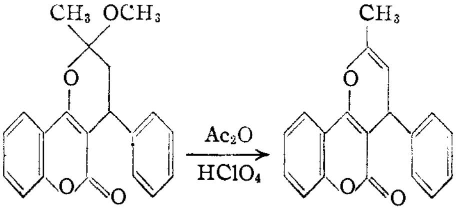
The methyl ketal, XVI, was treated with acetic anhydride containing perchloric acid and the dehydrated derivative of I, 2-methyl-4-phenyl-5-oxo-γ-pyrano(3,2-c)(1)benzopyran (XVII)[7] was obtained.



XVI XVII

This reaction parallels the formation of 2-methylchromene from 2-methyl-2-methoxychroman.[4]

When I was heated with phenol and zinc chloride in an attempt to form the phenyl ketal only XVII was isolated. An attempted reaction between I and glycolic acid in dioxane led to the recovery of unreacted I.

Experimental

Synthesis of Cyclic Ketals.—I was suspended in ten times its weight of the alcohol. Hydrogen chloride was then introduced from a cylinder. The mixture became warm and solution resulted after three to five minutes. After standing at room temperature for the time indicated in Table I the solution was poured into a large excess of ice-water with vigorous stirring. A gum or oil separated. The water was decanted and hot methanol added. Crystallization occurred readily or after refrigeration of the resulting solution. The pure racemates were obtained after fractional crystallization from methanol except as noted in Table I.

2-Methyl-2-methoxy-4-phenyl-5-oxodihydropyrano(3,2-c)(1)benzopyran (XVI).—Sixty grams of I was suspended in 300 ml. of methanol and hydrogen chloride passed in. The mixture became warm and a clear solution resulted. A mass of crystals then appeared. After cooling, the product was filtered off and washed with methanol and dilute sodium hydroxide solution. The mother liquor and the washings were then poured into an excess of water and the solid which precipitated was filtered off. The combined precipitates were recrystallized from benzene; yield 59 g., m.p. 163–164°.

Conversion of XVI to XVII.—Two grams of XVI was suspended in 20 ml. of acetic anhydride and two drops of perchloric acid added. The mixture was heated on a steam-bath for one hour giving a green solution. After being cooled the solution was poured into 200 ml. of ice and water to give a pink precipitate. After two recrystallizations from methanol 0.8 g. of XVII was obtained, m.p. 144–145°. The melting point of a mixture of this product with authentic XVII was 144.5–146°.

Reaction of I with Phenol and Zinc Chloride.—Fifteen grams of phenol was melted and 10 g. of I and 4 g. of anhydrous zinc chloride added. The mixture was heated at 70° for 15 minutes. After cooling, the melt was poured into 1 l. of ice-water and the gum which formed was dissolved in 95% ethanol. Dropwise addition of water caused a precipitate to form. After filtration the crystals were washed with 10% sodium hydroxide solution and recrystallized from ethanol. Three grams of material melting at 127–135° was obtained. After two more recrystallizations from methanol the melting point was 145–146°.

Acidification of the sodium hydroxide washings precipitated a small amount of unreacted I.

Attempted Reaction of I with Glycolic Acid.—Into a mixture of 10 g. of I and 10 g. of glycolic acid in 150 ml. of dioxane was introduced hydrogen chloride from a cylinder. Solution occurred in a few minutes. After standing 14 hours at room temperature the solution was poured into 600 ml. of ice-water giving a gum. The gum was dissolved in 100 ml. of boiling 95% ethanol and the solution refrigerated. After five days the crystals which had formed were separated by filtration; yield 6.0 g., m.p. 145–152°. Recrystallization from acetone–water raised the melting point to 159–161°. The melting point of a mixture of this product with authentic I was 159–161°.

MADISON 6, WISCONSIN RECEIVED OCTOBER 20, 1951

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, CARNEGIE INSTITUTE OF TECHNOLOGY]

Reactions of Unsaturated Compounds with Iodine–Amine Complexes. I. Reactions of Benzalacetophenone and Benzalacetone

BY PHILIP L. SOUTHWICK AND DAVID R. CHRISTMAN[1]

Complexes of iodine with ammonia, cyclohexylamine, benzylamine, morpholine and piperidine have all been found to react readily with benzalacetophenone. When sufficient additional amounts of ammonia or the amine are present, good yields can usually be obtained of 2-phenyl-3-benzoylethylenimines from ammonia or the primary amines, and of α,β-diaminobenzylacetophenones from the secondary amines. Benzalacetone reacts with the iodine–morpholine and iodine–piperidine complexes to yield α,β-diamino benzylacetones, but apparently does not yield ethylene imine ketones with iodine–ammonia or primary amine complexes. The products from both ketones are often obtained chiefly in the configurations which are not predominant in the similar products obtained by reactions of these amines with the corresponding ketone dibromides.

Recent work in this Laboratory[2] has shown that N-bromosuccinimide is capable of attacking the carbon to carbon double bond of certain β-phenyl-α,β-unsaturated ketones. The result of this attack which in most instances occurred only in the presence of catalytic amounts of benzoyl peroxide, was either the addition of two bromine atoms to the double bond, the substitution of a bromine atom for hydrogen on the α-carbon atom, or simply conversion of the ketone into its geometric isomer. However, efforts to elucidate the mechanisms of these reactions were largely unsuccessful.[2]

One of the questions raised by the results obtained with N-bromosuccinimide concerned the possibility that the bromo derivatives resulted not from the direct action of N-bromosuccinimide on the ketones, but from the action of the elementary bromine which might have been formed by the decomposition of the N-bromosuccinimide. Although there was reason for believing that free bromine was not involved in these reactions, it nevertheless became of interest to test the effect on α,β-unsaturated ketones of an N-halogen amide or amine the decomposition of which could not liberate a halogen capable of attacking the double bond. Benzalacetophenone, benzalacetone and similar α,β-unsaturated ketones do not form stable

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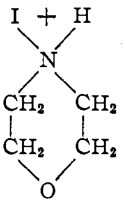
(1) Institute Graduate Fellow in Organic Chemistry, 1950–1951.

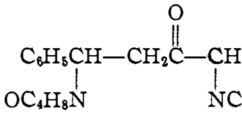
(2) P. L. Southwick, L. A. Pursglove and P. Numerof, THIS JOURNAL, **72**, 1600, 1604 (1950).

addition products with iodine, and the use of an N-iodo compound was therefore suggested. Among the compounds considered for trial on this basis was the orange-colored, crystalline complex formed from iodine and morpholine, "morpholine periodide," which was first described by Rice and Beal.[3] The compound has the composition $C_4H_9ONI_2$ and may perhaps be regarded as essentially the equivalent of a hydroiodide of N-iodomorpholine (I). When solutions or suspensions of this complex in alcohol or benzene were mixed with an excess of morpholine and benzalacetophenone or benzalacetone, any suspended complex was rapidly dissolved, the orange-red color of the solution was almost immediately discharged, and a white precipitate soon appeared. Investigation of the reaction mixtures disclosed that in the case of benzalacetophenone the product derived from the ketone was α,β-dimorpholinobenzylacetophenone (XV), a compound previously obtained by the action of morpholine on benzalacetophenone dibromide.[4] When the reaction was conducted with three moles of morpholine in addition to the mole incorporated in the iodine complex, this product was obtained in 87% yield in the form melting at 173–175°; the by-products of the morpholine–benzalacetophenone dibromide reaction,[4] the other diastereoisomer of α,β-dimorpholinobenzylacetophenone, and α-morpholinobenzalacetophenone, were not present in sufficient quantity to permit their separation from the reaction mixture. On the other hand, the product from benzalacetone, although corresponding in composition to the single α,β-dimorpholinobenzylacetone (m.p. 160°) previously obtained from benzalacetone dibromide,[5] melted at 163–164° and depressed the melting point of the known isomer to 142–155°.



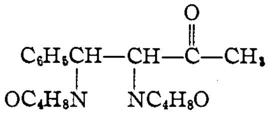
I

Acid hydrolysis of this new dimorpholino derivative of benzylacetone yielded benzaldehyde and a small amount of benzyl methyl diketone (isolated as the osazone), the same products obtained from the known α,β-dimorpholinobenzylacetone by this procedure.[6] This result eliminated the possibility that the compound could have the structure II and supported the assignment of the only other likely structure, that of an α,β-dimorpholinobenzylacetone (III). Thus it was concluded that the compound is a diastereoisomer rather than a structural isomer of the known α,β-dimorpholinobenzylacetone, and hence the second of the two possible racemates corresponding to formula III.



$$\underset{\mathrm{OC_4H_8N}}{\mathrm{C_6H_5CH}}\mathrm{{-}CH_2}\overset{\mathrm{O}}{\overset{\|}{\mathrm{C}}}\mathrm{{-}}\underset{\mathrm{NC_4H_8O}}{\mathrm{CH_2}}$$

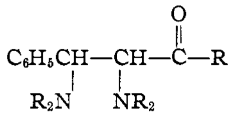
II



$$\underset{\mathrm{OC_4H_8N}}{\mathrm{C_6H_5CH}}\mathrm{{-}}\underset{\mathrm{NC_4H_8O}}{\mathrm{CH}}\mathrm{{-}}\overset{\mathrm{O}}{\overset{\|}{\mathrm{C}}}\mathrm{{-}CH_3}$$

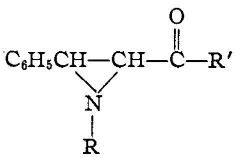
III

These results suggested that a very convenient new method was at hand for the preparation of compounds of the type illustrated by formula IV, a method which, moreover, might make such compounds accessible in configurations not previously secured or else obtained only with some difficulty. Furthermore, it seemed likely that by the use of iodine complexes of primary amines or of ammonia, ethylene imine ketones of the type V could be obtained. Further investigation with amines other than morpholine has shown these suppositions to be correct. It was found that reactions with α,β-unsaturated ketones could be carried out by adding previously prepared solutions of the iodine–amine complex plus three moles or more of the amine to solutions of the ketone, or by preparing solutions containing the ketone plus the amine or the ketone plus iodine and then adding either iodine or the amine as required. The order in which the three reactants were mixed altered the yield in some cases but not the nature of the product or products obtained. Although of the amines used only morpholine formed an easily crystallized complex with iodine, in all cases mixing of the amine with solutions of iodine in benzene or alcohol produced a red color indicative of complex formation. The reaction of the ketone with the iodine–amine complex could be followed by the decolorization of the solution, which often occurred very rapidly.



$$\underset{\mathrm{R_2N}}{\mathrm{C_6H_5CH}}\mathrm{{-}}\underset{\mathrm{NR_2}}{\mathrm{CH}}\mathrm{{-}}\overset{\mathrm{O}}{\overset{\|}{\mathrm{C}}}\mathrm{{-}R'}$$

IV



V

Among the secondary amines, piperidine, as well as morpholine, was investigated. The treatment of benzalacetophenone with piperidine and iodine produced the form of α,β-dipiperidinobenzylacetophenone previously obtained from the reaction of α-bromobenzalacetophenone or benzalacetophenone dibromide with piperidine.[7] The only

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(3) R. V. Rice and G. D. Beal, U. S. Patent 2,290,710, July 21, 1943; *C. A.*, **37**, 502 (1943).

(4) (a) N. H. Cromwell, THIS JOURNAL, **62**, 2897 (1940); (b) shortly after this paper was submitted for publication, R. H. Jordan, R. E. Lutz and D. F. Hinkley, *J. Org. Chem.*, **16**, 1442 (1951), described experiments in which two forms of α,β-dimorpholinobenzylacetophenone were obtained from benzalacetophenone dibromide. One of these compounds, their "isomer-B," was described as melting at 174–176° when the temperature was raised from 40° at 3°/min., and is apparently identical with the form melting at 173–175° which was obtained by Cromwell, ref. 4a, and by us. Our product is precipitated from solution in glacial acetic acid by dilution with water in accordance with the description of "isomer-B" by Jordan, Lutz and Hinkley. The latter authors, however, have compared Cromwell's 173–175° isomer with their "isomer-A" (m.p. 175–177° when taken up from 40° at 3°/min.). Our results indicate that "isomer-A," described as remaining dissolved when its glacial acetic acid solutions are diluted with water, is not the same substance, and that "isomer-B" is the compound with which the 173–175° product obtained by Cromwell and by us should be identified. These compounds melt with decomposition, and Jordan, Lutz and Hinkley have shown that by use of a preheated bath and a rapid rate of heating, melting points as high as 180° for "isomer-B" and 186° for "isomer-A" can be obtained (*cf.* footnote 17). Our product showed an instantaneous m.p. of 177–179°, in reasonable agreement with the value given for "isomer-B."

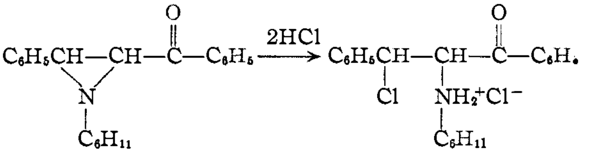
(5) N. H. Cromwell, THIS JOURNAL, **62**, 3470 (1940).

(6) This is the degradative method used by N. H. Cromwell, ref. 5, to elucidate the structure of the previously known isomer.

(7) (a) E. R. Watson, *J. Chem. Soc.*, **85**, 1319 (1904); (b) C. Dufraisse and H. Moureu, *Bull. soc. chim.*, **41**, 457, 850 (1927).

notable difference in the products from the different procedures was the almost complete absence of α-piperidinobenzalacetophenone from the piperidine–iodine product, although an appreciable proportion of this substance is obtained from benzalacetophenone dibromide. With benzalacetone, on the other hand, the piperidine–iodine reaction gave a previously undescribed racemate of α,β-dipiperidinobenzylacetone, m.p. 110–111°, and apparently little or none of the diastereoisomer (m.p. 122°), which Cromwell and Witt[8] obtained from the reaction of piperidine with benzalacetone dibromide. A mixture of the two compounds showed a melting point depression. The new diastereoisomer yielded the osazone of benzyl methyl diketone following acid hydrolysis and treatment with phenylhydrazine, as did the previously known form. The results with the piperidine–iodine complex therefore parallel those with the morpholine–iodine complex in that from benzalacetophenone a product obtained by the dibromide method is formed, whereas from benzalacetone the heretofore missing racemate of the α,β-diamino ketone results.

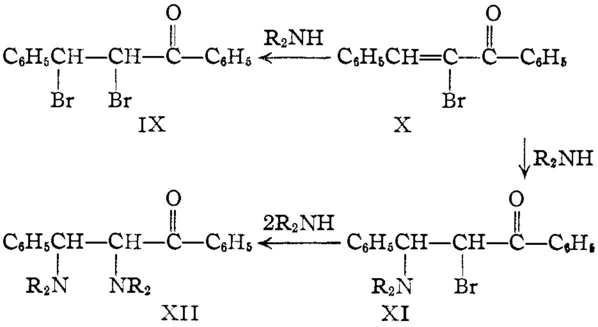
Since use of the secondary amines, morpholine and piperidine, had yielded interesting results, it was decided to proceed with the investigation of similar reactions with suitable primary amines and with ammonia. Cyclohexylamine and benzylamine, the primary amines chosen, reacted smoothly and rapidly with benzalacetophenone in the presence of iodine to form 1-cyclohexyl-2-phenyl-3-benzoylethylenimine (VI), m.p. 100–102°, and 1-benzyl-2-phenyl-3-benzoylethylenimine (VII), m.p. 60–62°, respectively. In each case, the crude ethylene imine ketone consisted almost entirely of a single diastereoisomer, and in each case the form obtained was that which is more soluble and therefore more difficult to secure in the pure state from the mixture of diastereoisomers produced from benzalacetophenone dibromide.[9] The cyclohexyl derivative (VI), which had not been described in this form at the time we first obtained it, was further characterized by treatment with hydrochloric acid to produce the hydrochloride of a cyclohexylaminochlorobenzylacetophenone. This substance failed to oxidize acidified potassium iodide solutions[10] and is therefore thought to be the hydrochloride of α-cyclohexylamino-β-chlorobenzylacetophenone (VIII). This compound, which melted at 190–191°, is not identical with the substance melting at 188–189°, apparently of the same structure but of different configuration, which was previously obtained from the other form of the ethylene imine of structure VI.[9a]


VI VIII

When benzalacetone was treated with benzylamine and iodine or cyclohexylamine and iodine, the reaction mixture darkened rather than becoming decolorized and no pure product derived from the ketone could be isolated. The preparation of ethylene imine ketones from benzalacetone dibromide has not been reported.

Benzalacetophenone reacted with ammonia and iodine to yield 2-phenyl-3-benzoylethylenimine (m.p. 100–102°) in the same configuration found in the product obtained by the action of ammonia on α-bromobenzalacetophenone.[11] Benzalacetone, however, undergoes the iodoform degradation when treated with iodine and ammonia.

The close correspondence in structure, if not in configuration, between the products obtained from the reactions of the iodine–amine complexes with unsaturated ketones and the products obtained from reactions of amines with dibromides of these unsaturated ketones suggests that the final stages in both reaction processes are similar. It has been shown by Cromwell and Cram[12] that the conversion of benzalacetophenone dibromide and similar substances into α,β-diamino derivatives by the action of an excess of a secondary amine proceeds as indicated by the sequence


IX X XI XII

Although it did not prove possible to isolate such a substance as an intermediate, it seems very probable that α-iodo-β-amino ketones (XVI) analogous to the bromo amino derivative (XI) are involved in the conversion of α,β-unsaturated ketones into α,β-diamino ketones by the action of iodine–amine complexes. The available information, however, does not support the view that the formation of an α,β-diiodide analogous to IX and an α-iodo-α,β-unsaturated ketone analogous to X precede the formation of the α-iodo-β-amino ketone. Although it is possible to show by means of titration experiments that under conditions approximating those used in these reactions (except for the absence of an amine) iodine does react to a small extent and chiefly in a reversible manner with benzalacetophenone,[13] efforts to demonstrate the possibility of securing α-iodobenzalacetophenone by the treat-

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[8] N. H. Cromwell and J. H. Witt, THIS JOURNAL, **65**, 308 (1943).

[9] (a) N. H. Cromwell, R. D. Babson and C. E. Harris, *ibid.*, **65**, 312 (1943); (b) N. H. Cromwell and H. Hoeksema, *ibid.*, **71**, 708 (1949); (c) N. H. Cromwell and R. A. Wankel, *ibid.*, **71**, 711 (1949); (d) N. H. Cromwell, N. B. Barker, R. A. Wankel, P. J. Vanderhorst, F. W. Olson and J. H. Anglin, Jr., *ibid.*, **73**, 1044 (1951), have recently advanced evidence that these lower-melting forms are of the *trans* configuration.

[10] See N. H. Cromwell and J. A. Caughlin, *ibid.*, **67**, 2235 (1945). These authors have used this test as a method of distinguishing between α-halo-β-amino ketones (positive test) and α-amino-β-halo ketones (negative test).

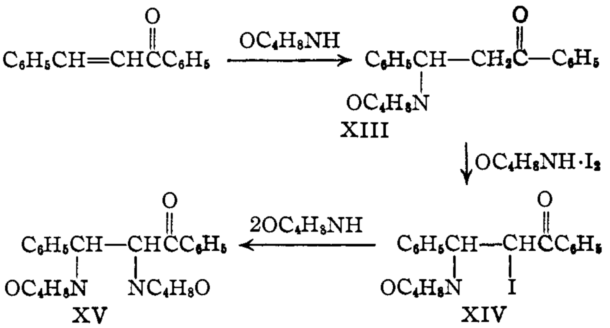
[11] (a) S. Ruhemann and E. R. Watson, *J. Chem. Soc.*, **85**, 1170 (1904); (b) N. H. Cromwell, *Chem. Revs.*, **38**, 83 (1946).

[12] N. H. Cromwell and D. J. Cram, THIS JOURNAL, **65**, 301 (1943).

[13] Similar results with benzalacetone were reported by V. I. Esafov, *J. Gen. Chem.*, **19**, 1115 (1949); *C. A.*, **44**, 5795a (1950).

ment of benzalacetophenone with iodine plus an alkaline reagent, such as triethylamine or sodium acetate, were uniformly unsuccessful. No evidence could be found for the formation of any of this iodinated ketone in these experiments.

Another sequence of reactions which might have accounted for the observed results is illustrated by the following equations



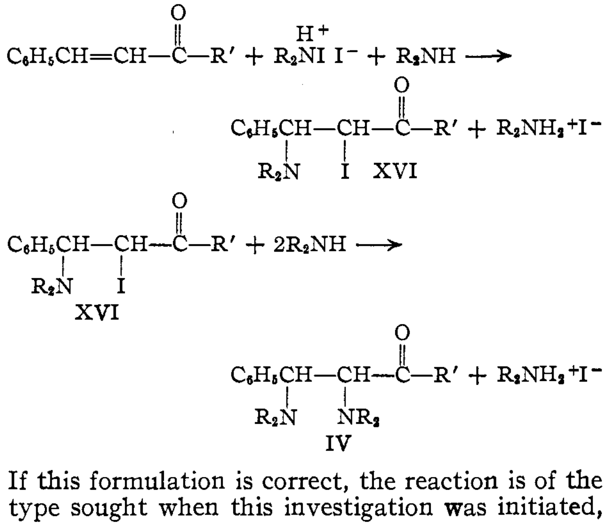
$$\underset{}{C_6H_5CH{=}CH\overset{O}{\overset{\|}{C}}C_6H_5} \xrightarrow{OC_4H_8NH} \underset{\substack{OC_4H_8N \\ \text{XIII}}}{C_6H_5\underset{|}{C}H}{-}CH_2\overset{O}{\overset{\|}{C}}{-}C_6H_5$$

$$\downarrow OC_4H_8NH\cdot I_2$$

$$\underset{\text{XV}}{C_6H_5\underset{\substack{|\\OC_4H_8N}}{CH}{-}\underset{\substack{|\\NC_4H_8O}}{CH}\overset{O}{\overset{\|}{C}}C_6H_5} \xleftarrow{2OC_4H_8NH} \underset{\text{XIV}}{C_6H_5\underset{\substack{|\\OC_4H_8N}}{CH}{-}\underset{\substack{|\\I}}{CH}\overset{O}{\overset{\|}{C}}C_6H_5}$$

The addition of amines to α,β-unsaturated ketones such as benzalacetophenone is, of course, well known.[11b] [illegible] When β-morpholinobenzylacetophenone (XIII) was prepared and treated with morpholine periodide and morpholine, α,β-dimorpholinobenzylacetophenone (XV) was indeed formed, but the consumption of the morpholine periodide required a much longer time than when benzalacetophenone was used (four hours as opposed to five minutes) and the yield of product was lower (61% as contrasted with 87%). Evidently, substances such as XIII are not important as intermediates when the iodine–amine complexes react with α,β-unsaturated ketones. Indeed, it is quite possible that all of the α,β-dimorpholinobenzylacetophenone formed in the experiment just described was produced from benzalacetophenone regenerated by the elimination of morpholine from β-morpholinobenzylacetophenone (XIII).

The objections which can be raised to the reaction mechanisms considered above led us to favor the conclusion that the actual course of reaction involves a direct addition of the iodine–amine complex to the double bond, the reaction sequence for an iodine–secondary amine complex being formulated as



$$C_6H_5CH{=}CH{-}\overset{O}{\overset{\|}{C}}{-}R' + \overset{H^+}{R_2NI}\,I^- + R_2NH \longrightarrow C_6H_5\underset{\substack{|\\R_2N}}{CH}{-}\underset{\substack{|\\I}}{CH}{-}\overset{O}{\overset{\|}{C}}{-}R' + R_2NH_2{}^+I^- \quad \text{XVI}$$

$$\underset{\text{XVI}}{C_6H_5\underset{\substack{|\\R_2N}}{CH}{-}\underset{\substack{|\\I}}{CH}{-}\overset{O}{\overset{\|}{C}}{-}R'} + 2R_2NH \longrightarrow \underset{\text{IV}}{C_6H_5\underset{\substack{|\\R_2N}}{CH}{-}\underset{\substack{|\\NR_2}}{CH}{-}\overset{O}{\overset{\|}{C}}{-}R'} + R_2NH_2{}^+I^-$$

If this formulation is correct, the reaction is of the type sought when this investigation was initiated, and may perhaps be regarded as analogous to the direct addition of nitrogen trichloride to benzalacetone and benzalacetophenone, a reaction discovered and investigated some years ago by Coleman and Craig.[14]

Further studies now in progress are designed to investigate the scope of the reaction of iodine–amine complexes with unsaturated compounds.

Experimental[15,16]

The experiments recorded below which describe the unsaturated ketone–iodine–amine reactions have been chosen to illustrate a number of the permissible variations in reaction conditions, in isolation procedure and in order of addition of reactants. In most cases the recorded procedures gave better results in the preparations with which they are concerned than did others which were tried, but they do not necessarily represent the optimum conditions. No single procedure has yet been found which appears to be equally satisfactory for the preparation of all the compounds described below.

Reactions of Benzalacetophenone with Iodine–Amine Complexes (A) Preparation of α,β-Dimorpholinobenzylacetophenone.—To a solution of 5 g. (0.024 mole) of benzalacetophenone and 8.4 g. (0.096 mole) of morpholine in 25 ml. of benzene a solution of 6.1 g. (0.024 mole) of iodine in 100 ml. of benzene was added, and the mixture was stirred. The initial mixing of the solutions caused a rise in temperature, the development of a red color in the solution, and the precipitation of the orange crystals of morpholine periodide. However, within five minutes of the time of mixing this precipitate had dissolved, the color of the solution had faded to light yellow, and a precipitate of white morpholine hydroiodide had appeared.

The morpholine hydroiodide was removed by filtration and the benzene by distillation under reduced pressure. The residual material was washed with water, then crystallized from methanol to yield 8.0 g. (an 87% yield) of α,β-dimorpholinobenzylacetophenone, m.p. 171–173°. Recrystallization of this compound raised its melting point to 173–175°. No melting point depression was observed when the product was mixed with an authentic sample of α,β-dimorpholinobenzylacetophenone, m.p. 173–175°, prepared by the action of morpholine on benzalacetophenone dibromide.[4a]

The filtrate from the first crystallization yielded a very small amount of a lower-melting compound or mixture, but too little to permit complete purification.

(B) **Preparation of α,β-Dipiperidinobenzylacetophenone.**—To a solution of 10 g. (0.048 mole) of benzalacetophenone and 12.2 g. (0.048 mole) of iodine in 50 ml. of absolute ethanol, 19.5 g. (0.229 mole) of piperidine was added slowly, with stirring, over a two-hour period. Shortly after the addition was complete, the color of the mixture faded from red to light orange. The crude dipiperidino ketone which was precipitated during the course of the reaction was removed by filtration, washed with water, and dried. The yield was 10.6 g. (58.6%) of a product melting with decomposition at 150–158°. The product was purified by extraction into 5 *N* hydrochloric acid, precipitation from the acid solution by addition of 20% sodium hydroxide and crystallization from methanol. This procedure yielded 5 g. of yellow, granular crystals melting with decomposition at 156–157° (instantaneous m.p. about 172°). A sample of α,β-dipiperidinobenzylacetophenone of the same melting point,[17] prepared from benzalacetophenone dibromide, did not depress the melting point of this product.

Efforts to secure additional products from the filtrates obtained in this experiment were not successful.

(C) **Preparation of 1-Benzyl-2-phenyl-3-benzoylethylenimine.**—A solution of 5 g. (0.024 mole) of benzalaceto-

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[14] Coleman and Craig, THIS JOURNAL, **49**, 2593 (1927); **50**, 1816 (1928).

[15] Microanalyses by Clark Microanalytical Laboratory, Urbana, Illinois.

[16] Melting points are corrected.

[17] Dufraisse and Moureu, ref. 7b, characterized this compound on the basis of an instantaneous melting point of 174°. We found the lower decomposition point recorded by Watson, ref. 7a, to be more accurately reproducible, however.

phenone in 25 ml. of benzene was added rapidly to a solution of 6.1 g. (0.024 mole) of iodine and 20 g. (0.186 mole) of benzylamine in 100 ml. of benzene. The color of the mixture faded to a light yellow within one minute. It was washed in a separatory funnel with two 50-ml. portions of water and the benzene was removed by distillation under reduced pressure. The residual oil was dissolved in methanol and the solution was allowed to stand overnight in a Dry Ice chest. During this period 5.5 g. (a 73% yield) of white plates was deposited, m.p. 58–62°. Three recrystallizations produced 3 g. of white plates, m.p. 60–62°. There was no depression of the melting point when this product was mixed with a sample of the form of 1-benzyl-2-phenyl-3-benzoylethylenimine of the same melting point prepared from benzalacetophenone dibromide.[9d]

(D) **Preparation of 1-Cyclohexyl-2-phenyl-3-benzoylethylenimine.**—A solution of 12.2 g. (0.048 mole) of iodine in 100 ml. of benzene was added slowly to a solution of 10 g. (0.048 mole) of benzalacetophenone and 19 g. (0.192 mole) of cyclohexylamine in 25 ml. of benzene. The solution faded to light green in color within 15 minutes. The precipitated cyclohexylamine hydroiodide was removed by filtration and the solvent was removed from the filtrate by distillation under reduced pressure. The resulting brown residue was washed with water, then dissolved in methanol and cooled in a refrigerator. The white, granular crystals which separated weighed 6.8 g. (a 46% yield) and melted at 100–102°. Recrystallization from methanol gave 6.5 g. of similar crystals, m.p. 101–102°.

Anal. Calcd. for $C_{21}H_{23}ON$: C, 82.58; H, 7.59; N, 4.59. Found: C, 82.34; H, 7.44; N, 4.79.

The melting point of a mixture of this compound with the higher-melting form of 1-cyclohexyl-2-phenyl-3-benzoylethylenimine (m.p. 106–107°) earlier obtained from benzalacetophenone dibromide[9a] was depressed to 88–89°.

Since this work was completed, our lower-melting form of this ethylene imine ketone has been described by Cromwell, *et al.*[9d]

(E) **Preparation of 2-Phenyl-3-benzoylethylenimine.**—A solution of 5 g. (0.024 mole) of benzalacetophenone in 50 ml. of methanol was added to a saturated solution of dry ammonia in 50 ml. of methanol. To this solution a solution of 6.1 g. (0.024 mole) of iodine in 50 ml. of methanol was added rapidly with stirring. The mixture faded to a light yellow color after standing for two hours. During the concentration of the solution under reduced pressure at room temperature, 3.1 g. (a 57% yield) of white crystals, m.p. 90–98°, separated. Following recrystallization from methanol, 3 g. of white needles was obtained, m.p. 100–102°. This compound produced no depression of the melting point of a sample of 2-phenyl-3-benzoylethylenimine of the same melting point produced by the action of ammonia on α-bromobenzalacetophenone.[11]

Reactions of Benzalacetone with Iodine–Amine Complexes. (A) **Preparation of α,β-Dimorpholinobenzylacetone.**—A mixture containing morpholine periodide was prepared by adding 15 g. (0.17 mole) of morpholine to a solution of 43.4 g. (0.171 mole) of iodine in 300 ml. of benzene. The precipitated orange-red morpholine periodide together with the supernatant benzene solution was added slowly with stirring to a solution of 25 g. (0.171 mole) of benzalacetone and 45 g. (0.517 mole) of morpholine in 100 ml. of benzene. The periodide dissolved and the color of the reaction mixture faded to light orange within two hours. The precipitated morpholine hydroiodide was removed by filtration, and a large volume of low-boiling (30–60°) petroleum ether was added to the filtrate. The crystalline product which separated was removed by filtration and the filtrate was concentrated somewhat with the separation of additional material. The combined precipitates were washed with water and dried to give 29.8 g. (a 55% yield) of a crude product melting at 154–157°. Following recrystallization from methanol there was obtained 24 g. (a 44% yield) of very pale yellow, granular crystals, m.p. 163–164°.

Anal. Calcd. for $C_{18}H_{26}O_3N_2$: C, 67.89; H, 8.23; N, 8.80. Found: C, 68.12; H, 7.87; N, 8.66.

The melting point of a mixture of this compound with the form of α,β-dimorpholinobenzylacetone obtained from benzalacetone dibromide[5] (m.p. 160°) was depressed to 142–155°.

In another experiment a 52% yield of a similar crude product was obtained in a reaction period of less than one minute by conducting the reaction of 8 g. of benzalacetone, 20 g. of morpholine and 13.4 g. of iodine in 200 ml. of methanol.

Hydrolysis of 4 g. of this compound with 10% sulfuric acid according to the procedure of Cromwell[5] yielded benzaldehyde, isolated as the phenylhydrazone (1.8 g.) and benzyl methyl diketone, isolated as the osazone (0.3 g.), which melted at 170–171° and showed no melting point depression when mixed with an authentic specimen.

(B) **Preparation of α,β-Dipiperidinobenzylacetone.**—A solution of 17.4 g. (0.0685 mole) of iodine in 200 ml. of benzene was added slowly, with stirring, to a solution of 10 g. (0.0685 mole) of benzalacetone and 23.3 g. (0.274 mole) of piperidine in 100 ml. of benzene. The solution faded to light orange in color in a period of two hours, and the precipitated piperidine hydroiodide was removed by filtration. The solvent was removed from the filtrate by distillation under reduced pressure, and the residue was washed with water, then recrystallized three times from methanol, to give 2.6 g. (a 12% yield) of pale yellow needles, m.p. 110–111°.

Anal. Calcd. for $C_{20}H_{30}ON_2$: C, 76.38; H, 9.62; N, 8.91. Found: C, 76.57; H, 9.58; N, 8.82.

A mixture of this product with the form of α,β-dipiperidinobenzylacetone (m.p. 122°) obtained from benzalacetone dibromide[8] melted at 105–107°. Hydrolysis of 4 g. of this compound as indicated above for α,β-dimorpholinobenzylacetone gave the same yields of benzaldehyde and benzyl methyl diketone.

Preparation of α,β-Dimorpholinobenzylacetophenone from β-Morpholinobenzylacetophenone.—A mixture prepared from 3.06 g. (0.012 mole) of iodine, 100 ml. of benzene and 4.2 g. (0.048 mole) of morpholine was added with stirring to a solution of 7 g. (0.024 mole) of β-morpholinobenzylacetophenone[18] in 25 ml. of benzene. After an hour at room temperature the morpholine periodide had not been consumed, and an additional 4.2 g. of morpholine was added. At the end of four hours the color of the complex had faded and the product was isolated essentially as in the preparation from benzalacetophenone, described above. The yield was 2.8 g. (61%) of a product melting at 170–172°.

Reaction of 1-Cyclohexyl-2-phenyl-3-benzoylethylenimine with Hydrochloric Acid.—Three grams of the ethylene imine ketone (m.p. 101–102°) was dissolved in 24 ml. of 5 *N* hydrochloric acid by heating at the reflux temperature for two hours. The reaction mixture was then allowed to stand for one day before the precipitated product was removed by filtration. Following three crystallizations from methanol, 2 g. of white granular crystals melting at 190–191° was obtained. The compound failed to oxidize acidified potassium iodide solutions.[10]

Anal. Calcd. for $C_{21}H_{25}ONCl_2$: C, 66.66; H, 6.66; Cl, 18.74. Found: C, 66.26; H, 6.77; Cl, 18.45.

A mixture of this compound with the form of α-cyclohexylamino-β-chlorobenzylacetophenone hydrochloride (m.p. 188–189°)[9a] obtained from the higher-melting form of this ethylene imine ketone showed a melting point depression to 180–188°.

Experiments on the Reaction of Iodine with Benzalacetophenone (A) **Determination of Free Iodine in a Methanolic Benzalacetophenone Solution.**—To a solution of 2.0016 g. (0.00961 mole) of benzalacetophenone in methanol was added a methanolic solution of 2.4424 g. (0.00961 mole) of iodine. The resulting solution was immediately diluted to 100 ml. with methanol and allowed to stand at room temperature. At intervals 10-ml. aliquots of this solution were removed for titration with a standardized sodium thiosulfate solution. By adding the thiosulfate solution rapidly it was possible to obtain fleeting end-points indicating the consumption of 20.6% of the iodine in 11 hours, and 25% in 72 hours. The iodine color began to return immediately after these fleeting end-points were reached and the final end-points obtained by slow titration indicated the permanent consumption of only 2.64% of the iodine in 11 hours and 5.63% of the iodine in 72 hours. A value of 1.12% was obtained for the iodine consumed after one hour, but the initial fleeting end-point was not obtained. The results appear to show that the equivalent quantities of iodine and benzalacetophenone react rather slowly in an essentially reversible manner

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[18] V. E. Stewart and C. B. Pollard, THIS JOURNAL, **58**, 1980 (1936); **59**, 2702 (1937).

under these conditions to approach a state of equilibrium in which approximately 20% conversion to the unstable benzalacetophenone diiodide has occurred. There is evidently also a very slow permanent consumption of iodine, but a mixture similar to that described above did not yield any detectable quantity of an iodinated benzalacetophenone after it had been allowed to stand for one week.

(B) Attempted Preparation of α-Iodobenzalacetophenone.—To a solution of 10 g. (0.048 mole) of benzalacetophenone and 25 g. (0.1 mole) of iodine in 100 ml. of methanol, 18.0 g. (0.178 mole) of triethylamine was added. The reaction mixture was allowed to stand for more than two days, then diluted with water to precipitate an oil. Following extraction with sodium thiosulfate solution to remove unchanged iodine, a portion of the oil was treated with excess morpholine. The formation of α,β-dimorpholinobenzylacetophenone could not be detected. From another portion of the oil a quantity of unchanged benzalacetophenone was easily separated, but no other pure product could be found.

A solution was then prepared containing 10 g. (0.048 mole) of benzalacetophenone, 12.2 g. (0.048 mole) of iodine and 8 g. (0.059 mole) of sodium acetate trihydrate in 80 ml. of 95% ethanol. The iodine color did not fade from the solution during an 18-hour period of heating under reflux. The mixture was cooled and diluted with an aqueous sodium thiosulfate solution to remove iodine and precipitate the ketone, which separated as an oil, then solidified. Recrystallization of this solid yielded 9.8 g. of pure, unchanged benzalacetophenone.

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[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, DAVIS CAMPUS OF THE UNIVERSITY OF CALIFORNIA]

The Interaction of Iodine and Bromine with Organic Halides

BY R. M. KEEFER AND L. J. ANDREWS

Solutions of iodine or bromine in organic iodides or bromides display pronounced light absorption in the 300–350 mμ region. This intense absorption, which is lacking in the spectra of halogens in solvents such as carbon tetrachloride or heptane, is regarded as characteristic of a 1:1 molecular complex. Equilibrium constants for the formation of a number of these organic halide–halogen complexes have been calculated from spectrophotometric data.

In recent publications[1] experimental evidence for the formation of 1:1 complexes between silver ion and certain organic iodides and bromides has been presented. Both iodine and silver ion show a pronounced tendency to [illegible] addition complexes with electron donor type [illegible] It has therefore seemed desirable to investigate [illegible] possibility that iodine and also bromine, as [illegible] silver ion, might form coördination complexes with organic halides. The results of a study of the ultraviolet absorption spectra of solutions of these halogens and various organic halides indicate that such complexes are formed. The spectrophotometric data have been used to evaluate equilibrium constants for the coördination reactions.

Experimental

The Organic Halides.—Samples of the various halides used in this work were prepared by drying and fractionating available Eastman Kodak Co. white label products. The iodides were washed with sodium thiosulfate solution before fractionation to remove traces of iodine. Isopropyl iodide (b.p. 88.2–89.0°) was prepared from isopropyl alcohol and hydriodic acid.[3]

Solvents.—Eastman Kodak Co. white label carbon tetrachloride was used without purification. The "heptane" was Skellysolve C which had been rendered optically pure by two washings with fuming sulfuric acid followed by washings with water and dilute sodium hydroxide solution. The dried product distilled from 92–97°.

The Absorption Spectrum Measurements.—Solutions (about 0.05 *M*) of the halogens in carbon tetrachloride or heptane were prepared and equilibrated to 25° before standardization. The more dilute halogen solutions used in the spectrum measurements were prepared from these solutions by volumetric procedures. Weighed samples of the organic halides were diluted to known volumes at 25° with either carbon tetrachloride or heptane. Known volumes of the halogen and the organic halide solutions were mixed for measurement on the Beckman spectrophotometer. In each case the blank cell contained a carbon tetrachloride or heptane solution of organic halide of the same concentration as that of the solution being measured. Glass stoppered absorption cells were used, and the cell housing was maintained at 25°. All extinction coefficients, ϵ, which are reported in Figs. 1 and 2 are related to the measured optical densities by the expression $d = \epsilon lc$ where l is the light path length in cm. and c is the concentration of halogen in moles/liter.

Results

In heptane or carbon tetrachloride, so called "normal" solvents, iodine gives a violet colored solution. Alkyl iodide solutions of iodine display the brown color which is generally regarded as indicative of halogen–solvent interaction.[2b] Alkyl bromide–iodine solutions are less brown than the iodide solutions, and in a solvent such as *t*-butyl chloride iodine is pinkish violet. These color gradations are qualitatively indicative of the relative tendencies for organic halide–iodine interaction. Such color gradations are not markedly apparent for bromine solutions of these halides.

The ultraviolet absorption spectra of iodine or bromine solutions of organic halides, Figs. 1 and 2, can be used to determine the extent to which these interactions occur. Curve IV of Fig. 1 gives the spectrum of a solution of iodine in heptane. A solution of iodine in carbon tetrachloride shows a spectrum almost identical with that of the heptane solution. The spectrum of iodine in *t*-butyl chloride is also very similar to that of iodine in the normal solvents except for a slight shift of the visible maximum toward the ultraviolet (525 to 498 mμ). However, solutions of iodine in *n*-butyl bromide (curve II) and *t*-butyl iodide (curve I) show, in addition to the slight shift of the visible maximum, marked absorption in the region of 280–360 mμ. In normal solvents iodine shows very little absorption at these wave lengths.

Bromine in methyl iodide (Fig. 2, curve II) shows a pronounced increase in the intensity of ab-

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[1] L. J. Andrews and R. M. Keefer, THIS JOURNAL, **73**, 3113 (1950); **73**, 5733 (1951).

[2] (a) S. Winstein and H. J. Lucas, *ibid.*, **60**, 836 (1938); (b) H. A. Benesi and J. H. Hildebrand, *ibid.*, **71**, 2703 (1949); (c) L. J. Andrews and R. M. Keefer, *ibid.*, **71**, 3644 (1949); (d) L. J. Andrews and R. M. Keefer, *ibid.*, **74**, 458 (1952).

[3] A. I. Vogel, "Textbook of Practical Organic Chemistry," Longmans, Green and Co., London, 1948, p. 283.