[CONTRIBUTION FROM THE COBB CHEMICAL LABORATORY, UNIVERSITY OF VIRGINIA]

AMINES AND IMINES OF 1,4-DIARYL UNSATURATED 1,4-DIKETONES[1]

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This investigation concerning the products of the action of amines on dibenzoylethylene dibromide (I) and dibenzoylacetylene (III) is an extension of earlier preliminary work in this field (1, 2, 3) and is related to the similar work done in the series based on benzalacetophenone (4, 5). Antimalarial tests (5, 6) in this field, which were first made on some of the dibenzoyl(dialkylamino)ethylenes[3] (*cf.* 5), added this novel type of compound to the list of those actively investigated during the war, and stimulated the synthesis of a number of new nuclear-substituted α-morpholinylbenzalacetophenones, saturated α,β-dimorpholinylketones, and related compounds, which have been considered in another paper (5).

The new mono- and di-alkylaminodibenzoylethylenes are listed in Table I in the experimental part, together with a number of their bromo derivatives. Three monoalkylamino compounds which were not obtained in crystalline form were characterized by conversion into crystalline bromo derivatives.

AMINODIBENZOYLETHYLENE

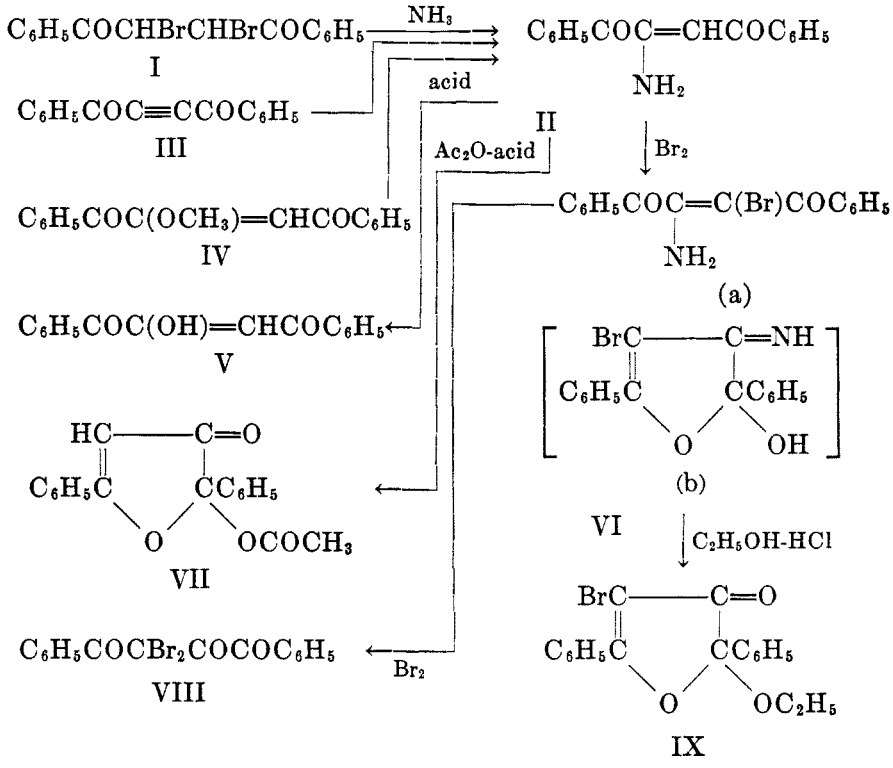
This compound, formulated as II, has been made by the action of ammonia on dibenzoylethylene dibromide (I) (1), on dibenzoylmethoxyethylene (IV) (7, 8, 9), and on dibenzoylacetylene (III) (1, 2, 10). It forms a crystalline hydrobromide which is hydrolyzed by water with regeneration of the amino compound. It is readily hydrolyzed by acids with loss of ammonia, to the triketone enol (V), in contrast with the typical substituted-amino analogs, *e.g.*, the morpholinyl (3), diethylamino, anilino, and methylanilino compounds (*cf.* XIV, XXIII), which are much more resistant toward this type of hydrolysis. The compound is not readily acylated by acetic anhydride, and it does not react with diazomethane.

The amino compound clearly must have the enamine structure (II) because of its properties, its intensely yellow color, and the synthesis from dibenzoylmethoxyethylene (IV) and from dibenzoylacetylene (III). This supposition is sup-

[1] (a) The larger part of the work reported is taken from the Doctorate Dissertation of the late Dr. Thad Amacker, University of Virginia, May 1943. (b) A number of the experiments and the ultra-violet absorptions were carried out by Mr. S. M. King. (c) A number of the derivatives in the table were made by Dr. N. H. Shearer, Master's Thesis, University of Virginia, May 1944.

[2] du Pont Co. Research Fellow, 1942–1943.

[3] In tests carried out at the Lilly Research Laboratories in the summer of 1943, dibenzoyl(dibutylamino)ethylene was found to lower the parasite count in ducks infected with *Plasmodium lophurae*. By present standards, however, (6) this compound and others of the type are regarded as "inactive."



ported by the ultra-violet absorption spectrum (Figure 1) (maxima at 259 and 360 mμ) which shows the general characteristics of those of the β-amino unsaturated ketone system, NC=C—C=O, (11), and resembles that of the reference compound, dibenzoyl(dimethylamino)ethylene (XIV) (Figure 2) (maxima at 254 and 340 mμ).

Bromination converts the amino compound (II) into the unstable hydrobromide of a monobromo derivative (VI). The crystalline material might possibly have the hydroxyfuranone-imine structure (VIb). It is colorless but dissolves to give a yellow solution. This property is analogous to that of the triketone enol (V) (7), which crystallizes from ethanol in a colorless form, but which on melting or dissolving gives the lower-melting and crystallizable enol form. The ultra-violet absorption spectrum of this amino compound (Figure 1) (maxima at 251 and 324 mμ) seems to be consistent with the open-chain structure (VIa) although the maximum at 324 mμ involves a very pronounced displacement toward the shorter wavelength relative to the corresponding maxima of II, XI, and XIV, and it is not far from the principal absorption maximum of 4-bromo-2,5-diphenyl-2-ethoxyfuranone-3 (IX) at 327 mμ (Figure 7). The large absorption maximum at 251 mμ, however, seems to be distinctive. Further data and study are obviously needed here.

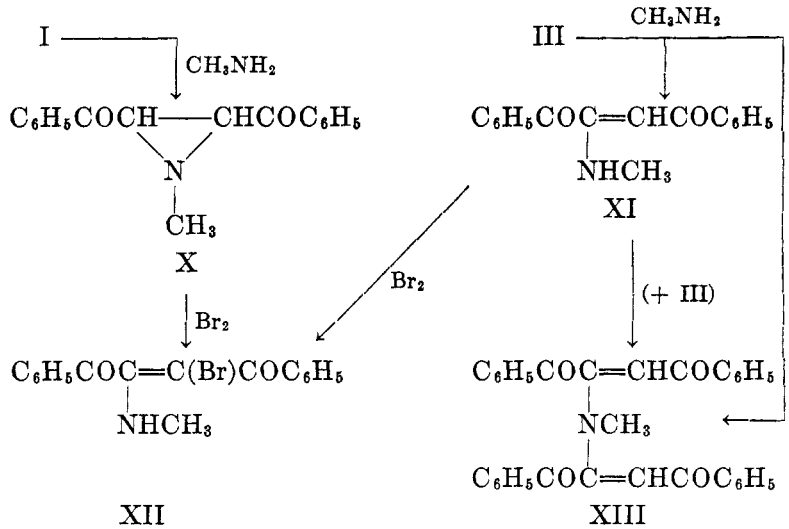
If the interpretation in terms of mobile ring-chain tautomerism is correct, then the bromo compound (VI) is less stable in the cyclic form than the oxygen analog

(4-bromo-2,5-diphenyl-2-hydroxyfuranone-3), which is believed to exist exclusively in the cyclic form (12). Whatever is the case, the bromo compound (VI) is readily converted by ethanolic hydrogen chloride into the 2-ethoxyfuranone (IX) with loss of nitrogen; bromination also involves elimination of the nitrogen but produces the dibromotriketone (VIII).

There is analogy between dibenzoylmethoxyethylene (IV) and methoxyquinones; both systems undergo similar displacement of methoxyl by amines, obviously by way of attack at the β-carbon of the β-methoxy unsaturated ketone system, —COCH=C(OCH_3)—, followed by elimination of methanol. The orienting or donor effect of the methoxyl is presumed to bar addition to the alternate α-methoxy unsaturated ketone system which is also present, —COC(OCH_3)=CH—, and to prevent the formation therefrom of isolable addition compounds. This effect is comparable with the facility of displacement of methoxyl in other simpler β-methoxy unsatuarated carbonyl systems such as that of β-methoxybenzalacetophenone (5, 13).

METHYL- AND DIMETHYL-AMINODIBENZOYLETHYLENES

Methyl- and dimethyl-amine react with dibenzoylethylene dibromide (I) to give compounds analogous to II in respect to empirical formula. The compound previously reported as the methylamino derivative (XI) is actually the dimethylamino compound (XIV) which has now been made unequivocally from pure dimethylamine.[4]



[4] The reason for the confusion in the earlier report (2) is that the commercial methylamine used then (1926) contained as a major impurity dimethylamine which apparently reacted faster than methylamine. The dimethylamine, in turn, contained a considerable proportion of methylamine. The nature of the interesting yellow byproduct of melting point 96.5° which was obtained when the dibromide (I) was treated with commercial dimethylamine is not clear; it may have been the methylamino compound (XI) which melts close to this point (101–102°) and which is now known to be formed in small amounts in the reaction between methylamine and *dl*-dibenzoylethylene dibromide (I).

The true monomethylamino product is obtained by the action of pure monomethylamine on the *meso* dibromide (I). However, in contrast with the parent amino compound (II), it is colorless and therefore appears to have the ethylenimine structure (X) [*cf.* (14, 3)] rather than the enamine structure (XI) or the hydroxyfuranone-imine structure analogous to VIb. This conclusion is supported by the isomerism of the compound with the true enamine (XI) made by the addition of methylamine to dibenzoylacetylene (III), and by the ultra-violet absorption spectrum (Figure 6) where there is observed a very high absorption only in the region 252 mμ which is characteristic of the benzoyl group. This absorption pattern is very similar to those of dibenzoyldimorpholinylethane (15) (247 mμ), bromodibenzoylmorpholinylethane (15) (251 mμ), dibenzoylethane (16) (240 mμ), and analogous N-substituted phenyl benzoyl ethylenimines (17, 18).

The true dibenzoyl-(methylamino)ethylene (XI) has now been made by the action of methylamine on dibenzoylacetylene (III). It melts at 101–102° and is bright yellow in color. Du Pont (10) has prepared a compound, supposedly this, in the same way, but reported the melting point 121°.

We obtained under some conditions a dimolecular reaction product, methylamino-*bis*-dibenzoylethylene (XIII), which was made also by the action of dibenzoylacetylene on the monomolecular product (XI).

The structures of both the mono- and di-molecular compounds (XI and XIII) are indicated by the mode of formation and are confirmed by the ultra-violet absorption spectra (Figures 2 and 5) which showed maxima at 254 and 340, and 242 and 360 mμ respectively, which resemble the absorption spectra of dibenzoyl-(dimethylamino)ethylene (XIV) (Figure 2) (maxima at 254 and 340 mμ) and of the α-(*tert*-amino)benzalacetophenones (18), where the structures are certain

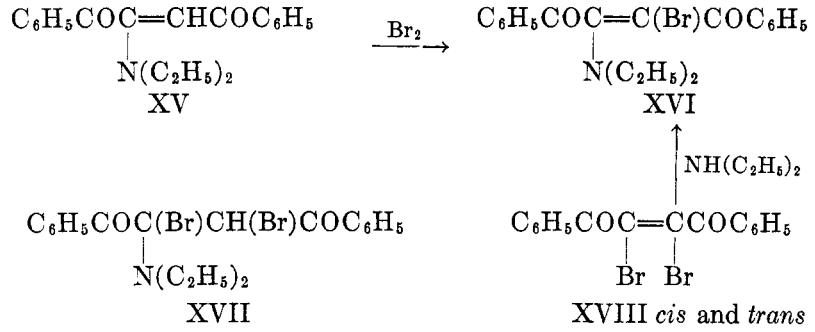
$$\begin{array}{l} C_6H_5COC{=}CHCOC_6H_5 \\ \quad\quad\quad\quad\quad\quad | \\ \quad\quad\quad\quad\quad N(CH_3)_2 \end{array}$$

XIV

It should be noted that in the preparation of the methylimine (X) from the *dl* rather than the *meso* dibromide (I) the methyl enamine (XI) was also obtained in 25% yield. It could hardly have been formed by rearrangement of the methylimine, in view of the demonstrated stability of the imine, and it seems clearly to be the secondary product of a forked reaction.

Dibenzoyl(dimethylamino)ethylene (XIV) was made by the action of dimethylamine on either dibenzoyldibromoethane (I) or dibenzoylacetylene (III). The structure can hardly be open to question here, in view of the modes of synthesis and the non-availability of hydrogen on nitrogen for tautomerism or chelation. The ultra-violet absorption spectrum of this compound (Figure 2) therefore serves as a reference standard. It shows typical absorption at 254 mμ and also absorption in the range of 340 mμ, which is intermediate between the absorption at 300 mμ of α-*tert*-aminobenzalacetophenones and at 350 mμ for the β-*tert*-amino isomer (17, 18).

Bromination of the methylimine (X) and also of the methyl enamine (XI) gave the same monobromo compound (XII), the structure of which is established by the ultra-violet absorption (maxima at 253 and 337 mμ), which resembles those of the bromo amino compound (VIa) (maxima at 251 and 324 mμ), dimethylaminodibenzoylethylene (XIV) (254 and 340 mμ), and chlorodibenzoyl(diethylamino)ethylene (Figure 3). The bromination of the methylimine (X) poses an interesting problem of mechanism which will be investigated; for the present it may be pointed out that the methylimine is stable in refluxing methanol, and was recovered largely unchanged after standing for 24 hours in methanol containing a small amount of added hydrogen bromide.



The dimethylamino compound (XIV) reacted rapidly with bromine, as was to be expected, but hydrolysis and loss of the nitrogen occurred as well and 4-bromo-2-hydroxy-2,5-diphenylfuranone-3 was obtained.

ETHYLAMINO AND DIETHYLAMINO COMPOUNDS

Ethylamine reacted with dibenzoylethylene dibromide to give an oil which evidently consisted largely of the desired amine or imine because upon bromination it was converted into a crystalline bromo compound. No crystalline product was obtained in the reaction with dibenzoylacetylene.

Diethylamine, acting on both the dibromide and on dibenzoylacetylene, gave a crystalline dibenzoyl(diethylamino)ethylene (XV) which was converted into the bromo derivative (XVI) on bromination in chloroform. In one of the bromination experiments, however, under similar conditions, evidence was obtained of the formation of an unstable intermediate dibromide (possibly XVII) which was not analyzed. This compound was converted by the action of diethylamine into the bromo derivative (XVI) and one equivalent of diethylamine hydrobromide, and it readily lost bromine with regeneration of the starting compound (XV) when attempts were made to crystallize it from ethanol.

Bromodibenzoyl(diethylamino)ethylene (XVI) was obtained in a second way by the action of diethylamine on either *cis*- or *trans*-dibenzoyldibromoethylene (XVIII). The *cis* isomer reacted very much more readily than did the *trans*. It is noteworthy that the configurations were not consistently transmitted through to the final products.

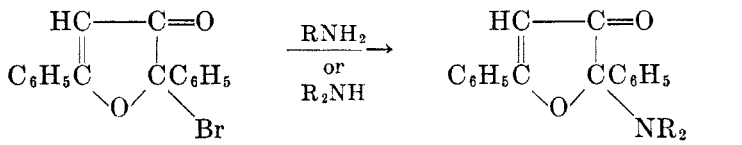
Similarly *cis*-dibenzoyldichloroethylene reacted with diethylamine to give the

chloro analog of XVI. The ultra-violet absorption spectrum of this compound (Figure 3) showed the characteristic broad maximum of the β-amino unsaturated ketone structure (255 and 330–360 mμ) (*cf.* XVI, Figure 2); the chlorine apparently had little effect on the absorption characteristics.

The above reactions of the type XVIII→XVI are of interest in connection with mechanism. Obviously the formation of an acetylenic intermediate is impossible here. The replacement of halogen must have involved 1,4-addition of the amine followed by loss of hydrogen halide. This would account for the loss of distinctive steric differences which could hardly survive the shifts of configurational centers entailed. The failure of excess amine to displace the second halogen of the dibenzoyldihalogenoethylenes (XVIII) and the isolation of only the mono-amine (XVI) under these conditions, shows that there is involved in XVI a considerably increased resistance toward addition of diethylamine; this would be expected in consequence of the donor influence of the amine nitrogen present. There is analogy here to the fact that amines add readily to dibenzoylethylene, benzalacetophenone, and to α-bromobenzalacetophenone, but do not add to α-subst.-aminobenzalacetophenones, or to dibenzoyl-(subst.-amino)ethylenes of the type XIV and XV.

2-(*tert*-AMINO)-2,5-DIPHENYL-3-FURANONES

For comparative purposes some structural isomers of the dibenzoyl-(subst.-amino)dibenzoylethylenes have been made by condensation of the 2-bromo-3-furanone (XIX) with secondary amines. From the mode of formation and the fact of isomerism with the enamines, the structures of the products are assumed to be 2-(subst.-amino)-3-furanones (XX). The ultra-violet absorption spectra of a typical one of these compounds (XXa, see Figure 7) (maxima at 242 and 312 mμ) shows a quite different type of pattern from those of most of the other compounds described above, and it shows the expected close similarities to the absorption spectrum of 2,5-diphenyl-2-methoxyfuranone-3 (maxima at 247 and 314 mμ) and 4-bromo-2,5-diphenylfuranone-3 (IX) (maxima at 253 and 327 mμ) (see Figure 7).



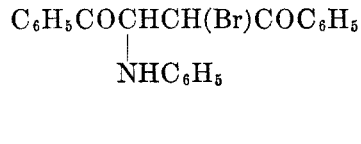
XIX XX

NR_2 = (a) $N(CH_3)_2$
(b) $N(n\text{-butyl})_2$
(c) morpholinyl

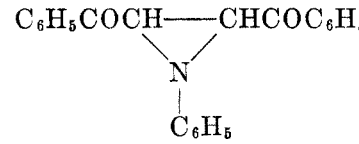
ANILINO AND METHYLANILINO DERIVATIVES

In the reaction between aniline and dibenzoylethylene dibromide (I) an intermediate monobromo monoanilino compound (XXI) was isolated when mild reaction conditions were employed. Doubtless other analogous intermediates

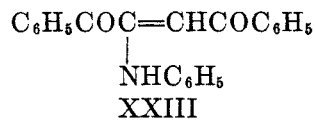
could be obtained in similar reactions with other amines, if special care were taken, as has been done in the reaction with morpholine (15) and as has been done in several other series, notably α,β-dibromopropiophenone (19) and benzalacetophenone dibromide (4, 5). Further treatment of the intermediate anilino bromo compound (XXI) with aniline under the usual reaction conditions caused elimination of hydrogen bromide and gave dibenzoylethylenephenylimine (XXII), the structure of which is shown by the ultra-violet absorption maximum occurring only in the region 253 mμ which is close to that expected of the benzoyl group (see Figure 6).



XXI



XXII



XXIII

The isomer of the phenylimine, the true anilinodibenzoylethylene (XXIII), is obtained by the addition of aniline to dibenzoylacetylene (10). It is brilliant yellow in color and shows the expected and characteristic absorption pattern (maxima at 256 mμ and a broad band with its peak at 375 mμ) (see Figure 4). It is to be noted that the absorption in the longer wavelength involves a pronounced shift in this direction as compared with the absorption of the methyl- and dimethyl-amino compounds in the range 330–340 mμ. A similar effect was observed by Bowden (11) in the comparable series, $C_6H_5COCH{=}CHNH_2$, and its N-ethyl, N,N-diethyl, and N-phenyl derivatives.

In the reaction between dibenzoylethylene dibromide (I) and methylaniline a high reaction temperature was required to obtain the desired product which is obviously of the type of XXIII. The same compound was obtained also by the addition of methylaniline to dibenzoylacetylene. Although it must have the same enamine structure, it is, in contrast with anilinodibenzoylethylene (XXIII), practically colorless. It shows a very strong absorption maximum at 342 mμ (see Figure 4) which seems to be fully consistent with the enamine structure; in fact it is almost coincident with the absorptions of methyl- and dimethyl-aminodibenzoylethylene in the range 340 mμ. But in comparison with the anilino compound (XXIII) there is to be seen a striking shift of the maximum toward the shorter wavelength, due doubtless to steric interference with coplanarity of the N-phenyl group and the rest of the system (*cf.* ref. 11).

THE 1,4-DIMESITOYLETHYLENE SERIES

A selection of representative enamines in this series have been made and are listed in Table I. Some abnormalities in this series are worthy of note, however. The dibromide (XXIV) when treated with methylaniline gave only *trans*-bromo-

dimesitoylethylene (XXV) and not the expected dimesitoyl-(methylanilino)-ethylene. And aminodimesitoylethylene (XXVI) on bromination also gave this same *trans*-bromodimesitoylethylene (XXV).

$$C_9H_{11}COCH(Br)CH(Br)COC_9H_{11} \xrightarrow{C_6H_5NHCH_3} C_9H_{11}COC(Br)=CHCOC_9H_{11}$$

XXIV XXV *trans*

$$C_9H_{11}COC(NH_2)=CHCOC_9H_{11} \xleftarrow{Br_2}$$

XXVI

The ultra-violet absorption characteristics of certain of the compounds which were studied, are to a degree in keeping with expectations (see Figure 8). The suppression of the maximum at about 250–260 mμ which characterizes a carbonyl group conjugated with a phenyl, is doubtless caused by steric inhibition of resonance by the *ortho* methyl groups; this effect is seen also in the lack of absorption maxima in this region in the cases of dimesitoylethane, *trans*-dimesitoylethylene (*cf.* 16) (Figure 8), and of acetomesitylene (20). The curve for aminodimesitoylethylene (XXVI) (Figure 8) shows the characteristic maximum (357 mμ) which is in the expected range of the system, —C(N)=CHCO—, and which is almost identical with that of aminodibenzoylethylene itself (II) (which absorbs at 360 mμ). The dimesitoyl(diethylamino)ethylene and the bromo methylamino compounds, however, show broader patterns of absorption at shorter wavelengths in the range 270–320 mμ.

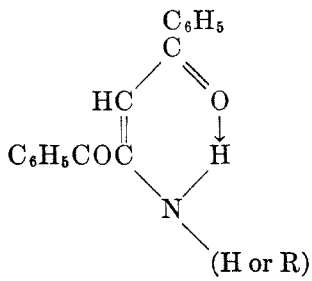
MECHANISM AND STEREOCHEMISTRY

The reaction between amines and dibenzoylethylene dibromide (I) may proceed by three paths: (a) elimination of two molecules of hydrogen bromide and addition to the resulting dibenzoylacetylene, (b) elimination of one hydrogen bromide, addition of the amine, and then loss of the second hydrogen bromide, or (c) direct displacement of one bromine followed by elimination of hydrogen bromide. Imine formation can not involve path (a). In the case of the *dl*-dibromide, to the extent that the reaction with methylamine leads to the formation of a significant proportion of the enamine, and in the reactions with ammonia, and with the secondary amines where imine formation is excluded, reaction may be by any one of these three paths. Work on these reactions and on the mechanism is in progress [*cf.* (15)].

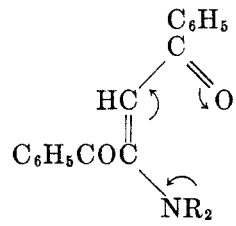
In the reaction between methylamine and the *dl* and *meso* dibromides there is some evidence of stereochemical influence affecting the course of the reactions, but at no place in the series of enamines and imines has there appeared evidence of *cis-trans* isomerism. From the nature of some of the intermediate steps involved

in the various syntheses it seems unlikely that separate and consistent configurational patterns could be retained; they certainly would be lost in paths (a) and (b) where 1,4-additions presumably occur [*cf.* (15)]. Therefore one would expect only mixtures, or as seems much more likely in view of the sharp type of differences entailed in the *cis-trans* relationship, predominantly and consistently one of the two stereoconfigurations.

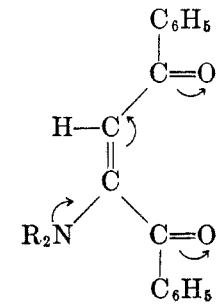
On theoretical grounds there may be a basis for postulating that certain of the enamines are *trans* (with respect to the carbonyl groups); chelation might offer a considerable stabilizing influence in those cases where nitrogen carries a free hydrogen (*cf.* II and XXVI). However, those cases where the nitrogen is tertiary cannot involve ordinary chelation (*cf.* XIV, XV); and there one can only suggest (a questionable hypothesis) that there might conceivably exist an attraction between the carbonyl and the spatially proximate amine group, related or akin to chelation, through resonance polarization which would produce opposite changes thereon (*cf.* XXVIII).



XXVII



XXVIII



XXIX

On the other hand there is analogy for a stabilizing influence in the *cis* configuration (*cis* with respect to the carbonyls) in the case of *cis*-dibenzoylmethylethylene (21, 22) and *cis*-dibenzoylphenylethylene (23)[5] where carbonyl group interaction (a quasi-chelation) has been suggested in order to account for the extraordinary relative reactivity and anomalous stability (23) (*cf.* XXIX). However the electron-repelling methyl and phenyl groups in the position *trans* to the directly-conjugated carbonyl group may play the dominant role. It would appear logical and reasonable to postulate that all of the enamines (but not necessarily the bromo derivatives), irrespective of whether or not they carry free hydrogens on the nitrogen, and also the triketone enol (V) and dibenzoylmethoxyethylene (IV), belong in this same category, with the *cis* configuration made the more stable by virtue of the *trans* relationship of the donor amine nitrogen or oxygen to the directly-conjugated and electronegative carbonyl oxygen (XXIX). Of particular significance in this connection is the fact that one typical enamine of the type under discussion, dibenzoylmorpholinylethylene (3), has been made by nitric acid oxidation of 3-morpholinyl-2,5-diphenylfuran, and dibenzoylalkoxyethylenes have similarly been made by nitric acid oxidation of the alkoxy-

[5] *Trans*-dibenzoylphenylethylene has now been made and as predicted is the *labile* stereoisomer (23).

diphenylfuranes (24); and these analogous and closely related compounds might be presumed from these syntheses to be of the *cis* configuration.

For the present, however, especially since not one *cis-trans* isomeric pair is yet known in the enamine field, it does not seem wise as yet to attempt definite

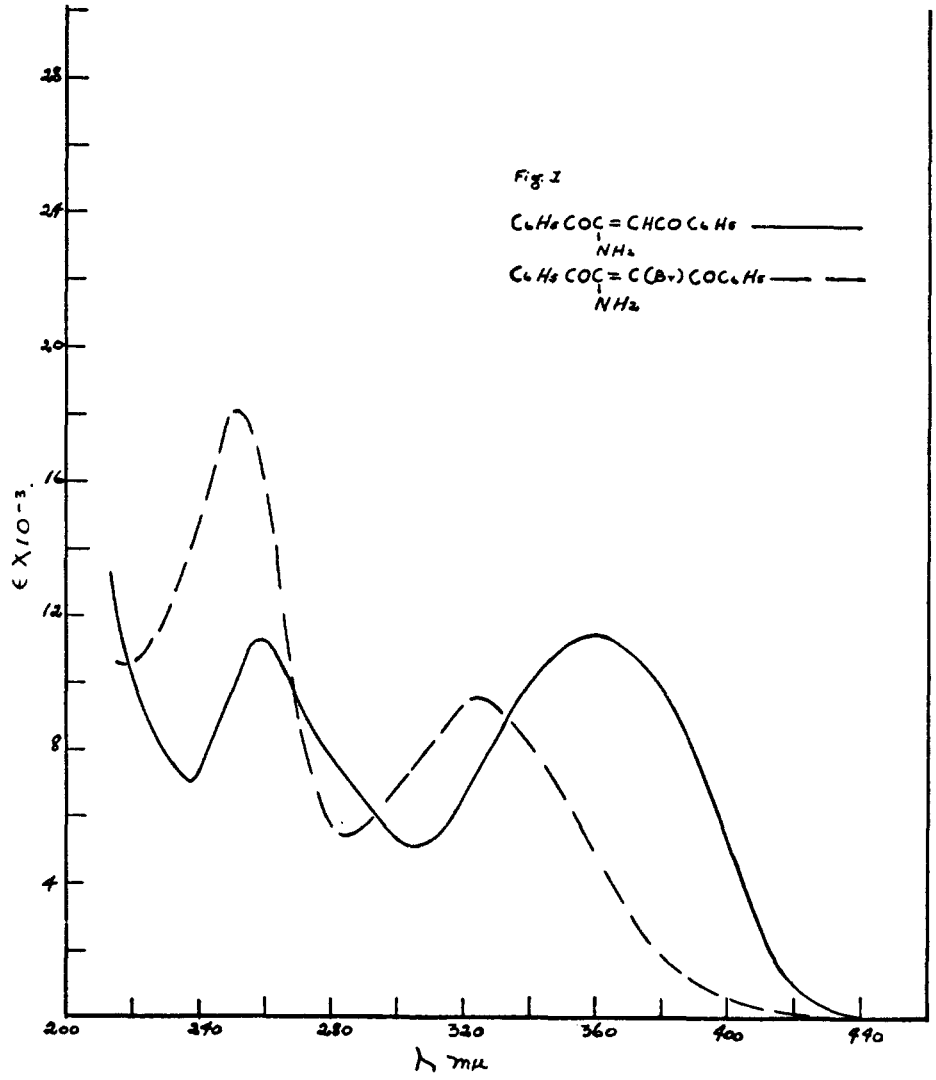


FIGURE 1

assignment of the type-configuration here, although it may be possible to do so on the basis of the ultra-violet absorptions. The ultra-violet absorption studies reported here are preliminary and are being extended in this and related fields, and consequently detailed discussion of the significance of the present results will be postponed and included in a later paper.

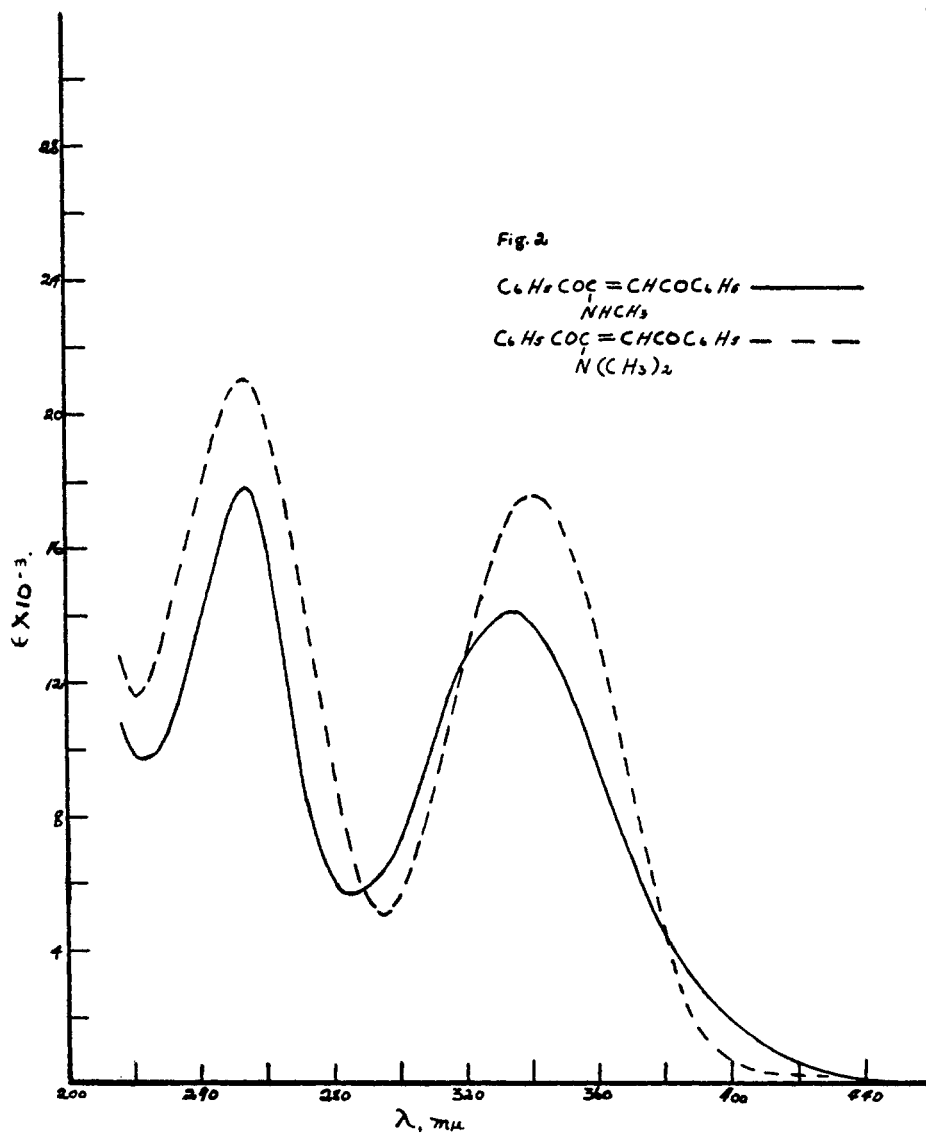


FIGURE 2

EXPERIMENTAL[6]

PREPARATION OF THE DIBENZOYL-(SUBST.-AMINO)ETHYLENES. PROCEDURES STARTING FROM DIBENZOYLETHYLENE DIBROMIDE (I).

Procedure A. Aminodibenzoylethylene (II) was best made in ethanolic ammonia at 70°. It was crystallized from ethanol and melted at 137.5–138.5°.

Procedure B. In other cases a suspension of the dibromide (I) in ethanol containing the amine in large excess was allowed to react (a) at 35° for 15 minutes, or (b) reacted at 50–65°

[6] Melting points are "corrected".

for 20–25 minutes, or (c) 70° for 15 minutes, or (d) 80° for 10 minutes, or was refluxed (e) for five or (f) twenty minutes or (g) forty minutes. In one case (h) isobutanol was used (refluxing for thirty minutes). There usually was evolution of heat and spontaneous reaction before the heating period was begun. The resulting colored (usually red) solution was cooled and diluted with water or 60% ethanol to dissolve the reagent amine hydrobromide and

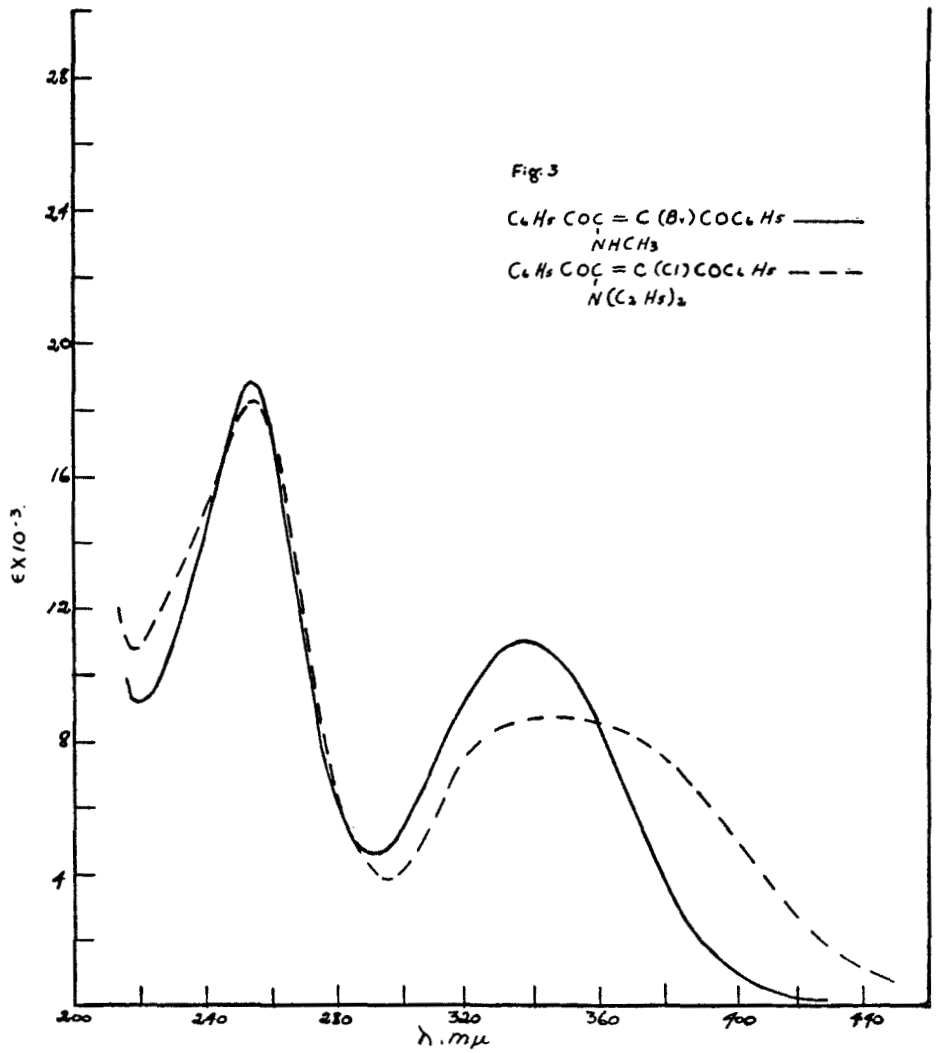


FIGURE 3

precipitate the very weakly basic product. In cases where the color of the product was dark, charcoal treatment was used in crystallization (i). In the reaction between dimesitoylethylene dibromide (XXIV) and methylaniline (in isobutanol; refluxing for 20 minutes) the product was identified as *trans*-dimesitoylbromoethylene (XXV).

Procedure C. In some cases ether was used as the solvent. Reaction was usually exothermic at the beginning. The reaction mixture was usually stirred, allowed to stand,

or refluxed gently for (a) five or (b) twenty minutes, or (c) allowed to stand overnight. The precipitated amine hydrobromide was filtered and the weakly basic product was recovered from the filtrate by (d) cooling and crystallization, or (e) concentrating and cooling. (f) In one experiment in ether as solvent using methylamine and the relatively much more soluble *dl*-dibenzoylethylene dibromide (I), the reaction proceeded more rapidly and with

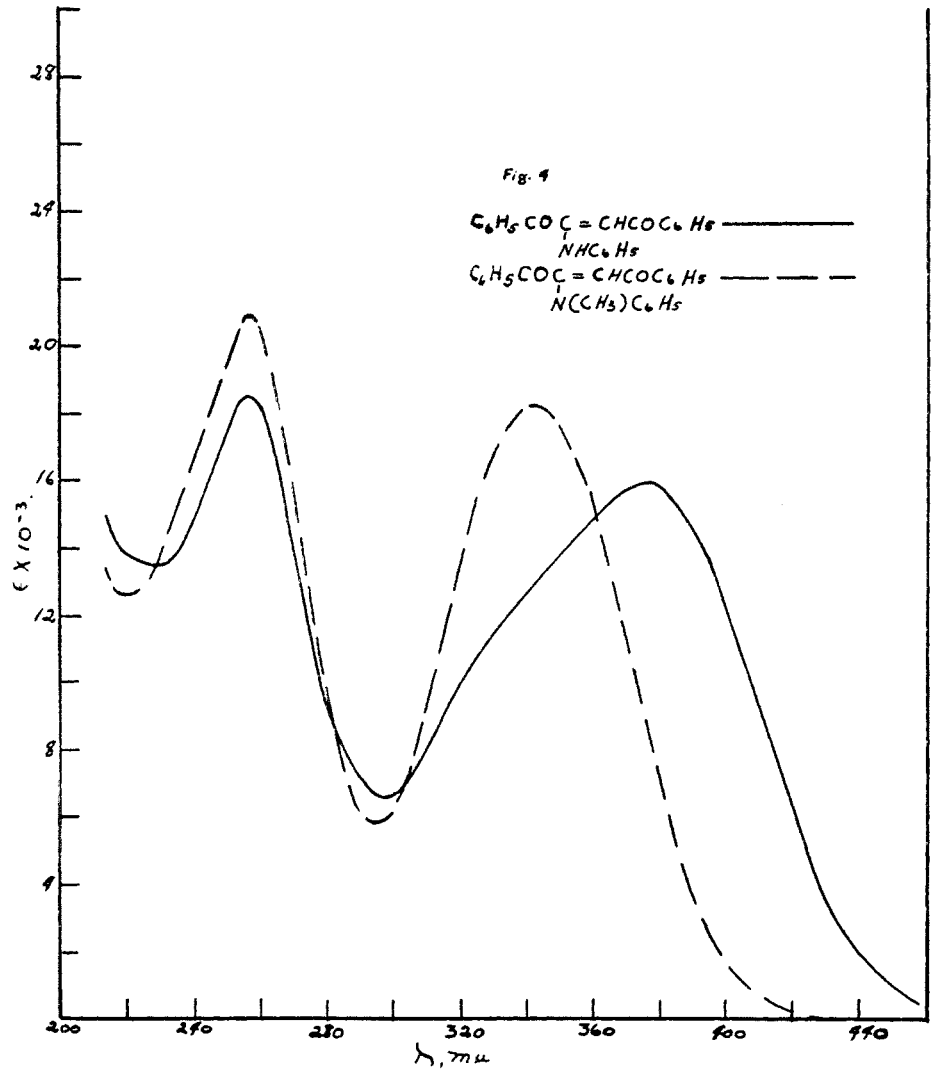


FIGURE 4

less coloration. The filtrates from crystallization of the product from 50% methanol upon concentrating and cooling gave a 25% yield of crude enamine (XI) which was purified and identified by mixture melting point with the sample made by Procedure D(a).

Procedure D started from *dibenzoylacetylene* (III). (a) In a typical experiment 1.2 g. (0.04 mole) of 25% aqueous methylamine was added to a solution of 5.6 g. (0.025 mole) of

III in 20 ml. of benzene. A vigorous exothermic reaction occurred. After ten minutes of stirring the benzene and water were evaporated at room temperature *in vacuo* and the dark red residue was crystallized from ethanol; 4.3 g. of light yellow needles, m.p. 97–99°.

(b) In the case of methylaniline a solution of 2.14 g. (0.02 mole) and 2.3 g. (0.01 mole) of III in 10 ml. of benzene was refluxed for 15 minutes. The product was precipitated by addition of isooctane.

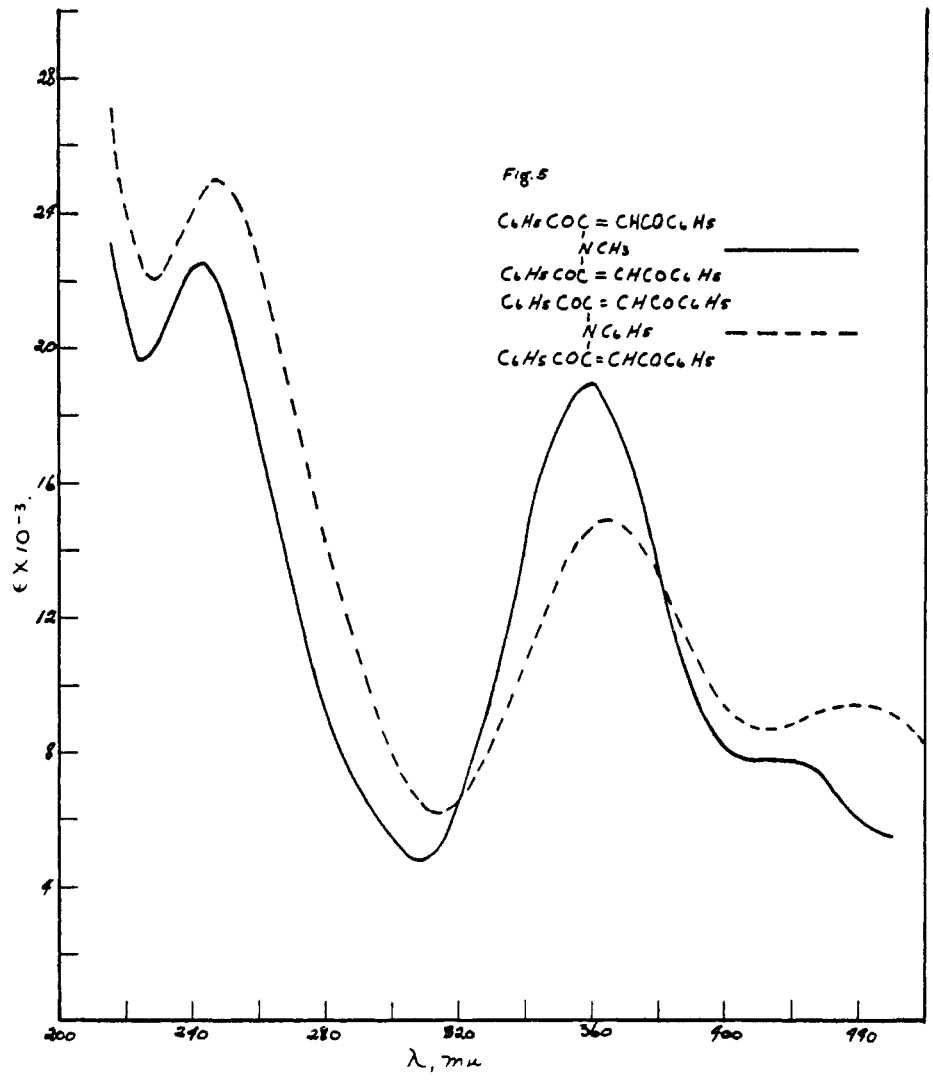


FIGURE 5

PREPARATION OF THE BROMO DERIVATIVES

Procedure E. The dibenzoyl-(subst.-amino)ethylene was dissolved in chloroform and treated by slow addition with the calculated amount of bromine. (a) The salt of the product sometimes precipitated. Water was added to the mixture or to the filtered precipitate to hydrolyze the salt and liberate the very weakly basic product. (b) When the salt did not crystallize the solution was evaporated and the residue crystallized.

In one experiment (c) on XV on a larger scale, an oil was obtained from which a small crop of crystals was isolated (it was not XVI); it appeared to be an unstable addition product (XVII). Overnight treatment with diethylamine (shaking) gave almost one equivalent of diethylamine hydrobromide; the reaction product was identified as XVI. The bulk of the non-crystalline material when treated with ethanol regenerated XV.

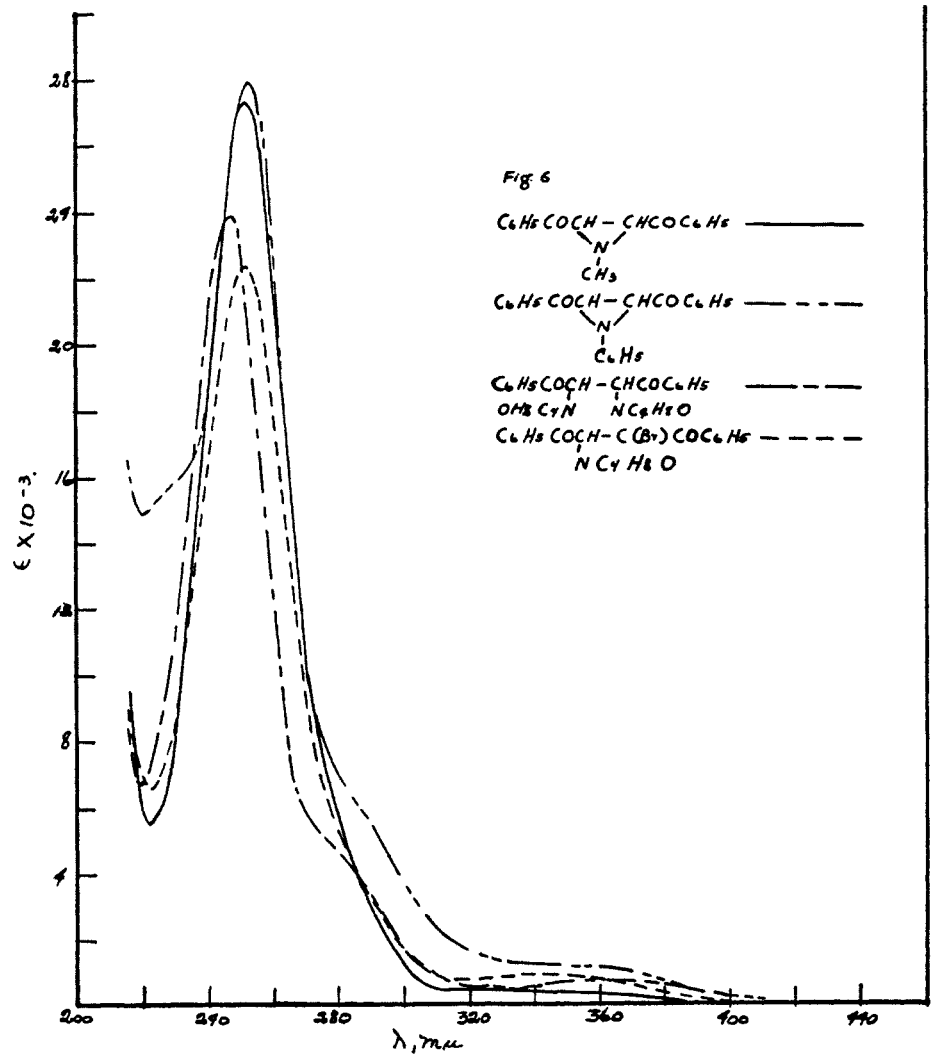


FIGURE 6

Procedure F. (a) Upon mixing 0.3 g. of *cis*-dibenzoyldibromoethylene (XVIII), 25 ml. of ethanol, and 3 ml. of diethylamine, heat was evolved and a yellow solution resulted. After heating to refluxing, the solution was diluted to the point of crystallization with water; yield of XVI, 0.2 g. (68%); m.p. 110–111°. (b) When a mixture of 5 g. of the *trans* isomer of XVIII in 50 ml. of ethanol and 20 ml. of diethylamine was refluxed for ten minutes and cooled, 4.5 g. of XVIII was recovered. From the filtrate was isolated 0.125 g.; m.p. 104–105° (identified as XVI); yield, allowing for recovery of material, 40%.

Procedure G. In the preparation of the chloro analog of XVI, the Procedure E(a) was

used, starting with *cis*-dibenzoyldichloroethylene. Crystallization of the product was brought about by dilution to the point of crystallization with dilute ethanol.

Aminodibenzylethylene hydrobromide crystallized from a solution of the base (II) in 30% hydrogen bromide-acetic acid as rectangular prisms. A crystalline sulfate (not analyzed) was obtained similarly from acetic anhydride and sulfuric acid. Hydrolysis occurred

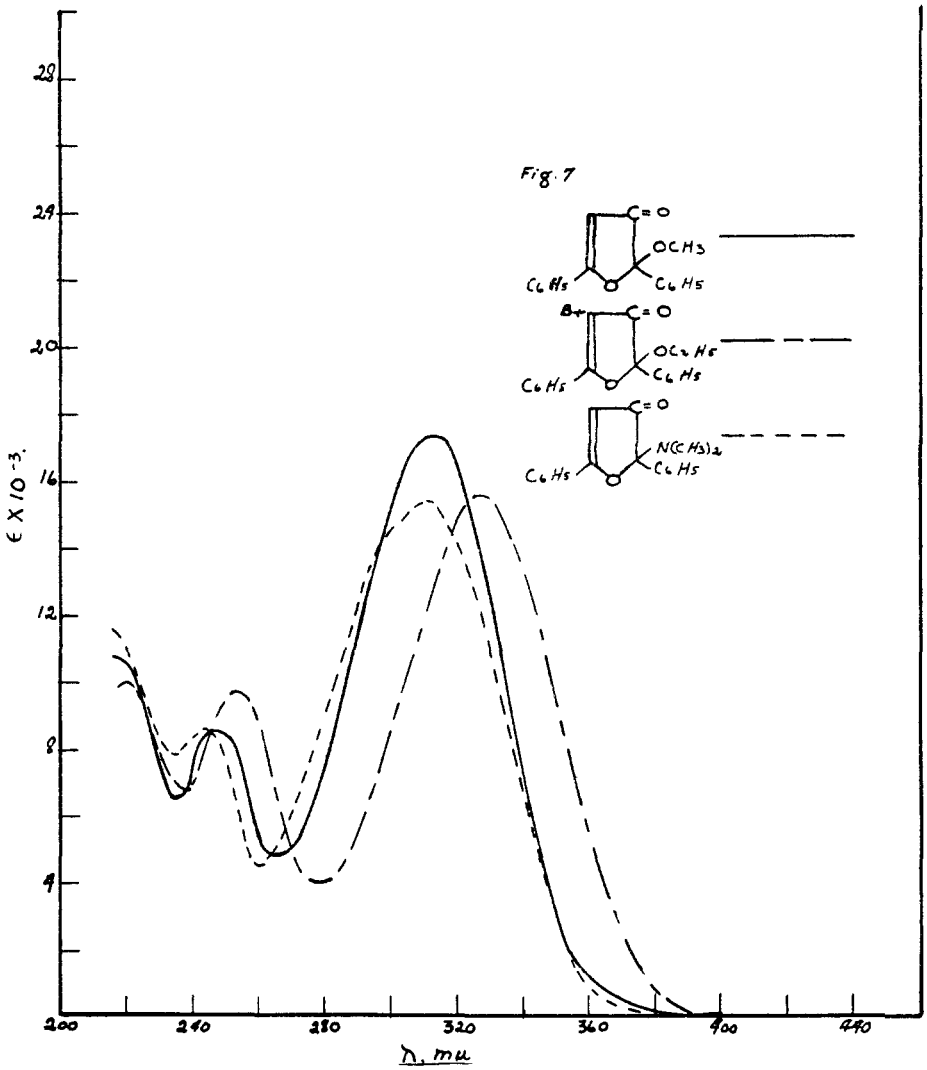


FIGURE 7

with regeneration of II in 60% ethanol or in contact with water overnight. Attempts to recrystallize resulted in hydrolysis to the triketone enol (V). Bromination of this salt in chloroform gave a white crystalline *hydrobromide* of VI (not analyzed). This salt was hydrolyzed to VI on treatment with water.

Reactions of aminodibenzoylethylene (II). *Hydrolysis* was affected by alcohol solutions containing traces of acids, on warming or standing at room temperature; the triketone enol

(V) was isolated and identified by mixture melting point with an authentic sample, and by its characteristic change in melting point upon fusion (colorless form 80–81°; yellow form 65–66°).

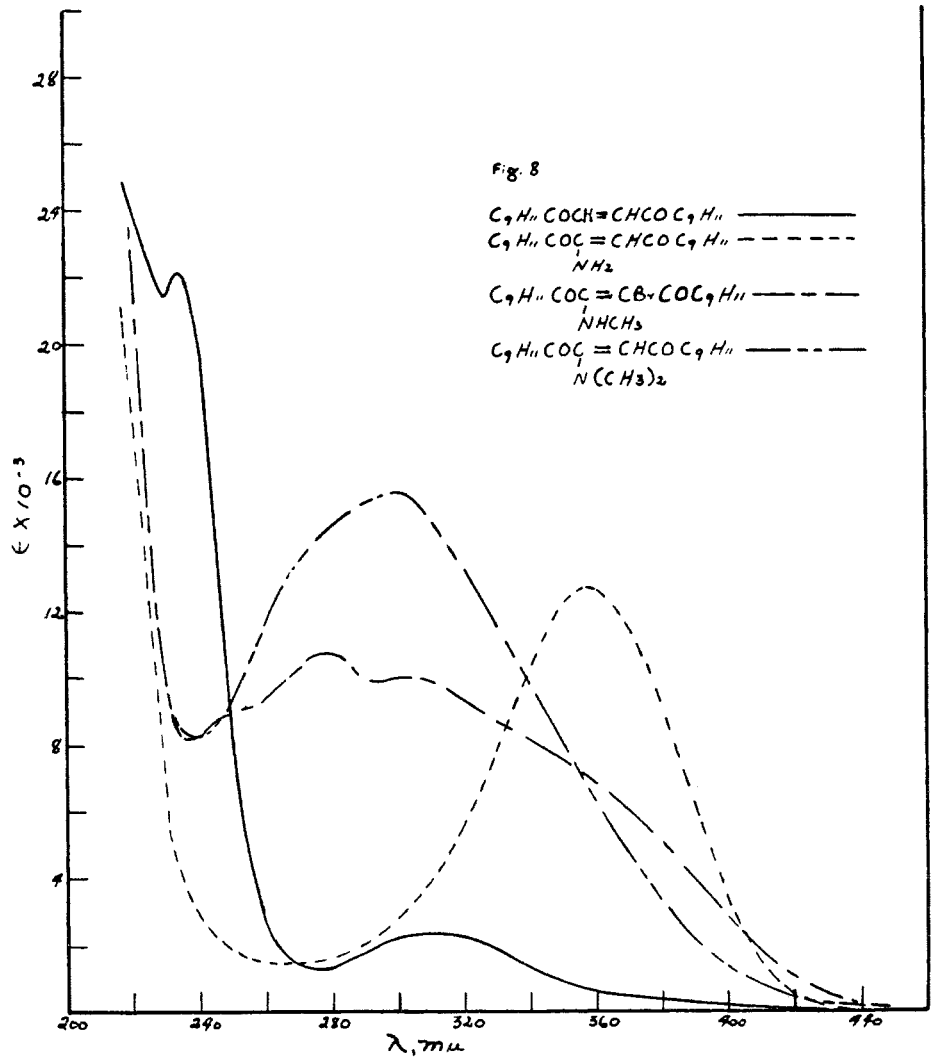


FIGURE 8

Bromination with one molecule in ethanol gave VI (identified); using two molecules, VIII was obtained (identified). *Acylation* in a 1-1 mixture of acetic acid-acetic anhydride (standing for 3 days at room temperature) gave VII. *Diazomethane* did not react with II.

Aminodimesitoylethylene (XXVI), when brominated (Procedure Db) gave, instead of the expected bromo derivative, *trans*-bromodimesitoylethylene (XXV) (yield 50%).

2-Anilino-3-bromo-1,4-diphenylbutanedione-1,4 (XXI). A mixture of 5 g. of the dibromide (I), 15 ml. of aniline, and 50 ml. of ethanol was warmed on a water-bath for 25 minutes; the dibromide was almost all dissolved during this time. The solution was filtered and

TABLE I

DIAROYL-(SUBST.-AMINO)ETHYLENES AND THE ETHYLENE IMINES

$$ArCOC\begin{pmatrix}NHR\\ or\\ NR_2\end{pmatrix} = C(X)COAr \text{ and } C_6H_5COCH\text{——}CHCOC_6H_5$$
$$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad \diagdown\ \diagup$$
$$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad N$$
$$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad R$$

(NHR or NR_2)	(X)	COLOR	PREP.[a] METHOD	YIELD, %	M.P., °C.	CRYST.[b] FROM	EMPIRICAL FORMULA	ANALYSES			
								C (or N)		H (or Br)	
								Calc'd	Found	Calc'd	Found
Dibenzoyl Series											
$-NH_2 \cdot HBr$	H	yellow	A	—[k]	195[d]	—	$C_{16}H_{14}BrNO_2$	—	—	24.07	24.01
$-NH_2$[c]	Br	none[e]	Ea	—	140–141	80% EtOH	$C_{16}H_{12}BrNO_2$	58.20	58.07[p]	3.64	3.77
$-NHCH_3$	H	yellow	D, Cf	68, 25	101–102.5	Bz-iOct.[n]	$C_{17}H_{15}NO_2$	76.98	76.66[q]	5.66	5.59
$-NCH_3$–(imine)		none	Ca, d, f	43	88–88.5	50% EtOH	$C_{17}H_{15}NO_2$	76.96	76.66	5.66	6.06
$-NHCH_3$	Br	none	Eb[l]	93	152–153	60% EtOH	$C_{17}H_{14}BrNO_2$	59.32	58.77	4.07	4.26
$-NHC_2H_5$[e]	Br	yellow	Eb	—	156.5–157	EtOH	$C_{18}H_{16}BrNO_2$	60.35	60.20	4.47	4.79
$-NH(n\text{-Butyl})$	Br	pale yel.	Eb	—	115–116	EtOH	$C_{20}H_{20}BrNO_2$	62.16	61.88	5.23	5.25
$-NC_6H_5$–(imine)		none	Be[m]	31	143–144	EtOH	$C_{22}H_{17}NO_2$	80.73	80.39	5.19	5.56
$-N(CH_2)_2$[f]	H	yellow	Ca, e, D	51, 64	160–162	EtOH	$C_{18}H_{17}NO_2$	77.42	77.10[r]	6.09	6.49
$-N(C_2H_5)_2$[g]	H	yellow	Be	73	142.5–143	80% EtOH	$C_{20}H_{21}NO_2$	78.13	78.19[s]	6.89	7.23
$-N(C_2H_5)_2$	Br	yellow	Eb, c, F		111–112	60% EtOH	$C_{20}H_{20}BrNO_2$	62.16	62.52	5.22	5.41
$-N(C_2H_5)_2$	Cl	yellow	G	77	126.5–127.5	EtOH	$C_{20}H_{20}ClNO_2$	70.24	70.14	5.90	5.85
$-N(n\text{-Butyl})_2$	H	yellow	Bf	90	83–84	80% EtOH	$C_{24}H_{29}NO_2$	79.30	78.81	8.04	8.28
—Piperidyl	H	yellow	Ba	25	181–181.5	EtOH	$C_{21}H_{21}NO_2$	4.39	4.33	—	—
$-N(CH_2)C_6H_5$[h]	H	none	Bh, Db	–, 78	143–144	60%EtOH	$C_{23}H_{19}NO_2$	80.89	80.50	5.63	5.76

Di-(*p*-methylbenzoyl) Series											
—N(C_2H_5)$_2$	H	yellow	Bb	90	126–127	dil.EtOH	$C_{22}H_{25}NO_2$	4.18	4.24	—	—
—N(*n*-Butyl)$_2$	H	yellow	Bc	51	74.5–75	80% EtOH	$C_{26}H_{33}NO_2$	3.58	3.57	—	—
—Piperidyl	H	yellow	Bg	57	171–171.5	EtOH	$C_{23}H_{25}NO_2$	4.03	3.89	—	—
—Morpholinyl	H	yellow	Bd	35	151–152	EtOH	$C_{22}H_{23}NO_3$	4.01	4.19	—	—
Di-(*p*-methoxybenzoyl) Series											
—N(C_2H_5)$_2$	H	yellow	Bc	49	119	EtOH	$C_{22}H_{25}NO_4$	3.81	3.99	—	—
Di-(*p*-chlorobenzoyl) Series											
—N(C_2H_5)$_2$	H	yellow	Bb	70	170–171	EtOH	$C_{26}H_{19}Cl_2NO_2$	3.72	3.67	—	—
Di-(*p*-bromobenzoyl) Series											
—N(C_2H_5)$_2$	H	yellow	Bb	44	164	EtOH	$C_{20}H_{19}Br_2NO_2$	3.01	2.87	—	—
Dimesitoyl Series[i]											
—NHCH$_3$[j]	Br	none	Eb	—	142.5–143[d]	EtOH	$C_{23}H_{26}BrNO_2$	64.32	63.26	6.10	6.02
—N(CH_3)$_2$	H	yellow	Cb, e	92	149–150	60% EtOH	$C_{24}H_{29}NO_2$	79.30	79.00	8.04	8.33
—N(CH_3)$_2$	Br	pale yel.	Eb	—	140	EtOH	$C_{24}H_{28}BrNO_2$	65.01	64.49	6.34	6.45

[a] Refers to general procedures outlined in the experimental part. [b] Solvent abbreviations: EtOH = ethanol; Bz = benzene; iOct. = isooctane. [c] The hydrochloride (not analyzed) melted at 200–202° d. [d] Melts with decomposition. [e] The action of ethylamine on the dibromide (I) by Procedure Cc gave an oil which decomposed upon attempted distillation *in vacuo*; it was characterized by bromination to XVI. [f] Bromination in chloroform gave 4-bromo-2,5-diphenyl-2-hydroxyfuranone-3. [g] The hydrochloride (not analyzed) melted at 185°; it was precipitated from acetone by the addition of ethanolic-hydrogen chloride. The base was not hydrolyzed by the action of a refluxing mixture of 1 ml. of saturated ethanolic hydrogen chloride and 15 ml. of ethanol (30 minutes). [h] Not hydrolyzed by dil.-ethanolic hydrogen chloride (refluxing for 25 minutes). [i] *Cf.* Procedure Bh for the reaction between dimesitoylethylene dibromide and methylaniline. [j] The action of methylamine on the dibromide by Procedure Cb gave an oil which was characterized by bromination to this compound. This compound is unstable and difficult to purify. [k] See experimental part. [l] Forms a yellow solution but crystallizes as colorless leaflets. [m] Prepared from bromodibenzoylanilinoethane (XXI) using ethanol saturated with ammonia. [n] Crystallized also from 50% methanol. *Anal.* for nitrogen: [p] Calc'd: 4.24. Found: 3.36. [q] Calc'd: 5.28. Found: 5.35. [r] Calc'd: 5.02. Found: 5.23. [s] Calc'd: 4.56. Found: 4.55.

TABLE II

ULTRA-VIOLET ABSORPTION MAXIMA AND MINIMA FOR SOME AMINE DERIVATIVES OF SATURATED AND UNSATURATED 1,4-DIKETONES, AND RELATED COMPOUNDS, IN ABSOLUTE ETHANOL SOLUTION

COMPOUND	MAXIMA		MINIMA		FIG. NO.
	λ, mμ	ε × 10^{-3}	λ, mμ	ε × 10^{-3}	
Aminodibenzoylethylene (II)	259	11.3	238	7.00	1
	360	11.4	305	5.01	
Aminobromodibenzoylethylene (VIa)	251	18.1	217	10.6	1
	324	9.52	285	5.42	
Dibenzoyl(methylamino)ethylene (XI)	253	17.8	223	9.66	2
	334	14.0	285	5.64	
Dibenzoyl(dimethylamino)ethylene (XIV)	254	21.0	221	11.6	2
	340	17.5	295	5.00	
Bromodibenzoyl(methylamino)ethylene (XII)	253	18.8	220	9.16	3
	337	11.0	290	4.56	
Chlorodibenzoyl(diethylamino)ethylene	255	18.3	219	10.8	3
	345	8.68	295	3.80	
Dibenzoyl(phenylamino)ethylene (XXIII)	256	18.5	230	13.4	4
	375	15.9	298	6.60	
Dibenzoyl(methylphenylamino)ethylene	256	20.8	220	12.6	4
	342	18.3	295	5.8	
Methylamino-*bis*-dibenzoylethylene (XIII)	242	22.6	225	19.6	5
	360	19.0	307	4.92	
Phenylamino-*bis*-dibenzoylethylene	247	25.0	227	22.1	5
	373	14.9	315	6.24	
	440	9.48	410	8.68	
Dibenzoylethylene methylimine (X)	252	27.4	222	5.50	6
Dibenzoylethylene phenylimine (XXII)	253	27.8	220	14.8	6
	345	0.60	335	0.58	
Dibenzoyldimorpholinylethane	247	23.9	220	6.70	6
	362	0.40	327	0.28	
Bromodibenzoylmorpholinylethane	251	22.4	222	6.64	6
	345	0.48	315	0.42	
2,5-Diphenyl-2-methoxyfuranone-3	247	8.54	235	6.48	7
	314	17.4	268	4.88	
4-Bromo-2,5-diphenyl-2-ethoxyfuranone-3 (IX)	220	10.0	238	6.70	7
	253	9.76	278	3.96	
	327	15.6			
2-(Dimethylamino)-2,5-diphenylfuranone-3 (XXa)	242	8.59	235	7.80	7
	312	15.4	260	4.47	
Dimesitoylethylene (trans)	234	22.2	230	21.4	8
	310	2.48	275	1.30	
Aminodimesitoylethylene (XXVI)	357	12.7	270	14.1	8
Bromodimesitoyl(methylamino)ethylene	279	10.8	236	8.17	8
	303	10.2	295	10.0	
Dimesitoyl(dimethylamino)ethylene	300	15.6	237	8.30	8

diluted with 60% ethanol; yield 1.9 g.; m.p. 130–133° (decomp.) (40%). The compound was very unstable; several crystallizations from ethanol gave a sample melting at 139–140°d.

Anal. Calc'd for $C_{22}H_{18}BrN_2O$: C, 64.71; H, 4.44.
Found: C, 63.98; H, 4.16.

Methylamino-bis-dibenzoylethylene XIII. A solution of 1.4 g. (0.005 mole) of dibenzoyl-(methylamino)ethylene (XI) and 3.7 g. (0.016 mole) of dibenzoylacetylene in 10 ml. of benzene was refluxed for ten minutes; it turned a dark red. On cooling a crystalline precipitate was obtained, filtered, and washed with ether; yield 1.2 g. (46%); m.p. 194–197°d. After several crystallizations from a methanol-butanone mixture it melted at 202–203°d; yellow needles.

Anal. Calc'd for $C_{35}H_{25}N_2O_4$: C, 79.34; H, 5.03; N, 2.80.
Found: C, 79.12; H, 5.30; N, 3.63.

This compound was obtained as a by-product along with dibenzoyl(methylamino)-ethylene (XI) when dibenzoylacetylene (III) was treated in benzene solution with gaseous methylamine.

Anilino-bis-dibenzoylethylene was made (like XIII, above) from XXIII and III (refluxing time 20 minutes). The product was precipitated by cooling and addition of ether; yield 0.8 g. (47%); m.p. 175–185°d. Recrystallizations from ethanol-butanone mixture gave yellow needles, m.p. 194–195°.

Anal. Calc'd for $C_{33}H_{27}NO_4$; C, 81.26; H, 4.85; N, 2.49.
Found: C, 81.83; H, 4.80; N, 2.67.

This compound was also isolated from the reaction products of aniline and dibenzoylacetylene, and identified by mixture melting point with the sample above.

2-Dimethylamino-2,5-diphenylfuranone-3 (XXa). A solution of 1.1 g. of dimethylamine in dry benzene was added to a benzene solution of 2 g. of XIX under a reflux condenser, and after the vigorous reaction subsided, the mixture was refluxed for about one minute. The precipitated dimethylamine hydrobromide was filtered, the filtrate was evaporated, and the residue crystallized from 60% ethanol; colorless; yield 1.5 g. (70%); m.p. 116–117°.

Anal. Calc'd for $C_{18}H_{17}NO_2$: C, 77.40; H, 6.14.
Found: C, 77.64; H, 6.34.

2-Dibutylamino-2,5-diphenylfuranone-3 (XXb) was prepared like XXa (refluxing time 15 minutes); yield 50%; crystallized from 60% ethanol; colorless; m.p. 99.5–100°.

Anal. Calc'd for $C_{24}N_{29}NO_2$: C, 79.30; H, 8.04.
Found: C, 79.52; H, 8.14.

2-Morpholinyl-2,5-diphenylfuranone-3 (XXc) was prepared liked XXa; yield 75%; crystallized from ethanol; colorless, m.p. 148.5–149°.

Anal. Calc'd for $C_{20}H_{19}NO_3$: N, 4.34. Found: N, 4.16.

Ultraviolet absorptions were carried out in absolute ethanol as solvent, using a Beckman DU Quartz Spectrophotometer, and concentrations of about 0.00045–0.00055 molar. The solutions were made up and used as rapidly as possible to minimize deterioration of the samples. For data see Figures 1–8 and Table II.

SUMMARY

The action of ammonia and secondary amines on dibenzoylethylene dibromide and on dimesitoylethylene dibromide produces the corresponding diaroyl-(amino or subst.-amino)ethylene. In the several instances investigated the same product was obtained by addition of ammonia or the secondary amine to dibenzoylacetylene.

The action of the primary amines, methylamine and aniline, on *meso*-dibenzoylethylene dibromide produces respectively the ethylene-methylimine and -phenylimine. Methylamine reacts with the *dl*-dibromide to give the enamine as a second product. Methylamine and aniline add to dibenzoylacetylene to give the corresponding and isomeric enamines and also the dimolecular products, the amine-*bis*-dibenzoylethylenes.

The bromoamino- (and subst.-amino)-dibenzoylethylenes are obtained by bromination of the enamines. The bromo enamine was obtained in two special

cases, one by the bromination of the methylimine, and the other by the action of diethylamine on *cis*- or *trans*-dibenzoyldibromoethylene.

Three subst-aminodiphenylfuranones were made as type examples.

Abnormal reactions in the dimesitoylethylene series are cited.

Reactions of these compounds and their ultra-violet absorption spectra are considered and evidence is presented for the structures assigned. Only one configurational type seems to be involved. Some points of mechanism and stereochemistry of the reactions involved are discussed.

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