

In order to determine more definitely the formulas of these phthalides they were prepared from the naphthoylbenzoic acids following the method used by Limpricht for the preparation of tolyl-phenylphthalide. The α -naphthoylbenzoic acid was made as described by Heller and Schülke but the method of purifying the product was modified. The crude acid was dissolved in dil. sodium hydroxide solution and this solution was very slowly neutralized with dil. hydrochloric acid. In this way the brown impurities were precipitated before the nearly colorless acid. By repeated recrystallization from toluene this product gave hard crystals, m. p. 176° , and rosetts of needle-shaped crystals, m. p. 165° . Heller and Schülke found only the higher melting product (their observed melting point was 173°) which they identified as α -naphthoylbenzoic acid. On fusion with potassium hydroxide, the acid with lower melting point gave β -naphthoic acid and benzoic acid and is, therefore, the β -naphthoylbenzoic acid described by Pickles and Weisman.¹⁰ Fifty g. of phthalic anhydride gave 82.5 g. of the purified acids (88% yield) which on separation gave 16.5 g. of the acid with low melting point and 58 g. of the other.

Forty g. of α -naphthoylbenzoic acid was heated on a water-bath with 40 cc. of acetic anhydride for 16 hours and then evaporated in a vacuum desiccator over stick sodium hydroxide. The solid product, recrystallized from acetic anhydride, melted at 141° , and with water gave acetic acid and α -naphthoylbenzoic acid. It is slightly soluble in alcohol, soluble in benzene, ether, acetone and chloroform and very soluble in acetic anhydride. Ten g. of this acetyl derivative of α -naphthoylbenzoic acid, benzene and aluminum chloride gave 0.5 g. of α -naphthyl-phenylphthalide identical with that prepared by the other method.

Four g. of β -naphthoylbenzoic acid was heated on the water-bath for 4 hours with 6 cc. of acetic anhydride and after evaporation the product was recrystallized from acetic anhydride, m. p. 140° . It is insoluble in alcohol and is soluble in ether, acetone, benzene, chloroform and acetic anhydride. Four g. of this acetyl derivative with benzene and aluminum chloride gave 0.5 g. of β -naphthoyl-phenylphthalide, identical with that prepared by the other method.

¹⁰ Pickles and Weisman, *Proc. Chem. Soc.*, **20**, 201 (1904).

Intermediate Compound from Naphthalene with Benzene.—The intermediate compound was prepared from 5 g. of phthalic anhydride, 5 g. of naphthalene in benzene solution and 9 g. of aluminum chloride. The precipitate was washed with benzene and then heated with 20 cc. of benzene and 3.75 cc. of acetic anhydride. There appeared to be some reaction but it was not possible to separate any phthalide from the gummy mass. Again, the intermediate compound from benzene reacts much better with naphthalene than the intermediate compound from naphthalene reacts with benzene.

Intermediate Compound from Benzene with Anthracene.—The intermediate compound was prepared from 10 g. of phthalic anhydride, benzene and aluminum chloride to which 15 g. of anthracene and 7.5 cc. of acetic anhydride dissolved in 140 cc. of benzene were added. The temperature was slowly raised to 70° and kept there for 15 minutes and there was considerable evolution of hydrogen chloride. The yield was 6 g. of benzoylbenzoic acid, 0.3 g. of a yellowish-white crystalline solid, m. p. 171–3°, 1 g. of a brownish-white crystalline solid, m. p. 280–3° and 10 g. of a non-crystalline gum. These crystalline products are probably anthryl-phenylphthalides, but they could not be further identified. The phthalide, m. p. 171–173°, was nearly insoluble in acetic acid, slightly soluble in benzene and alcohol and soluble in ether, acetone, chloroform and ethyl acetate. The other phthalide was insoluble in acetic acid and toluene, slightly soluble in benzene and alcohol and soluble in acetone, ether, chloroform and ethyl acetate.

Compounds Derived from α -Naphthyl-phenylphthalide

A mixture of 3.25 g. of α -naphthyl-phenylphthalide, 15 cc. of alcohol and 10 g. of potassium hydroxide dissolved in a minimum quantity of water was heated and then more alcohol was added until all was in solution; 100 cc. of water was then added and the solution evaporated until it just began to be cloudy. Ten g. of zinc dust was added and the solution was boiled for 16 hours. The excess of zinc was filtered off, and on cooling 3 g. of a white solid separated. This potassium salt was dissolved in water and the solution acidified; and another gram of the acid was obtained by acidifying the original solution. This precipitate was dried in the vacuum oven for 16 hours at 145° and then melted at 189°.

SILVER SALT. Calc. for $C_{24}H_{17}O_2Ag$: Ag, 24.24. Found: 24.3, 24.13.

This α -naphthyl-phenylmethyl-benzoic acid (1,2) was slightly soluble in ethyl alcohol and soluble in benzene, ether, chloroform and acetone. Some of this substance was dissolved in ammonia, the excess of ammonia boiled off and the barium salt precipitated by barium chloride. Of this barium salt 1.7 g. was ground with 2 g. of barium hydroxide and placed in an electric furnace. The tube was connected with a pump and the tem-

perature slowly raised. At about 210° the hydrocarbon distilled and was collected in the cooler part of the tube as a light-yellow oil which solidified on cooling; when recrystallized from acetic acid it consisted of white needle-shaped crystals, m. p. 152° . This seems to be identical with the α -naphthyl-diphenylmethane described by Acree¹¹ (m. p. 150°).

Compounds Derived from β -Naphthyl-phenylphthalide

Twenty-two g. of β -naphthyl-phenylphthalide was reduced with zinc dust and gave 21 g. of acid. This acid, crystallized from benzene, melted at $76-77^{\circ}$ but when dried in the vacuum oven these crystals lost benzene and melted at 150° .

SILVER SALT. Calc. for $C_{24}H_{17}O_2Ag$: Ag, 24.24. Found: 23.9, 23.9.

The acid is soluble in ethyl alcohol and benzene and very soluble in ether, chloroform and acetone.

Eleven g. of the barium salt of this β -naphthyl-phenylmethyl-benzoic acid (1,2) was heated as before and at about 225° , gave 7 g. of β -naphthyl-diphenylmethane which melted at $73-74^{\circ}$ after crystallization from alcohol.

Calc. for $C_{28}H_{18}$: C, 93.83; H, 6.17. Found: C, 94.25; H, 6.20.

This hydrocarbon was slightly soluble in alcohol, soluble in petroleum ether and very soluble in ether, chloroform, benzene and acetone.

Summary

1. The Friedel and Crafts reaction with phthalic anhydride has been studied.
2. A new method for the preparation of mixed phthalides has been described.
3. It has been found that phthalic anhydride, aluminum chloride, and naphthalene give a mixture of both naphthoylbenzoic acids.
4. Nine new substances have been described: α -naphthyl-phenylphthalide, β -naphthyl-phenylphthalide, acetyl derivative of α -naphthoylbenzoic acid (1,2), acetyl derivative of β -naphthoylbenzoic acid (1,2), two anthryl-phenylphthalides, α -naphthyl-phenylmethyl-benzoic acid (1,2), β -naphthyl-phenylmethyl-benzoic acid (1,2), β -naphthyl-diphenylmethane.

This research was performed under the direction of Professor F. B. Allan.

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¹¹ Acree, *Ber.*, **37**, 617 (1904).