acteristic is the ready solubility and yellow to brown coloration in cold sulfuric acid. When the sulfuric acid solutions were warmed, alkyl mercaptans were evolved. The resulting solution when cooled, diluted and made alkaline yielded a solid precipitate which proved to be triphenylcarbinol.

$$(C_6H_5)_3C—S—R + H_2O\ (H_2SO_4) \longrightarrow (C_6H_5)_3C—OH + H—S—R$$

It seems certain, after consideration of the evidence, that our sulfur-containing products were of the triphenylmethyl alkyl sulfide class.[23]

The authors wish to express their appreciation for the suggestions offered by Professor L. W. Jones during the course of the investigation and also for the aid of the duPont Fellowship held by one of us during the latter part of the work.

Summary

1. Addition products of methyl, ethyl and propyl sulfides with hexaphenylethane have been prepared.

2. It has been found that the alkyl sulfides accelerate the rate of oxidation of hexaphenylethane in bromobenzene solution. This is apparently not so with carefully purified carbon disulfide and acetone, which also yield addition products with hexaphenylethane.

3. Observations have been made concerning the probable course of the thermal decomposition of the hexaphenylethane methyl sulfide addition product.

PRINCETON, NEW JERSEY

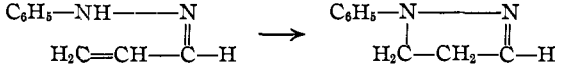
[CONTRIBUTION FROM THE LABORATORY OF ORGANIC CHEMISTRY OF THE STATE UNIVERSITY OF IOWA]

CONDENSATION PRODUCTS OF BENZALACETOPHENONE AND SOME OF ITS DERIVATIVES[1]

BY L. CHAS. RAIFORD AND H. L. DAVIS

RECEIVED JUNE 30, 1927 PUBLISHED JANUARY 5, 1928

Fischer and Knoevenagel[2] found that phenylhydrazine and acrolein react to give 1-phenylpyrazoline instead of the expected hydrazone. Much later Auwers and Müller[3] argued that this product is formed through the rearrangement of an unstable hydrazone, and noted that in those



[23] Ref. 4, p. 124.

[1] From a portion of the thesis submitted to the Graduate College of the State University of Iowa in partial fulfilment of the requirements for the degree of Doctor of Philosophy by H. L. Davis, August, 1925.

[2] Fischer and Knoevenagel, *Ann.*, **239**, 194 (1887).

[3] Auwers and Müller, *Ber.*, **41**, 4230 (1908).

cases where the latter can be isolated, heating with acetic acid causes rearrangement. Auwers and Voss[4] isolated the hydrazones of cinnamic aldehyde and benzalacetone and found that they rearrange to the corresponding pyrazolines at higher temperatures or by heating with acetic acid. They concluded that phenylhydrazones from α,β-unsaturated ketones of the type R—CH=CH—CO—R′ can be isolated only when R is an aryl radical. Their failure to isolate the hydrazone of benzalacetophenone indicates that the stability of these products must be influenced also by the character of the radical R′. Its structure seems more important than its weight. When it is an aryl radical, hydroxyl and alkoxyl substituents favor rearrangement, while the nitro group stabilizes the hydrazone.[5] When halogen is present Straus[6] found that the closing of the pyrazoline ring occurs readily when the substituent is in either ketone or hydrazine residue. When both are substituted the hydrazone is quite stable and requires energetic treatment for rearrangement.

These conclusions are here questioned because the methods of preparation seem to be varied too much to permit a fair comparison of the products. In some cases the conditions were such that a hydrazone of this group might rearrange. In others the record does not include positive identification of the products.

In the present study the conclusion of Auwers and Voss that the "hydrazone of benzalacetophenone is so labile that it cannot be isolated, even at low temperature" was first tested. By conducting the experiment in glacial acetic acid solution at room temperature and also by following as carefully as possible the directions of Auwers and Voss, there was obtained a product that melted at 117–120°.[7] This substance was shown to be a hydrazone by examination of its reduction products,[8] and also by observing its direct rearrangement to 1,3,5-triphenylpyrazoline,[9] m. p. 135–136°.

To test the effect of substituents in the ketone and hydrazine residues, previously studied by Straus, and referred to above, attempts were made to prepare hydrazones containing some of the radicals mentioned by him. It will be shown below that in no instance was such a hydrazone isolated, but that in each of the five cases tested the corresponding pyrazoline was obtained.

[4] Auwers and Voss, *Ber.*, **42**, 4412 (1909).

[5] Auwers and Lämmerhirt, *Ber.*, **54**, 1000 (1921).

[6] Straus, *Ber.*, **51**, 1458 (1918).

[7] The failure to give a sharp melting point may mean that a rise in temperature caused rearrangement of part of the material into the pyrazoline.

[8] Tafel, *Ber.*, **22**, 1854 (1889).

[9] Knorr and Laubmann, *Ber.*, **21**, 1210 (1888); see also Fromm, *Ann.*, **394**, 305 (1913).

Experimental Part

Methyl-3-bromo-4-acetylaminophenyl Ketone.—A solution of 2.6 cc. of bromine in 51.2 cc. of glacial acetic acid was dropped during twenty minutes into a solution of 5.12 g. of the acetylamino derivative in the volume of acid indicated above, to which an equal volume of water had been added,[10] while the whole was constantly shaken. After three and three-fourths hours this was poured with rapid stirring into 500 cc. of cold water containing about 1 g. of sodium bisulfite. Flocculent masses of fine needles separated and were removed. Addition of 100 cc. of concd. ammonia solution to the cold filtrate precipitated additional product; yield, 79%. Crystallization from alcohol gave leaflets; m. p. 138–138.5°.[11]

Anal. Subs., 0.5107, 0.2491: 19.79 cc. of 0.1 *N* $AgNO_3$, 12.4 cc. of N_2 at 20° and 746.5 mm. Calcd. for $C_{10}H_{10}O_2NBr$: Br, 31.25; N, 5.46. Found: 30.93, 5.63.

When the above-described product was refluxed for a few minutes with four times its weight of 6 *N* hydrochloric acid and the hot solution filtered through "Norit," crystals of the hydrochloride of the amino compound were deposited. These were suspended in water, an equal volume of ether was added and, after shaking, the lower layer made faintly alkaline, and extraction with ether completed. Treatment of the dried extract with hydrogen chloride precipitated nearly colorless needles; m. p. 155–156°.

Anal. Subs., 0.2500: 19.87 cc. of 0.1 *N* $AgNO_3$. Calcd. for $C_8H_9ONClBr$: halogen, 46.10. Found: 45.85.

Five g. of the above-described acetyl derivative was oxidized with potassium permanganate in the presence of magnesium sulfate, the mixture filtered, the filtrate evaporated to one-fourth its volume and acidified with concentrated hydrochloric acid. Crystals of 3-bromo-4-acetylaminobenzoic acid separated; yield, 83%. Crystallization from alcohol gave nearly colorless, long needles; m. p. 226–229°.

Anal. Subs., 0.5164: 20.08 cc. of 0.1 *N* $AgNO_3$. Calcd. for $C_9H_8O_3NBr$: Br, 31.00. Found: 31.06.

The same product was obtained in 70% yield by the oxidation of 3-bromo-4-acetylaminotoluene with potassium permanganate. Crystallization from alcohol gave long, colorless needles; m. p. 225–227°. Identity with the above-described product was proved by mixed melting point and analysis.[12]

Styryl-4-acetylaminophenyl Ketone.—To a solution of 9.36 g. of methyl-4-acetylaminophenyl ketone in 100 cc. of alcohol there was added 5.84 cc. of benzaldehyde and then 11 cc. of 20% sodium hydroxide solution, with stirring. The mixture became orange colored and in ten minutes began to deposit flocculent masses of fine needles. Within two hours the mixture was nearly solid and after four and one-half hours the crystals were filtered off and washed with cold alcohol. When the filtrate was poured into 600 cc. of water a second portion of the product mixed with some resin sepa-

[10] Baeyer and Bloem [*Ber.*, **17**, 965 (1884)] obtained methyl-2-acetylamino-5-bromophenyl ketone by bromination in glacial or dilute acetic acid. With chloroform or sulfuric acid as solvent, bromine went into the methyl radical. In the present work an acetic acid solution of the 4-acetylamino derivative gave a good yield of methyl substituted product mixed with but small amounts of the nuclear compound.

[11] This product cannot possibly be identical with the isomeric bromo-aceto-acetanilide, m. p. 138°, reported by Knorr [*Ann.*, **236**, 79 (1886)] and obtained by the action of bromine on the anilide of acetoacetic acid.

[12] It is of interest to note here that Friedländer, Bruckner and Deutsch, *Ann.*, **388**, 30 (1912), found 224° for the melting point of 2-acetylamino-6-bromobenzoic acid. Our product cannot be identical with this.

rated.[13] Filtration of the hot alcoholic solution through "Norit," and cooling the filtrate gave yellow crystals; m. p. 160–161°.[14]

Anal. Subs., 0.5021: 18.77 cc. of 0.1 *N* HCl. Calcd. for $C_{17}H_{15}O_2N$: N, 5.28. Found: 5.23.

Styryl-3-bromo-4-aminophenyl Ketone.—To a mixture of 10 g. of the acetylaminobromophenyl ketone and 6.8 cc. (20% excess) of benzaldehyde in 100 cc. of alcohol, 10 cc. of 20% sodium hydroxide solution was added. The mixture became yellow immediately and red after standing a short time. After four hours the crystals that had formed were filtered off and the filtrate was treated as indicated above. The yield was nearly quantitative. Crystallization from alcohol gave fine, yellow needles; m. p. 146–147°.

Anal. Subs., 0.6807: 22.51 cc. of 0.1 *N* $AgNO_3$. Calcd. for $C_{17}H_{14}O_2NBr$ and $C_{15}H_{12}ONBr$: Br, 23.22, 26.45. Found: 26.42.

Acetylation of the above product as directed by Sudborough[15] gave almost a quantitative yield of diacetyl derivative. Crystallization from alcohol gave colorless plates; m. p. 130–131°.

Anal. Subs., 0.6035: 15.77 cc. of 0.1 *N* $AgNO_3$. Calcd. for $C_{19}H_{16}O_3NBr$: Br, 20.72. Found: 20.87.

Styryl-3,5-dibromo-4-aminophenyl Ketone.—A solution of 2 g. of the required dibromo-amino-acetophenone[16] and 1.25 cc. (1.5 molecular proportions) of benzaldehyde in 175 cc. of alcohol was treated with 5 cc. of 20% sodium hydroxide solution and the mixture allowed to stand for twenty-four hours. After filtration to remove a small amount of flocculent material that had separated, a large amount of material crystallized promptly from the filtrate.[17] After an hour this was collected on a filter and the second filtrate diluted with 4 volumes of water as described above. The combined product was crystallized in cream-colored needles from a mixture of benzene and ligroin (60–70°); m. p. 133–134°.

Anal. Subs., 0.3734: 19.6 cc. of 0.1 *N* $AgNO_3$. Calcd. for $C_{15}H_{11}ONBr_2$: Br, 41.99. Found: 41.94.

The above-described product was further identified by conversion into a diacetyl

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[13] The total weight of material was more than that required by theory, and since the resin could not be separated alone, the yield of the ketone was not determined.

[14] Giua and Bagiellae, *Gazz. chim. ital.*, **51**, II, 120 (1921), reported 154° as the melting point of this product in the crude form and 168° after crystallization. Although their analytical data agree with those required by this condensation product, the fact that they give 164–165° as the melting point of *p*-acetylaminoacetophenone, while the accepted value is 168°, suggests the possibility that the melting point they reported for the condensation product was actually made on the starting material. This explanation of the discrepancy is supported by their misinterpretation of the work of Rupe and Koschitz, *Z. Farben-ind.*, **5**, 317 (1906), on the condensation of *p*-acetylaminobenzaldehyde with acetophenone and who reported 179° as the melting point of the product. Giua and Bagiellae objected to this on the erroneous assumption that the product had been obtained by the interaction of benzaldehyde and *p*-acetylaminoacetophenone.

[15] Sudborough, *J. Chem. Soc.*, **79**, 533 (1901).

[16] Fuchs, *Monatsh.*, **36**, 122 (1915).

[17] This behavior was noted in more than 20 different preparations of this material and seemed to be characteristic.

derivative in 90% yield by Blanksma's[18] method. Crystallization from alcohol gave yellow granules resembling sand; m. p. 173–174°.

Anal. Subs., 0.4209: 18.11 cc. of 0.1 *N* $AgNO_3$. Calcd. for $C_{19}H_{15}O_2NBr_2$: Br, 34.40. Found: 34.37.

The Hydrazone of Styrylphenyl Ketone.—To a solution of 20 g. of benzalacetophenone in 100 cc. of glacial acetic acid, 9.5 cc. of phenylhydrazine was added gradually with shaking and the mixture allowed to stand. After about an hour[19] long, yellow crystals began to separate and for the next fifteen minutes crystallization was rapid; yield, 78%. Repeated crystallization from alcohol gave needles that melted at 117–120°.[20]

Anal. Subs., 0.2923: 19.52 cc. of 0.1 *N* HCl. Calcd. for $C_{21}H_{18}N_2$: N, 9.39. Found: 9.35.

Rearrangement to the Pyrazoline.[21]—Five g. of the hydrazone suspended in 25 cc. of glacial acetic was gently refluxed and the reddish-orange solution that resulted gradually faded to light yellow. After an hour, when the mixture was allowed to cool, it became an almost solid mass of yellow needles that melted at 135–136°.[22] Crystallization from alcohol caused no change; yield, 95%.

Reduction of the Hydrazone.—Ten g. of the hydrazone suspended in a mixture of 150 cc. of alcohol and 15 cc. of glacial acetic acid was reduced by sodium amalgam as directed by Tafel.[8] The resulting solution was poured off from the mercury, evaporated to half its volume, made strongly alkaline and distilled with steam. The distillate was rendered acid to methyl red and extracted with ether. From this extract aniline was isolated and identified as acetanilide. The aqueous residue was acidified with sulfuric acid and evaporated to dryness. The resulting solid was dissolved in water as far as possible, the liquid made alkaline and extracted with ether. From this dry extract gaseous hydrogen chloride precipitated α,γ-diphenyl-α-propylamine hydrochloride.[23] Crystallization from 6 *N* hydrochloric acid gave long, colorless needles; m. p. 195–195.5°. It was further identified by the preparation of the picrate and the acid tartrate.[24]

This hydrazone was also obtained when the experiment was carried out as nearly as could be judged as directed by Auwers and Voss. Five g. of benzalacetophenone was dissolved in 40 cc. of alcohol; 2.38 cc. each of glacial acetic acid and phenylhydrazine were added and the mixture was allowed to stand at room temperature. After twenty-four hours an orange-colored oil had separated which crystallized in twenty-seven days. Filtration gave 2.3 g. of solid that, after recrystallization from alcohol, melted at 117–120°. This product was shown by mixed melting point to be identical with the hydrazone described above. Heating with acetic acid rearranged it to the pyrazoline; m. p. 135–136°.

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[18] Blanksma, *Chem. Weekblad*, 6, 719 (1909).

[19] In this preparation it is necessary to remove the crystals within three hours after they begin to separate or they will be contaminated with the pyrazoline. The filtrate obtained at this point deposited a mixture of the hydrazone and pyrazoline.

[20] The failure to show a constant melting point suggests rearrangement as the heating proceeds.

[21] Though the pyrazoline had no noticeable effect on the skin, the hydrazone of benzalacetophenone exhibited severe vesicant action, producing chemical dermatitis.

[22] Knorr and Laubmann, ref. 9, found 134–135°.

[23] Excess of gas should be avoided since this appears to cause the hydrochloride of the amine to dissolve.

[24] Henrich, *Ann.*, **351**, 180 (1907).

1,3-Diphenyl-5-(4-chlorophenyl)-pyrazoline.—To a solution of 20 g. of 4-chlorobenzalacetophenone[25] in 200 cc. of glacial acetic acid the theoretical amount of phenylhydrazine was added and the mixture allowed to stand for four days. The color darkened but no solid was deposited. The liquid was cooled until a part of the acid solidified, the mixture poured into a Büchner funnel and the acid allowed to melt and pass through the filter paper. No solid remained. Upon standing for an hour this filtrate deposited orange-colored needles; yield, 28% in eight hours. Crystallization from alcohol gave diamond-shaped plates; m. p. 129–130°.

Anal. Subs., 0.3587: 10.65 cc. of 0.1 *N* $AgNO_3$. Calcd. for $C_{21}H_{17}N_2Cl$: Cl, 10.67. Found: 10.54.

When 1.5 g. of the above-described material was boiled for one hour with 5 cc. of glacial acetic acid and the solution cooled, no crystals separated. Seeding caused deposition of 1.25 g. of unchanged starting material.

1,5-Diphenyl-3-(4-acetylaminophenyl)-pyrazoline.—Six cc. (20% excess) of phenylhydrazine was mixed gradually with a solution of 13.6 g. of styryl-4-acetylaminophenyl ketone in 75 cc. of glacial acetic acid and the mixture allowed to stand at room temperature for twenty-four hours. A reddish color was developed but no crystals were deposited. When the mixture was poured with stirring into 600 cc. of ice water, a yellow solid separated in nearly quantitative yield. Crystallization from alcohol gave fine, branched, hair-like, yellow needles; m. p. 241–242°. Separate portions boiled with acetic acid and treated with sodium amalgam, respectively, suffered no change.

Anal. Subs., 0.2323: 19.48 cc. of 0.1 *N* HCl. Calcd. for $C_{23}H_{21}ON_3$: N, 11.83. Found: 11.74.

1,5-Diphenyl-3-(3-bromo-4-aminophenyl)-pyrazoline.—Slightly more than the theoretical amount of phenylhydrazine was gradually added with shaking to a solution of 7.77 g. of the required ketone dissolved in 50 cc. of glacial acetic acid. After one and three-fourth hours "burrs" of crystals appeared on the surface of the liquid. During the next four hours 4.5 g. of orange-colored crystals deposited and were removed. On standing overnight, the filtrate deposited 2.6 g. more of the same material. Crystallization from alcohol gave cream-colored needles; m. p. 200.5°. The product was not affected by boiling acetic acid or by sodium amalgam.

Anal. Subs., 0.5221: 13.35 cc. of 0.1 *N* $AgNO_3$. Calcd. for $C_{21}H_{18}N_3Br$: Br, 20.40. Found: 20.43.

1,5-Diphenyl-3-(3,5-dibromo-4-aminophenyl)-pyrazoline.—Ten g. of the required ketone dissolved in 25 cc. of acetic acid was treated with 2.8 cc. of phenylhydrazine and the mixture allowed to stand at room temperature. After two days 6.17 g. of orange-colored solid had separated. After removal of this the filtrate deposited more on standing; yield, 72%. Crystallization from alcohol or benzene gave orange needles; m. p. 180–181°. The product could be neither rearranged nor reduced.

Anal. Subs., 0.1716: 7.34 cc. of 0.1 *N* $AgNO_3$. Calcd. for $C_{21}H_{17}N_3Br_2$: Br, 33.97. Found: 34.37.

[25] Obtained in 85% yield from Eastman's *p*-chlorobenzaldehyde by Walther and Raetze's method [*J. prakt. Chem.*, **65**, 280 (1902)]. The rate of this condensation was very rapid. Under the conditions, the action of unsubstituted benzaldehyde on acetophenone required two to three hours with efficient stirring; the *p*-chloro derivative condensed within one minute. The previous authors reported 103–104° as the melting point of the product, while 113–114° was found in this work. The purity of the material here in question was checked by analysis.

Anal. Subs., 0.4515: 18.55 cc. of 0.1 *N* $AgNO_3$. Calcd. for $C_{15}H_{11}OCl$: Cl, 14.62. Found: 14.57.

1-(*p*-Bromophenyl)-3-phenyl-5-(*p*-chlorophenyl)-pyrazoline.—The theoretical amount of 4-bromophenylhydrazine in acetic acid was added to a warm solution of *p*-chlorobenzylidene-acetophenone. The crystals that separated during the first few hours turned out to be *p*-bromophenylhydrazine. The filtrate, which was nearly black by reflected light, gave a 31% yield of pyrazoline on standing for twenty-four hours longer. Fine, cream-colored crystals were obtained by crystallization from alcohol; m. p. 142–143°. The product was not affected by boiling acetic acid or by sodium amalgam, which indicated that it was not a hydrazone.

Anal. Subs., 0.4104: 19.85 cc. of 0.1 *N* $AgNO_3$. Calcd. for $C_{21}H_{16}N_2ClBr$: halogen, 28.06. Found: 27.90.

Summary

1. A method has been described for the preparation of methyl-3-bromo-4-acetylaminophenyl ketone and its structure has been established.

2. A condensation product from phenylhydrazine and benzalacetophenone different from that reported by Auwers and Voss has been obtained. Its behavior toward sodium amalgam and its rearrangement when heated with acetic acid show that it is a hydrazone.

3. A number of new halogen substitution products of 1,3,5-triphenylpyrazoline have been obtained. In the preparation of these compounds we have been unable, thus far, to confirm Straus' conclusion that the presence of halogen substituents in all three of the phenyl radicals of the hydrazone of benzalacetophenone stabilizes the compound. Further study is in progress in which it is hoped to test the effect of molecular symmetry of the ketone in this rearrangement.

IOWA CITY, IOWA

[CONTRIBUTION FROM THE LABORATORY OF ORGANIC CHEMISTRY OF THE UNIVERSITY OF WISCONSIN]

THE EFFECT OF CERTAIN BETA SUBSTITUENTS IN THE ALCOHOL UPON AFFINITY AND REACTIVITY IN ACETAL FORMATION

BY JOHN N. STREET AND HOMER ADKINS

RECEIVED AUGUST 13, 1927 PUBLISHED JANUARY 5, 1928

The study of the relations of the structure of the alcohol and aldehyde to the affinity and reactivity manifested in acetal formation has been continued by determining the location of the equilibrium point of the reaction of acetaldehyde with various alcohols which may be regarded as β substitution products of ethanol. The type reaction may be represented as follows

$$CH_3CHO + 2RCH_2CH_2OH \rightleftharpoons CH_3CH(OCH_2CH_2R)_2 + H_2O$$

The β substituents used were the chloro, bromo, iodo, ethoxy, methoxy, methylene, carbethoxy, amine hydrochloride and nitro groups.

The methods of experimentation and the concentrations of reactants