127–129° alone or mixed with an authentic specimen prepared according to Snyder and others.[2,5]

3,5-Diethylphthalic Acid.—The 5.4 g. of crystals obtained during the evaporation of the ether extract of the fusion mixture was crystallized from dilute methanol. The result was 3.4 g. (27%) of nearly pure acid, m. p. 190° with decomp. alone or mixed with a sample prepared from the alkali fusion of the maleic anhydride adduct of 2-ethylhexenal anil.[2] This sample which melted at 194° with decomp. was analyzed.

Anal. Calcd. for $C_{12}H_{14}O_4$: C, 64.83; H, 6.35. Found: C, 65.40; H, 6.51.

The acid lost water when melted and formed the anhydride in the theoretical yield. The anhydride was crystallized from hexane and melted at 55–56°. It was monobasic toward 0.1 *N* sodium methylate.

Anal. Calcd. for $C_{12}H_{12}O_3$: C, 70.55; H, 5.93. Found: C, 70.79; H, 6.10.

The alkali fusion of the 2-ethylhexenal anil adduct was run under conditions similar to the alkali fusion of III. These are somewhat milder than those used by Snyder and others[2] and probably are more favorable to the formation of the 3,5-diethylphthalic acid. The yield of this acid was 10% and that of pure 3,5-diethylbenzoic acid was 14%. The formation of both of these acids is expected from the alkaline fusion of the anil adduct based on the structure elucidated by Snyder and co-workers.[2]

Summary

1. Maleic anhydride has been shown to add to the 3,6-carbon atoms of a 1,4-dihydropyridine.

2. The alkali degradation of the adduct led to butyric, 3,5-diethylbenzoic and 3,5-diethylphthalic acids and to aniline.

3. 3,5-Diethylphthalic acid was also formed as a product of the alkaline degradation of the anil of 2-ethylhexenal.

BRECKSVILLE, OHIO RECEIVED JUNE 12. 1950

---

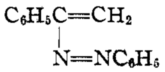
[5] Snyder, THIS JOURNAL, **63**, 3282 (1941).

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, COLUMBIA UNIVERSITY]

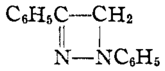
The Reaction of Phenylhydrazine with α-Haloacetophenones[1]

BY DAVID Y. CURTIN AND E. W. TRISTRAM

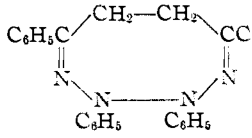
The reaction of phenylhydrazine with α-iodo, bromo- or chloroacetophenone has been found[2] to give a yellow crystalline product, I, m. p. 137°, which has the empirical formula C_7H_6N. Two possible structures (Ia and Ib) for the compound were suggested by Hess.[2] A dimeric structure, Ic, was later proposed by Culman.[3] More recently Bodforss[4,5] and Van Alphen[6] have accepted structures Ia and Ib, respectively, for I. This paper presents additional chemical and physical data bearing on the structure and proposes a new formulation for I.


$C_6H_5C(=CH_2)N=NC_6H_5$

Ia



Ib



Ic

Many molecular weight determinations of I have been made[3,5] in an effort to choose between the monomer, $C_{14}H_{12}N_2$, molecular weight, 208, and the dimer, $C_{28}H_{24}N_4$, molecular weight 416, but most of the values obtained have fallen in the range 300–350.

We have found I to exist in two different crystalline modifications. One crystallizes as yellow needles, m. p. 137–138.5°. The other is obtained as red platelets, m. p. 132–136°. Evidence that the crystals are polymorphic forms of the same compound was obtained by evaporating their benzene solutions and measuring the infrared absorption spectra of the films obtained. The spectra, which are shown in Fig. 1, are identical. All experiments described in this paper except the X-ray analysis described below, were performed with the yellow, higher melting modification of I.

We have redetermined the molecular weight by measuring the freezing point lowering of solutions of I in two different solvents, benzene and diphenylamine. The weighted average of the four determinations in benzene is 387 ± 9; the weighted average of the six determinations in diphenylamine is 393 ± 20. These results are only 7 and 5.5%, respectively, below the dimeric molecular weight.

To obtain further evidence concerning the molecular weight of I a single red crystal was investigated with X-rays. The results of the X-ray study indicate with a high probability that the molecular weight is 416. In view of the cryoscopic determinations which are substantiated by the X-ray data, we feel that the formula of I is established as $C_{28}H_{24}N_4$.

Contributions to the chemistry of I have been made by several investigators. Culman[3] further studied the decomposition of I by acids, first noted by Hess,[2] and from the reaction isolated

---

[1] Abstracted from a thesis presented by E. W. Tristram in partial fulfillment of the requirements for the Ph.D. degree at Columbia University. Presented before the Division of Organic Chemistry at the Philadelphia Meeting of the American Chemical Society, April 10, 1950.

[2] Hess, *Ann.*, **232**, 234 (1886).

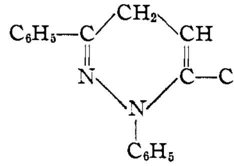
[3] Culman, *ibid.*, **258**, 235 (1890).

[4] Bodforss, *Ber.*, **52**, 1762 (1919).

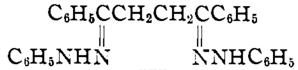
[5] Bodforss, *ibid.*, **72**, 468 (1939).

[6] Van Alphen, *Rec. trav. chim.*, **65**, 109 (1946).

1,3,6-triphenyl-1,4-dihydropyridazine (II) in 60% yield (m. p. not reported) and a base of unknown structure.


II

Bodforss[4,5] noted the stability of I toward alkaline or neutral permanganate and reported the failure of I to react with a variety of reagents including acetyl chloride and benzoyl chloride. I with phenyl isocyanate gave a compound $C_{20}H_{18}O_2N_4$, the structure of which was not elucidated. I, when treated with sodium in alcohol, was quantitatively reduced to diphenacyl bisphenylhydrazone (III).



$$\underset{\substack{\| \\ C_6H_5NHN}}{C_6H_5C}CH_2CH_2\underset{\substack{\| \\ NNHC_6H_5}}{CC_6H_5}$$

III

Presumably by analogy with the acyloin condensation and the pinacol reduction, the reaction with sodium was interpreted by Bodforss as being consistent with a fourteen carbon structure for I.

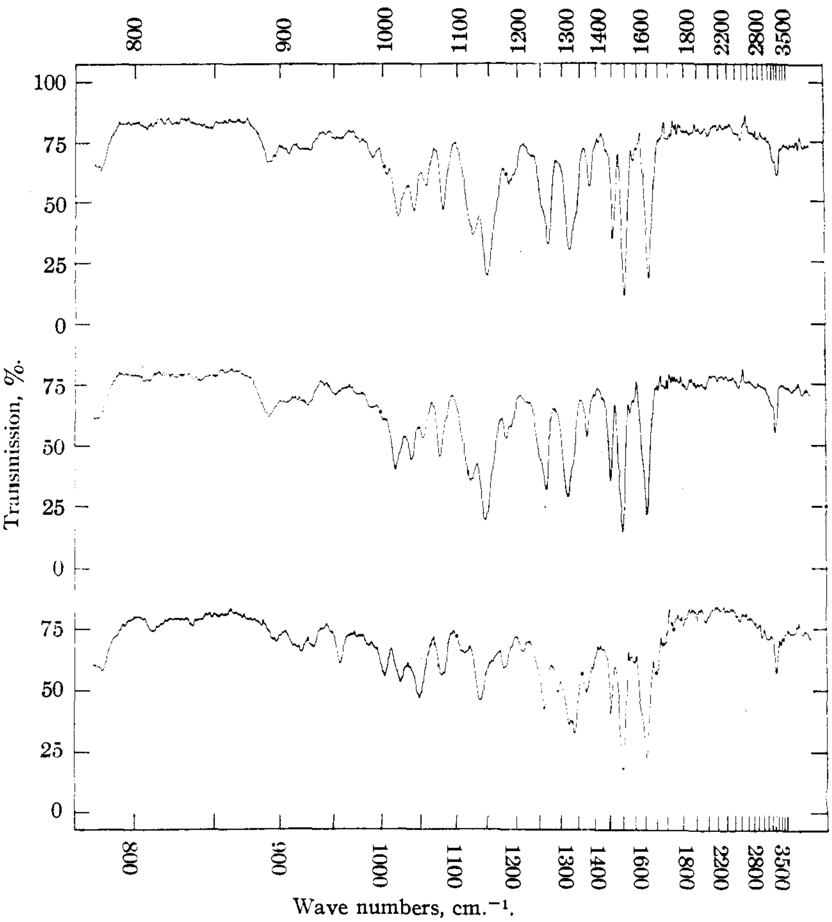
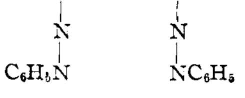


Fig. 1.—Infrared spectra: upper curve, yellow modification of I; middle curve, red modification of I; lower curve, 1,3,6-triphenyl-1,4-dihydropyridazine (II).

Van Alphen[6] reported that I was not reduced by hydrogen over Raney nickel. With ozone I reacted only with great difficulty to give small amount of glyoxal and diphenacyl.

During the course of this work it has been observed that I reacts with hydroxylamine hydrochloride and sodium acetate in water–ethanol solution to give diphenacyl dioxime in 90% yield. We have also successfully accomplished the hydrogenation of I with a platinum catalyst in ethanol solution at room temperature to give III in almost quantitative yield.

The reactions above indicate the presence of the 1,4-diphenylbutane carbon skeleton in I. In particular the conditions of the catalytic reduction are so mild that the reaction is evidence not only that I contains the 1,4-diphenylbutane grouping but that the same order of attachment of the carbon and nitrogen atoms that exists in the

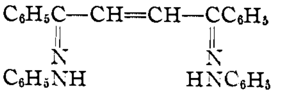


$$\underset{\substack{| \\ N \\ | \\ C_6H_5N}}{C_6H_5C}-C-C-\underset{\substack{| \\ N \\ | \\ NC_6H_5}}{CC_6H_5}$$

A

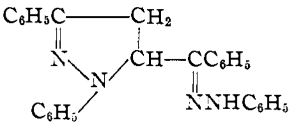
product (III) is to be found in I. This leads to the partial formulation, A, for I.

Various possible structures for I may now be considered in the light of the known chemical and physical properties of the compound. The fact that α-haloacetophenones had been reported to dimerize when treated with various bases[7] suggested structures Id or Ie. A direct attempt



$$\underset{\substack{\| \\ N \\ C_6H_5NH}}{C_6H_5C}-CH{=}CH-\underset{\substack{\| \\ N \\ HNC_6H_5}}{CC_6H_5}$$

Id


Ie

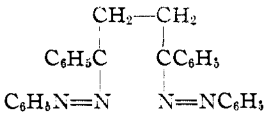
was made to exclude Id from consideration by synthesizing it from dibenzoylethylene and phenyl hydrazine. The reaction afforded a new compound, IV, the elementary analysis of which was in accord with that calculated for the monophenylhydrazone of dibenzoylethylene. When IV proved unreactive toward a second mole of phenylhydrazine even under drastic conditions, it was not investigated further. Structure Id,

---

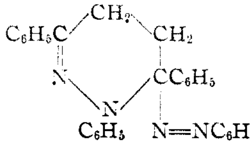
(7) Bogoslovskii, *J. Gen. Chem. U. S. S. R.*, **14**, 993 (1944) [*C. A.*, **39**, 4600 (1944)].

which has a carbon–carbon double bond is inconsistent with the observed stability of I to permanganate oxidation.[4,5] In addition, the infrared absorption spectrum of I, is inconsistent with structures Id and Ie since there is no discernible absorption peak in the neighborhood of 3300 cm.$^{-1}$, the region of the spectrum corresponding to the characteristic N–H stretching frequency.[8]

Three structures, Ic, If and Ig, having the requisite atomic skeleton can be conceived of as



If



Ig

arising from the dimerization of Hess' diene structure, Ia. Ic is the formulation advanced by Culman.[3] These three structures seem to be the only ones which satisfy the requirements that I contain no carbon–carbon double bond, have no nitrogen–hydrogen bond, and might reasonably be expected to give diphenacyl bisphenylhydrazone upon the addition of one mole of hydrogen. On the basis of the chemical evidence alone a choice among these structures is impossible.

Evidence as to the nature of the functional groups present has been obtained by measuring the ultraviolet absorption spectrum of I. The spectrum of Ig should be similar to the curve obtained by the addition of the spectra of 1-benzeneazo-1-phenylcyclohexane, V, and benzaldehyde methylphenylhydrazone, VI. The spectra of the model compounds V and VI are shown in Fig. 2. The spectrum of I and the spectrum obtained by adding the molar extinction coefficients of V and VI are presented in Fig. 3.

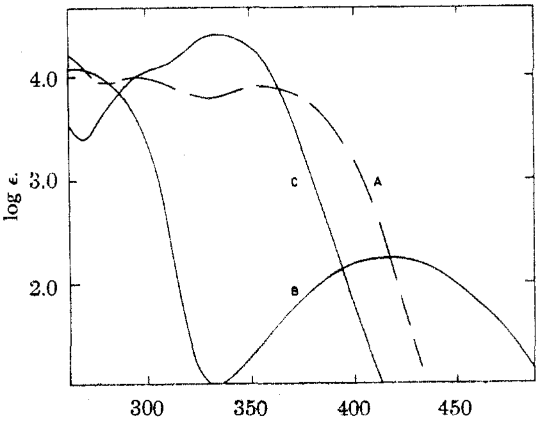
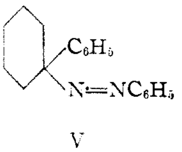
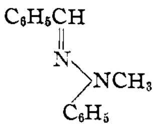


Fig. 2.—A. 1,3,6-Triphenyl-1,4-dihydropyridazine; B. 1-benzeneazo-1-phenylcyclohexane; C, benzaldehyde methylphenylhydrazone.



V



VI

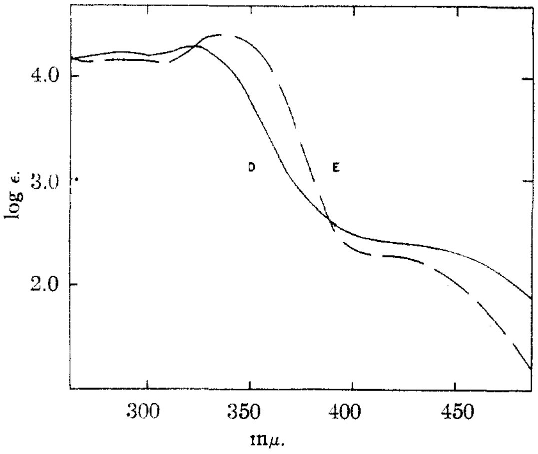


Fig. 3.—D, Compound I: E, addition of curves B and C.

The similarity of the two curves is apparent. While it is impossible to predict with certainty the ultraviolet absorption that structures Ic and If would have, it is to be expected that Ic would produce a spectrum similar to that given by VI while If should be similar to V. In Fig. 2 the spectrum of 1,3,6-triphenyl-1,4-dihydropyridazine (II) has been included. The similarity of many aspects of the infrared spectra of I and II (Fig. 1) is also striking since structures Ig and II differ only by a phenylazo group and carbon–carbon double bond. It seems, therefore, that structure Ig is most consistent with the chemical evidence and spectra of I.

A possible path for the formation of I is suggested by the reaction of phenylhydrazine with other α-haloketones. If the initial step in the reaction were the formation of the hydrazone, VII, it might be expected to form readily the azovinyl intermediate (Ia) by the elimination of hydrogen halide. Mattox and Kendall[9] and Djerassi[10] have demonstrated that steroids containing the α-halocarbonyl grouping upon treatment with phenylhydrazine are converted to α,β-unsaturated phenylhydrazones. By a dimerization of the intermediate Ia, the product, Ig, can be formed directly. This dimerization is suggestive of the Diels–Alder reaction.[11]

In an effort to obtain information concerning

---

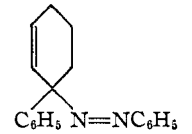
(8) Barnes, Gore, Stafford and Williams, *Anal. Chem.*, **20**, 402 (1948). While the absence of a peak around 3300 cm.$^{-1}$ in the spectrum of I is not made convincing by Fig. 1, a careful examination of the spectrum in this region with a calcium fluoride prism, showed a peak at 2958 cm.$^{-1}$ but no discernible absorption from 3000 to 3600 cm.$^{-1}$.

(9) Mattox and Kendall, THIS JOURNAL, **70**, 882 (1948).

(10) Djerassi, *ibid.*, **71**, 1003 (1949).

(11) Kloetzel, "Organic Reactions," John Wiley and Sons, Inc., New York, N. Y., Vol. IV, 1948, p. 1.

the mechanism, the reaction of α-chloroacetophenone with phenylhydrazine was carried out in the presence of an excess of butadiene with the thought that the adduct, VIII, might be formed.



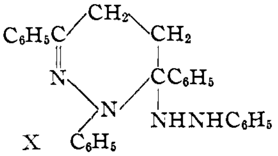
VIII

However, the only compound isolated, in normal yield, was the product I. This result indicates either that the diene Ia is not present as a reaction intermediate or that the rate of reaction of Ia with butadiene is too slow to compete with its dimerization, and therefore does not exclude the dimerization mechanism as a possible route for the formation of I. IX was excluded as a possible intermediate since when it was prepared by the

$C_6H_5COCHClCH_2COC_6H_5$
IX

addition of hydrogen chloride to dibenzoylethylene and treated with phenylhydrazine it gave the same product, IV, as was obtained by the reaction of phenylhydrazine with dibenzoylethylene.

The reduction of I by sodium and alcohol or catalytically with hydrogen can readily be explained either through an intermediate hydrazine, X, or by direct formation of the product (III).



X

The decomposition of I by strong acids is a complicated reaction giving a mixture of products. Using Culman's procedure we were able to obtain only small yields of 1,3,6-triphenyl-1,4-dihydropyridazine (II). After many attempts to improve the yield, conditions were found which gave II in 35% of the theoretical amount. The stoichiometry of the acid decomposition suggests that the other products of the reaction are nitrogen and benzene. Various experiments designed to isolate benzene from the reaction mixture were unsuccessful but the presence of phenol, isolated in 20% yield as the tribromo derivative, was demonstrated. That the phenol probably arises from the decomposition of benzenediazonium sulfate was shown by pouring the acidic filtrate from a decomposition reaction into an alkaline solution of β-naphthol whereby the coupled product 1-benzeneazo-2-naphthol was obtained. The mechanism of this acid-catalyzed decomposition requires further investigation. The first step in the conversion of I to diphenacyl dioxime by treatment with hydroxylamine hydrochloride and sodium acetate may be the decomposition of I to give II, followed by the reaction of II with hydroxylamine to yield the dioxime.

Experimental[12]

Preparation of I.—The directions of Hoogeveen[13] for the preparation of I were followed but it was found advantageous to run the reaction at room temperature or below to obtain a purer product. In a typical experiment, 40 g. (0.20 mole) of α-bromoacetophenone when treated with 40 g. (0.49 mole) of anhydrous sodium acetate and 21 g. (0.20 mole) of phenylhydrazine in 600 cc. of ethanol gave 25 g. (60%) of recrystallized product, yellow needles (from ethanol), m. p. 137–138°. Subsequent recrystallizations from ethanol raised the melting point to 137.5–138.5°. Upon standing overnight in ethanol at room temperature the yellow needles were converted to red platelets, m. p. 132–136°.

Anal. Calcd. for $C_{28}H_{24}N_4$: C, 80.74; H, 5.81; N, 13.45. Found for yellow needles: C, 80.54; H, 5.94; N, 13.67. Found for red platelets: C, 80.49; H, 5.72; N, 13.65.

When a similar experiment was conducted in the presence of a thirty mole excess of butadiene I (78% yield, m. p. 135–138°) was obtained and no other product was isolated.

Cryoscopic Molecular Weight Determinations.—The molecular weight of I in two different solvents, benzene and diphenylamine, was determined using the Beckmann freezing point apparatus. The benzene was thiophene-free, reagent quality, dried over sodium wire. Concentrations of I were varied from 7.2 to 20.1 molal. The molecular depression constant of benzene employed was 5.12° per mole. The weighted mean of four determinations at four concentrations ranging from 7.2 to 20.1 molal was 387 ± 9 (calcd. for $C_{28}H_{24}N_4$, 416.) The diphenylamine was purified by vacuum sublimation and melted at 53–54°. The molecular depression constant of diphenylamine was taken as 8.6° per mole. The weighted mean from six determinations in solutions with concentrations ranging from 14.9 to 37.6 molal was 393 ± 20. The freezing diphenylamine solutions were difficult to stir causing the reproducibility of the temperature readings to be poor.

X-Ray Study.[14]—The red and yellow modifications of I when finely powdered and exposed to X-rays gave different diffraction patterns proving they were different crystals with different unit cell dimensions. A single red platelet of I was investigated with X-rays by the Weissenberg Equi-Inclination technique as described by Buerger.[15] A rotation picture and Weissenberg pictures of the zero, first and second levels of the reciprocal lattice were taken about each of two axes. The crystal was found to be monoclinic, space group $P2_1/a(C^5_{2h})$, having the unit cell dimensions $a = 19.8$ Å., $b = 11.8$ Å., $c = 10.9$ Å., $\beta = 113°$. From the measured value, 1.22 g. per cc., for the density of I at 25° the weight of the unit cell was found to be 1722 molecular weight units.

The calculated weight of the unit cell containing eight molecules of molecular formula $C_{14}H_{12}N_2$ or four molecules of molecular formula $C_{28}H_{24}N_4$ is 1664. The observed value of 1722 is in agreement with this figure (3.6% high). Since there are only four crystallographically equivalent positions in the space group $P2_1/a$ the probability is high that the unit cell contains only four molecules, and therefore that the molecular weight of I is 416.

Catalytic Hydrogenation of I.—I (20.8 g., 0.050 mole) in 200 cc. of ethanol was hydrogenated for thirty hours at fifty pounds pressure with 0.2 g. of platinum oxide. Two additional 0.2 g. samples of platinum oxide were added during the course of the reaction. The yield of diphenacyl

---

[12] All melting points are corrected. The microanalyses were performed by Miss Lois May and by the Clark Microanalytical Laboratory.

[13] Hoogeveen, *Rec. trav. chim.*, **50**, 669 (1931).

[14] We wish to thank Dr. Irving W. Ruderman, Professor Ralph J. Holmes and Professor Isidor Fankuchen for helpful advice during the course of the work. We are also grateful to the Geology Department of Columbia University for the use of their X-ray apparatus.

[15] Buerger, "X-Ray Crystallography," John Wiley and Sons, Inc., New York, N. Y., 1942.

bisphenacylhydrazone (III), recrystallized once from ethanol–acetone, was 17.9 g. (86%) of faintly yellowish crystals, m. p. 172–185°. A second crop, 1.0 g., m. p. 172–182°, was obtained by further evaporation of the filtrate; total yield, 18.9 g. (91%). Using a preheated melting point apparatus, the m. p. of the product after several recrystallizations was 180–185° (dec.). The m. p. has been reported as 174°, 180°, and 195°.[5,16,17] By treatment with hydroxylamine hydrochloride in ethanol, III was converted to diphenacyl dioxime, m. p. 202–203°, in 70% yield. Subsequent recrystallization raised the m. p. to 206–208°. A mixed m. p. with an authentic sample was not depressed.

Reaction of I with Hydroxylamine.—A solution of 7.5 g. (0.11 mole) of hydroxylamine hydrochloride and 10 g. (0.12 mole) of sodium acetate in 40 cc. of water was added to a sludge of 7.5 g. (0.018 mole) of I in 200 cc. of ethanol. After refluxing for forty-four hours the clear yellow solution was concentrated by distilling off 100 cc. of solvent. The precipitate which appeared on cooling was filtered, washed with ethanol and triturated with water to remove inorganic salts. The yield of colorless crystals, m. p. 205–208°, was 4.3 g. (90%). One recrystallization from ethanol raised the m. p. to 207–208°. A mixed m. p. with a known sample of diphenacyl dioxime showed no depression. A mixed m. p. with a sample of dibenzoylethylene dioxime, m. p. 209–211°, was 196–198°.

Acid Decomposition of I.—In our hands, Culman's method[3] of decomposing I with ethanolic hydrogen chloride did not give good yields. Better results were obtained with the following procedure. To a solution of sulfuric acid (25 cc.) and water (13 cc.) cooled to 10° was added 5 g. (0.012 mole) of I with shaking. The resulting orange sludge was poured into an ice-water mixture with stirring whereupon a flocculent, yellowish precipitate was formed. The solid was collected and after recrystallization from ethanol 1.4 g. (38%) of 1,3,6-triphenyl-1,4-dihydropyridazine (II) was obtained as light yellow needles, m. p. 113.5–115.5°. A mixed m. p. with II prepared from diphenacyl and phenylhydrazine[4] showed no depression.

To demonstrate the presence of benzenediazonium ion in the reaction mixture the filtrate above was added to a vigorously stirred solution of β-naphthol and 40 g. of sodium hydroxide in about 400 cc. of ice and water. The orange red dye obtained, from ethanol-water and acetic acid–water, melted at 131.5–132°. A mixed m. p. with an authentic sample of 1-benzeneazo-2-naphthol showed no depression. In this experiment the yield of 1,3,6-triphenyl-1,4-dihydropyridazine, m. p. 113.5–115.5°, was 1.4 g. (38%). When the original reaction was boiled for ten minutes and treated with bromine an 18% yield of tribromophenol, m. p. 91–92°, could be obtained.

Reaction of *trans*-Dibenzoylethylene with Phenylhydrazine to Give IV.—*trans*-Dibenzoylethylene (1.0 g.) was heated for five minutes with phenylhydrazine (1.0 g.) and acetic acid (0.5 g.) in 15 cc. of 2:1 ethanol-water. Bright yellow needles of IV, m. p. 180–182°, were obtained by recrystallization of the product from ethanol.

Anal. Calcd. for $C_{22}H_{18}ON_2$: C, 80.95; H, 5.56; N, 8.58. Found: C, 81.06; H, 5.42; N, 8.57.

Reaction of α-Chlorodiphenacyl with Phenylhydrazine to Give IV.—α-Chlorodiphenacyl[18] (1.0 g.) when shaken at room temperature with 1.0 g. of phenylhydrazine and 1.0 g. of sodium acetate in 40 cc. of ethanol and allowed to stand overnight gave IV, m. p. 177–181° after recrystallization from ethanol (no depression of m. p. with IV obtained above).

Infrared Absorption Spectra (Fig. 1).—The spectra of the red and yellow modifications of I and also 1,3,6-triphenyl-1,4-dihydropyridazine (II) were measured using a ratio recording, double beam infrared spectrophotometer.[19] For each compound a film was laid down on a sodium chloride half crystal by evaporation of a concd. solution of the pure solid in benzene. The films of I did not crystallize upon evaporation of the solvent; the film of II partially formed flat crystals parallel to the face of the salt crystals.

Ultraviolet Absorption Spectra (Fig. 2).—The absorption spectra of 1,3,6-triphenyl-1,4-dihydropyridazine (II), benzaldehyde methylphenylhydrazone, 1-benzeneazo-1-phenylcyclohexane,[20] and I were obtained with a Beckmann Quartz Spectrophotometer, Model DU. In all cases the weighed solid was dissolved in 95% ethanol and its absorption measured immediately over the range 240–600 mμ. For the addition curve, the molar extinction coefficients of the two model compounds at each wave length were added and the logarithm of the sum was plotted against wave length in the usual fashion.

Summary

1. The product, I, of the reaction of phenylhydrazine with α-haloacetophenones has been shown by cryoscopic measurements and X-ray analysis to have a molecular weight corresponding to the formula $C_{28}H_{24}N_4$.

2. The crystalline modification of I stable at room temperature is monoclinic; space group C_{2h}^5; unit cell dimensions, a = 19.8 Å., b = 11.8 Å., c = 10.9 Å., β = 113°.

3. The reaction of I with acid has been reinvestigated and the catalytic hydrogenation and reaction with hydroxylamine have been studied.

4. The chemical reactions together with the ultraviolet and infrared absorption spectra indicate that I is 6-benzeneazo-1,3,6-triphenyl-1,4,5,6-tetrahydropyridazine.

NEW YORK 27, N. Y. RECEIVED MAY 31, 1950

---

[16] Kapf and Paal, *Ber.*, **21**, 3056 (1888).

[17] Schlotz, *ibid.*, **51**, 1645 (1918).

[18] Paal and Schulze, *ibid.*, **35**, 168 (1902).

[19] Savitzky, "A Ratio-recording, Double Beam Infrared Spectrophotometer Using Phase Discrimination and a Single Detector," Ph.D. Dissertation, Columbia University, May, 1949. We are indebted to Professor Ralph S. Halford for the use of this instrument.

[20] Kindly supplied by Mrs. Charlotte Russell who synthesized the compound according to the directions of Grammaticakis, *Bull. soc. chim. France*, 438 (1947).