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ADDITION REACTIONS OF NUCLEOPHILES TO DIBENZOYLACETYLENE

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Abstract—Several enamine diones have been prepared through the nucleophilic addition of different amines to dibenzoylacetylene (DBA). Thus, the reaction of aniline, piperidine, *o*-aminophenol and N-phenylbenzylamine with DBA gave the corresponding 1:1 adducts namely, 1,4 - diphenyl - 2 - (N - phenylamino)but - 2 - ene - 1,4 - dione (**1**), 1,4 - diphenyl - 2 - piperidinobut - 2 - ene - 1,4 - dione (**2**), 2 - (N - 2 - hydroxyphenylamino)1,4 - diphenylbut - 2 - ene - 1,4 - dione (**3**) and 1,4 - diphenyl - 2 - (N - phenylbenzylamino)but - 2 - ene - 1,4 - dione (**4**). UV absorption data reveal that the adducts **1** and **3**, formed from aniline and *o*-aminophenol, respectively, are the E-isomers, arising through a *trans*-mode of addition whereas the adducts **2** and **4**, formed from piperidine and N-phenylbenzylamine are the Z-isomers, formed through a *cis*-mode of addition.

The reaction of N-phenacylaniline with DBA gave 2,3 - dibenzoyl - 1,4 - diphenylpyrrole (**5**), whereas the reaction of 1,8 - diaminonaphthalene with DBA gave a mixture of products consisting of 2 - benzoyl - 2 - phenacyl - 2,3 - dihydroperimidine (**11**) and 2 - benzoylperimidine (**12**). The reaction of 2-aminopyridine with DBA gave a mixture of two 1:1-adducts, 2 - (2 - imino - 1(2H) - pyridyl) - 1,4 - diphenylbut - 2 - ene - 1,4 - dione (**14**) and 1,4 - diphenyl - 2 - (N - 2 - pyridylamino)but - 2 - ene - 1,4 - dione (**15**).

Several examples of nucleophilic addition to acetylenic ketones are reported in the literature.[1] Nitrogen-containing nucleophiles like ammonia and amines, in general, add to acetylenic ketones to give simple 1:1-adducts, consisting of α,β-unsaturated β-aminoketones. The reaction of a few primary and secondary amines with dibenzoylacetylene (DBA), for example, has been studied by Du Pont, who has shown that enamine diones are formed very readily in these cases.[2] In a recent investigation, Heine *et al.*[3] have shown that diaziridines react with DBA at ambient temperatures to give the corresponding 2 - (alkylidenehydrazino) - 1,4 - diphenyl - 2 - butene - 1,4 - diones, arising through a Michael type of addition reaction. No detailed study concerning the stereochemistry of amine additions to DBA has been reported in the literature. McMullen and Stirling[4] have examined the reaction of some primary and secondary amines to few monoaryl acetylenic ketones and have observed that secondary amines give rise to enamines with E-configuration, whereas, the reaction of primary amines leads to an equilibrium mixture of adducts, consisting of E- and Z-isomers. Further, it has been observed that the ratio of Z- to E-isomers in these reactions depends on several factors like the nature of the amine and the solvent employed.

The object of the present investigation has been to study the reaction of a few monofunctional and bifunctional nitrogen-containing nucleophiles with DBA, with a view to using these reactions for the synthesis of different enamine diones and also to examine the stereochemistry of some of these addition reactions. In this connection, we have examined the reactions of aniline, piperidine, N-phenylbenzylamine, *o*-aminophenol, N-phenacylaniline, 1,8-diaminonaphthalene and 2-aminopyridine with DBA.

RESULTS AND DISCUSSION

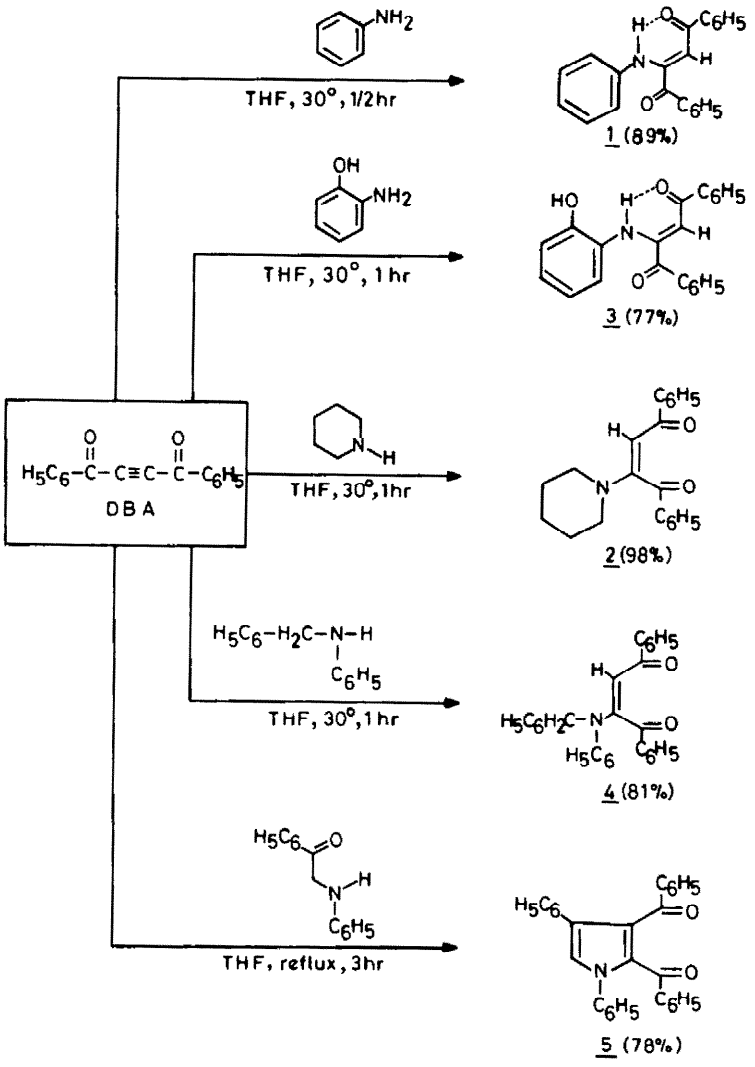
Synthesis of enamine diones

The reaction of aniline and piperidine with DBA has been reported earlier to give the corresponding 1:1-addition products.[2,5] In the present studies, we have reinvestigated these reactions with a view to examining the stereochemistry of these additions and also the electron-impact induced transformation of the corresponding adducts.

Treatment of a mixture of aniline with DBA in tetrahydrofuran, for example, gave an 89% yield of a product, identified as 1,4 - diphenyl - 2 - (N - phenylamino)but - 2 - ene - 1,4 - dione (**1**) (Scheme 1). The NMR spectrum of **1** showed a singlet at 6.3 δ (1H), multiplets centred around 7.26 δ (5H), 7.7 δ (6H) and 8.12 δ (4H) and a broad singlet at 12.75 δ (1H). Of these, the sharp singlet at 6.3 δ is assigned to the olefinic proton, whereas the broad singlet at 12.75 δ which is exchangeable with D_2O is assigned to the NH proton. Of the three multiplets, the one at 7.26 δ is assigned to the phenyl protons of the aniline nucleus, as one would expect these protons to appear at a higher field due to the electron-donating ability of the amine function. The multiplet at 8.12 δ is assigned to the ortho protons of the two benzoyl groups, whereas the multiplet at 7.7 δ is assigned to the remaining protons at the meta and para positions of the benzoyl groups.

Similarly, the reaction of piperidine with DBA gave a 98% yield of 1,4 - diphenyl - 2 - piperidinobut - 2 - ene - 1,4 - dione (**2**). The NMR spectrum of **2** showed signals at 1.67 δ (6H) and 3.35 δ (4H) for the methylene protons of the piperidine nucleus. Of these, the down-field signal at 3.35 δ is attributed to the methylene protons adjacent to the N atom, whereas, the signal at 1.67 δ is attributed to the remaining methylene protons. The olefinic proton appeared as a singlet at 6.13 δ and the benzoyl protons appeared as two sets of multiplets at 7.38 δ (6H) and 7.91 δ (4H), respectively.

The reaction of a bifunctional nucleophile like *o*-aminophenol with DBA gave a 77% yield of a 1:1-adduct, identified as 2 - (N - hydroxyphenylamino) - 1,4 - diphenylbut - 2 - ene - 1,4 - dione (**3**). The structure of **3** was confirmed on the basis of elemental analysis and spectral evidences. The NMR spectrum of **3** showed a singlet at 5.82 δ (2H) which is assigned to the vinylic proton. Two other singlets were observed at 6.45 δ (1H) and 12.88 δ (1H), which were exchangeable with D_2O and these are assigned to the OH and NH protons,



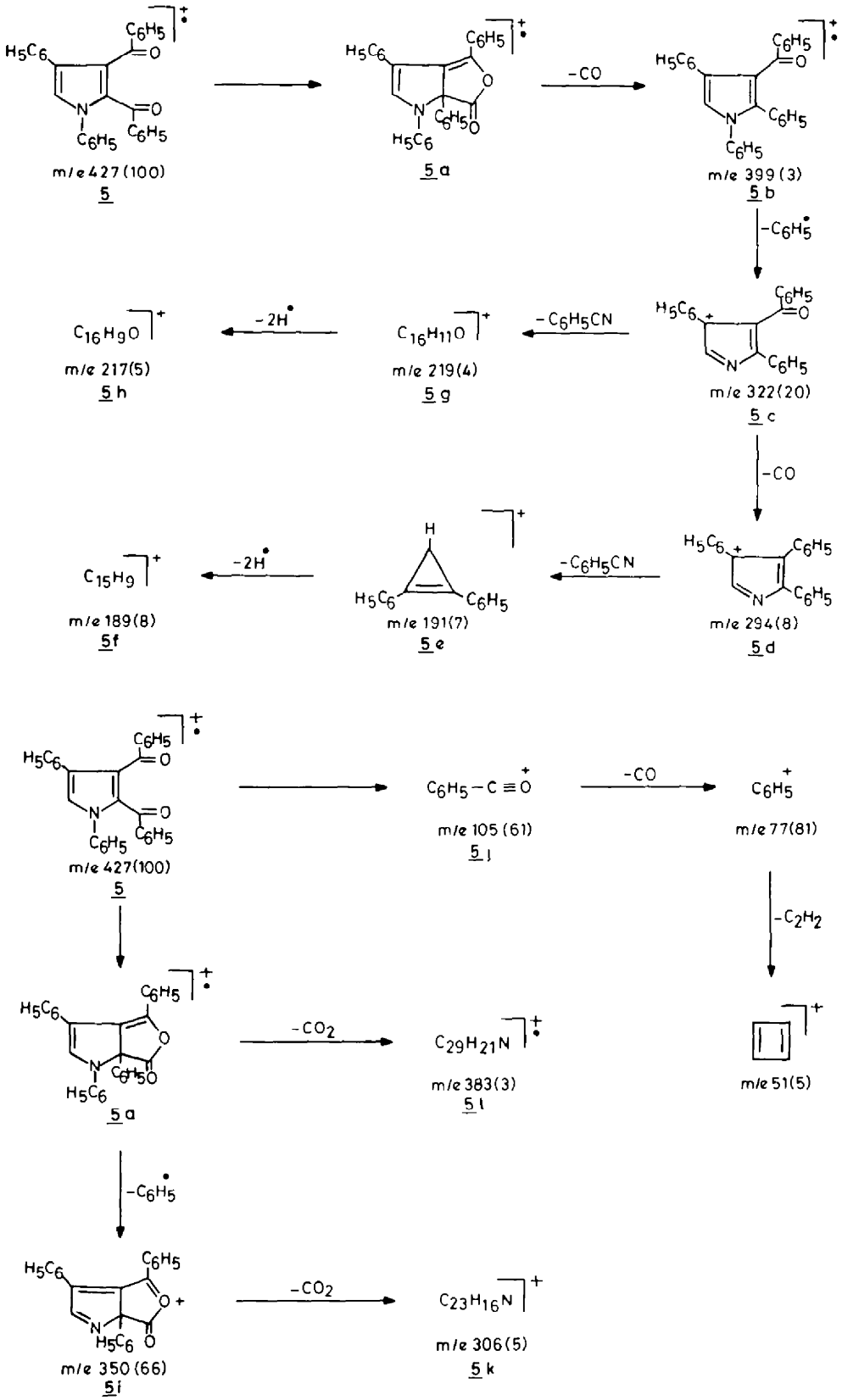
Scheme 1.

respectively. The aromatic protons of the two benzoyl groups in **3** appeared as two multiplets at 7.35 δ (6H) and 7.72 δ (4H), respectively, whereas the phenyl protons of the amine nucleophile appeared as a multiplet at a higher field namely, 6.98 δ (4H).

The reaction of a secondary amine like N-phenylbenzylamine with DBA gave an 81% yield of a 1:1-adduct, identified as 1,4 - diphenyl - 2 - (N - phenylbenzylamino)but - 2 - ene - 1,4 - dione (**4**). The NMR spectrum of **4** showed a singlet at 4.77 δ (2H), assigned to the methylene protons and a second singlet at 6.05 δ (1H) assigned to the vinylic proton. The aromatic protons appeared as groups of multiplets centered around 7.18 δ (10H), 7.42 δ (6H) and 7.85 δ (4H), respectively.

Potts and Elliott[6] have shown that the reaction of nucleophiles containing suitably positioned CO function, with DBA could provide a convenient route to synthesizing heterocyclic compounds. Thus, for example, the reaction of *o*-aminoacetophenone with DBA gave 2,3 - dibenzoyl - 4 - methylquinoline. We have examined the reaction of N-phenacylaniline with DBA with a view to studying the nature of products formed in this reaction. Refluxing of a mixture of N-phenacylaniline and DBA in THF, gave a 78% yield of a product identified as 2,3 - dibenzoyl - 1,4 - diphenylpyrrole (**5**). The structure of **5** was confirmed on the basis of analytical results and spectral data. The NMR spectrum of **5**, for example, showed a multiplet around 7.3 δ, assigned to the aromatic protons.

The mass spectrum of **5** showed a molecular ion peak at *m/e* 427 (100), which happens to be the highest intensity peak in the spectrum. The relatively high stability of the molecular ion of **5** is attributed to the aromatic character of the pyrrole system. Other peaks in the spectrum were observed at *m/e* 399 (3), 383 (3), 350 (66), 322 (20), 306 (5), 294 (8), 219 (4) 217 (5), 191 (7), 189 (8), 105 (61), 77 (81) and 51 (5). Some of the possible fragmentation modes are shown in Scheme 2. The peak at *m/e* 399 could be assigned to the fragment **5b**, formed through the loss of a CO group from either **5** or the intermediate **5a**, formed through a pericyclic reaction.[7] The peaks at *m/e* 322, 294 and 191 can be assigned to the fragments **5c**, **5d** and **5e**, formed through the successive loss of C_6H_5, CO and C_6H_5CN fragments from **5b**, as shown in Scheme 2. Loss of a C_6H_5CN moiety from **5c** will lead to the fragment **5g** at *m/e* 219, which in turn can lose hydrogen to give the fragment **5h** at *m/e* 217. Elimination of RCN fragments from α-substituted


m/e 427 (100)
5
5a
-CO
m/e 399 (3)
5b
-C6H5•
m/e 322 (20)
5c
-CO
m/e 294 (8)
5d
-C6H5CN
m/e 191 (7)
5e
-2H•
m/e 189 (8)
5f
-C6H5CN
m/e 219 (4)
5g
-2H•
m/e 217 (5)
5h
m/e 427 (100)
5
m/e 105 (61)
5i
-CO
m/e 77 (81)
-C2H2
m/e 51 (5)
5a
-CO2
m/e 383 (3)
5l
-C6H5•
m/e 350 (66)
5i
-CO2
m/e 306 (5)
5k

Scheme 2.

pyrroles, under electron-impact is a known pathway for the fragmentation of these systems.[8] The fairly intense peak at *m/e* 350, however, can be attributed to the fragment **5i**, formed through the loss of a phenyl group from **5a**.

The formation of **5** in this reaction is rationalized in terms of the addition of N-phenacylaniline to DBA giving rise to an enamine dione intermediate, which undergoes cyclization to a hydroxy pyrroline derivative. Loss of water from the pyrroline intermediate will result in the formation of the pyrrole derivative **5**. It might be pointed out in this connection that the reaction of N-phenacylaniline with dimethyl acetylenedicarboxylate is known to give an analogous pyrrole derivative namely, dimethyl 1,4 - diphenylpyrrole - 2,3 - dicarboxylate.[9]

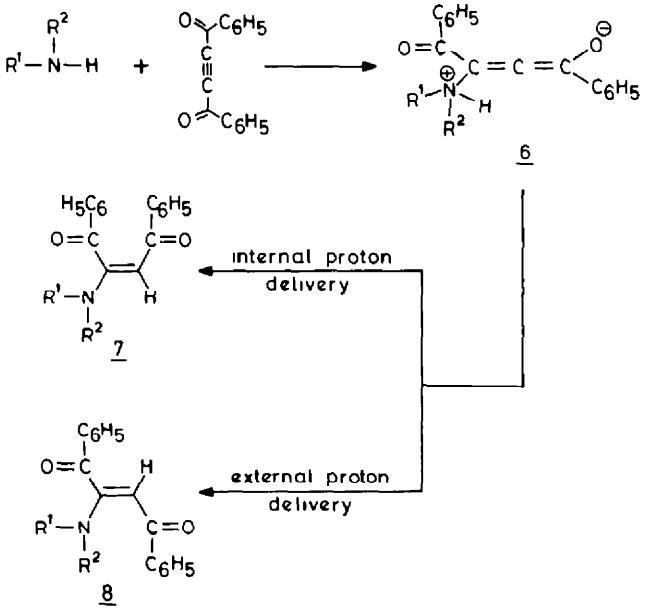
Stereochemistry of the addition of amines to dibenzoylacetylene

Detailed studies of the stereochemistry of amine additions to acetylenic esters have been carried out by several groups of workers.[10–13] Huisgen *et al.*[11,13] have shown that in the case of primary amines, for example, enamine fumarates, which are thermodynamically more stable than the corresponding maleate isomers, are formed. Thus, in the reaction of aniline with dimethyl acetylenedicarboxylate, the exclusive formation of dimethyl anilinofumarate has been observed. In the case of secondary amines, however, the addition leads to a mixture of enamine maleates and fumarates, depending upon several factors like the nature of the attacking nucleophile, the relative ease of isomerization of the products and also the nature of the solvent used for these reactions.

No detailed study of the stereochemistry of the addition of amines to DBA is reported in the literature. McMullen and Stirling[4] have studied the addition of a few primary and secondary amines to monoaroyl acetylenic ketones and have shown that the *trans*-enamines, arising through a *cis*-mode of addition are formed in the case of secondary amines, whereas, in the case of primary amines, a mixture of both *cis*- and *trans*-addition products are formed.

The reaction of an amine nucleophile with DBA would be expected to proceed through a resonance stabilized zwitterionic intermediate, **6**, as shown in Scheme 3. This intermediate in the absence of any external proton source, would undergo a stereo-specific collapse, resulting in an internal proton delivery and leading to the formation of a *cis*-disubstituted alkene derivative, **7**. However, in the presence of an external proton source one would expect the formation of the *trans*-disubstituted alkene derivative, **8**, along with that of the *cis*-isomer. Huisgen *et al.*,[13] in their studies on the addition of amines to acetylenic esters, have shown that in several cases even the excess of attacking nucleophile can serve as the external proton source. In the case of primary amines, an additional factor would be the extra stability of the *trans*-isomer through intramolecular H-bonding of the proton attached to the nitrogen nucleophile. Thus, we find that in the addition reactions of aniline and *o*-aminophenol with DBA, the products formed are predominantly of the *trans*-geometry. However, in the case of secondary amines like piperidine and N-phenylbenzylamine, the addition is assumed to proceed through a *cis*-mode, resulting in the formation of the corresponding *cis*-derivatives. It might be pointed out in this connection that unlike in the cases of the enamine maleates and fumarates, formed from acetylenic esters, the stereochemistry of the amine addition products of DBA cannot be ascertained on the basis of the NMR chemical shifts of the vinylic protons. In the adducts, **1–4**, that have been obtained in the present studies, the chemical shifts of the vinylic protons have been found to be in the range of 5.82 δ–6.30 δ and no discernable difference has been observed between the chemical shifts of the vinylic protons of the *cis*-dibenzoylalkene adducts and the *trans*-dibenzoylalkene adducts. However, our stereochemical assignments for these addition products find support from UV spectral studies.

An examination of the electronic absorption data of a



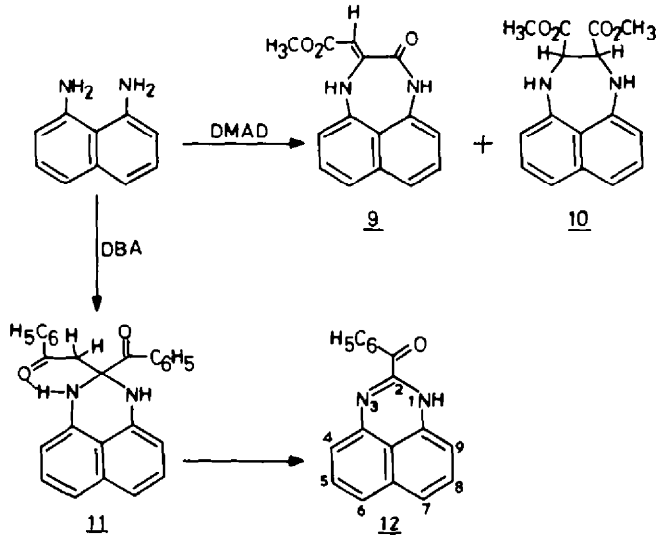
Scheme 3.

few enamine fumarates and maleates which are reported in the literature[11,12] reveals that the enamine maleates are characterized by a strong absorption band around 280 nm. In the case of enamine fumarates, however, this band is shifted to a longer wavelength and is generally observed around 320 nm. A similar observation has been made by Omar and Basyouni,[14] in the case of the thiol adducts of acetylenic ketones. These investigators have found that the E-isomers, arising through a *cis*-mode of addition, exhibit longer wave absorption bands as compared to the Z-isomers formed through a *trans*-mode of addition.

The UV absorption values of some of the enamine diones that we have prepared in the present studies, are listed in Table 1. It is evident from Table 1, that the adducts **1** and **3**, obtained from the reactions of aniline and *o*-aminophenol, respectively with DBA, exhibit a bathochromic shift in the longer wavelength absorption band. In contrast, the adducts **2** and **4**, obtained from the reactions of piperidine and N-phenylbenzylamine with DBA, show the longer wavelength absorption band around 345–350 nm. It has been reported earlier that the adducts formed from the reactions of dimetylamine and N-methylaniline with DBA also show the presence of such an absorption band around 345 nm.[15]

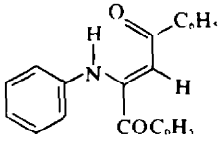
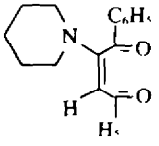
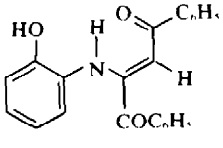
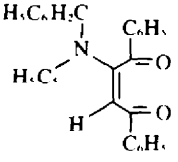
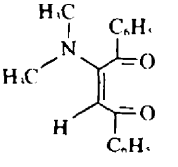
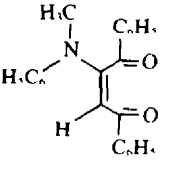
Reactions of bifunctional amine nucleophiles with dibenzoylacetylene

In continuation of our general interest in synthesizing 1,2-dibenzoylalkenes through the addition of nucleophiles to DBA, we have examined the reactions of a few bifunctional nucleophiles like, 1,8 - diaminonaphthalene and 2-aminopyridine with DBA. The reaction of 1,8 - diaminonaphthalene with dimethyl acetylenedicarboxylate is reported to give a mixture of products consisting of 2 - oxo - 2 - carbomethoxymethylene - 1,2,3,4 -



Scheme 4.

Table 1. UV absorption data of some enamine diones

Compound		λ_{max} (nm)	ϵ
	(1)	258 375	22,600 19,000
	(2)	255 350	22,000 20,500
	(3)	260 392	15,000 27,000
	(4)	258 347	22,000 18,600
		254† 350	21,000 17,500
		256† 342	20,800 18,300

†See Ref. 15.

tetrahydronaphtho - [1,8 - ef] - [1,4] - diazepine (**9**) and 2,3- -dicarbomethoxy - 1,2,3,4 - tetrahydronaphtho - [1,8 - ef] - [1,4] - diazepine (**10**) (Scheme 4).[16] Treatment of an equimolar mixture of 1,8 - diaminonaphthalene with DBA in THF at room temperature gave a mixture of products consisting of 2 - benzoyl - 2 - phenacyl - 2,3 - dihydroperimidine (**11**) (9%) and 2 - benzoylperimidine (**12**) (89%) (Scheme 4). The structures of both **11** and **12** have been arrived at on the basis of analytical results and spectral information.

Compound **12**, for example, analyzed for $C_{18}H_{12}N_2O$. Its IR spectrum showed an NH stretching frequency at 3360 cm^{-1} and a carbonyl band at 1658 cm^{-1}, respectively. In addition, the spectrum showed absorption bands at 1624, 1590 and 1520 cm^{-1}, characteristic of the stretching frequencies of 2-substituted perimidine systems.[17] The proton NMR spectrum of **12** showed a multiplet at 6.23 (1H) assigned to the H_9-proton of the perimidine nucleus. The upfield shift of this proton is attributed to the presence of the adjacent NH group of the perimidine ring. Other protons of the perimidine ring appeared as a complex multiplet centred around 7.55 δ (3H) and 8.31 δ (2H and NH), respectively. The multiplet at 8.31 δ accounted for three protons, which include the NH proton of the perimidine ring system.

The mass spectrum of **12** showed a molecular ion peak at *m/e* 272 (100). Other peaks in the spectrum were observed at *m/e* 271 (14), 244 (12), 243 (3), 105 (41), 77 (71) and 51 (6). Some of the possible fragmentation modes are shown in Scheme 5.

Analytical results have shown that compound **11** has the molecular formula $C_{26}H_{20}N_2O_2$. The IR spectrum of **11** showed a band at 3276 cm^{-1}, characteristic of a H-bonded NH group. In addition, the spectrum showed a CO absorption band at 1650 cm^{-1}. The proton NMR spectrum of **11** (Fig. 1) showed an AB quartet with chemical shifts at 3.14 δ (1H) and 4.53 δ (1H) and J_{AB} = 17.5 c/s, indicating the presence of two non-equivalent methylene protons. The magnetic nonequivalence of the two methylene protons may be attributed to the restricted rotation of the $C_6H_5COCH_2$ group due to the H-bonding between the NH and CO groups in **11**. In addition, the spectrum of **11** showed several multiplets centred around 6.07 δ (2H), 6.5 δ (1H), 7.0 δ (5H), 7.48 δ (6H) and 7.92 δ (4H). Of these, the multiplets at 7.48 δ and 7.92 δ are assigned to the benzoyl group protons, whereas, the other multiplets at 6.07 δ, 6.5 δ and 7.0 δ account for the aromatic protons of the perimidine nucleus and the two NH protons.

Further support for the structure of **11** was derived from its mass spectrum. The mass spectrum of **11** showed a molecular ion peak at *m/e* 392 (4). Other peaks in the spectrum were observed at *m/e* 375 (1), 374 (3), 272 (61), 271 (7), 270 (2), 269 (2), 268 (1), 244 (7), 243 (7), 242 (7), 166 (30), 141 (2), 140 (11), 139 (4), 105 (100), 77 (98) and 51 (40), which could be assigned to some of the fragments shown in Scheme 6. As is evident from Scheme 6, a prominent mode of fragmentation of **11** is through the loss of a $C_6H_5COCH_3$ moiety to give the molecular ion of **12** at *m/e* 272. The peaks at *m/e* 271, 244, 243, 242, 166, 141, 140 and 139 can be assigned to fragments like **12a**, **12b**, **12c**, **12e**, **12f**, **12i**, **12h** and **12k**, formed through the fragmentation of the molecular ion of **12** (see Scheme 5). The mass spectrum of **11** clearly reveals that it is very readily transformed to **12**, under electron impact. Other peaks in the mass spectrum of **11** at *m/e* 375, 374, 269 and 268 could be assigned to the fragments **11a**, **11b**, **11c** and **11d**, as shown in Scheme 6.

Additional support for the structure of **11** was derived from its thermal decomposition studies. On heating **11** around 150–160° for 0.5 hr resulted in the formation of a 73% yield of **12**. The formation of **12** from **11** is rationalized in terms of a concerted loss of an acetophenone fragment as shown in Scheme 4.

Further to our studies, we have examined the reaction of 2-aminopyridine with DBA. The reaction of 2-aminopyridine with DBA gave a mixture of two 1:1-adducts consisting of 2 - (2 - imino - 1 - (2H) - pyridyl) - 1,4 - diphenylbut - 2 - ene - 1,4 - dione (**14**) and 1,4 - diphenyl - 2 - (N - 2 - pyridylamino)but - 2 - ene - 1,4 - dione (**15**) (Scheme 7). The structures of both **14** and **15** were established on the basis of analytical results and spectral data.

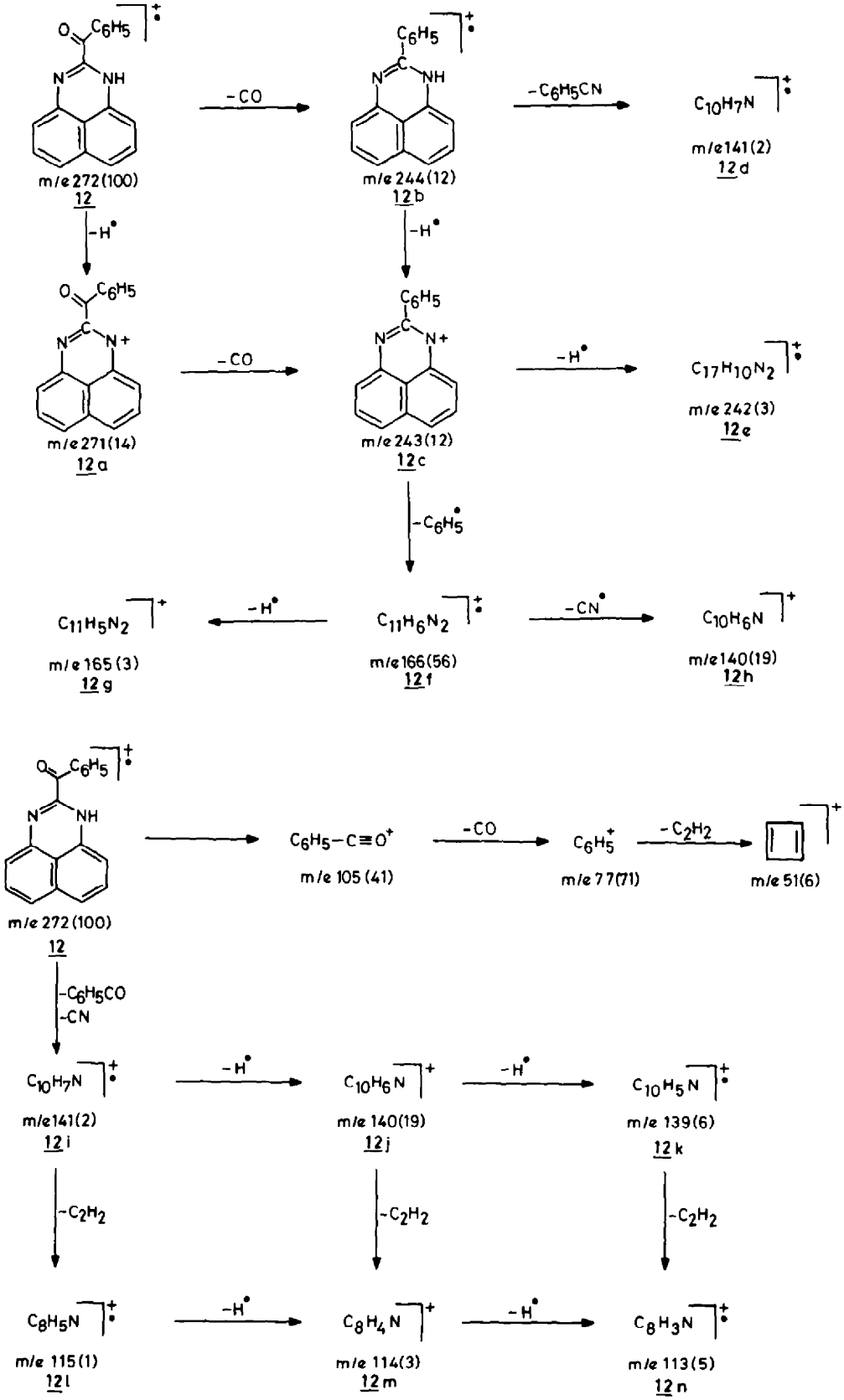
The IR spectrum of **14**, for example, showed a band at 3115 cm^{-1}, characteristic of an NH stretching frequency and two bands at 1668 and 1653 cm^{-1}, respectively, due to two carbonyl groups. The NMR spectrum of **14** showed several multiplets at 5.96 δ (1H), 6.63 δ (2H), 7.53 δ (11H) and two singlets at 7.0 δ (1H) and 7.13 δ (1H). Of these, the multiplet around 5.96 δ is assigned to the H_5-proton of the pyridine ring, which is the most shielded proton. The multiplet around 6.63 δ can be assigned to the H_3 and H_4 protons of the pyridine ring, whereas the signal at 7.13 δ could be assigned to the H_6-proton of the pyridine ring. The complex multiplet centred around 7.53 δ could be assigned to the aromatic protons of the two benzoyl groups and the NH proton. The singlet at 7.03 δ is assigned to the vinylic proton in **14**.

The mass spectrum of **14** showed a molecular ion peak at *m/e* 328 (40), which undergoes the loss of an NH fragment to give the ion **14a** at *m/e* 313 (7). Similar nitrene eliminations from 2-aminopyridine derivatives are reported in the literature.[18,19] A pericyclic transformation of the dibenzoylalkene function will lead to **14b**, which in turn can undergo elimination of fragments like CO_2, CO and C_6H_5 to give the ions **14c**, at *m/e* 284 (9), **14d**, at *m/e* 300 (10) and **14e**, at *m/e* 251 (20), respectively. Further elimination of a CO group from **14e** can lead to the fragment **14f** at *m/e* 223 (100). Elimination of HCN from the molecular ion **14**, however, will lead to the fragment **14i** at *m/e* 301 (8). The peaks at *m/e* 105 (61), 78 (66) and 77 (37) can be attributed to benzoyl, pyridyl and phenyl fragments, respectively. Other peaks in the spectrum of **14** were observed at *m/e* 222 (12), 221 (32), 209 (25), 207 (53), 195 (24), 181 (22), 121 (13), 91 (8) and 51 (15). Some of the possible pathways for the formation of these fragments are shown in Scheme 8.

The IR spectrum of **15** showed two absorption bands at 3160 and 1710 cm^{-1}, which have been assigned to a H-bonded NH and CO group, respectively. The UV spectrum of **15** showed two absorption maxima at 258 and 380 nm, characteristic of enamine diones (Table 1).

The NMR spectrum of **15** showed a sharp singlet at 6.22 δ (1H), which is assigned to the vinylic proton. In addition, the spectrum showed several multiplets centred around 6.83 δ (2H), 7.35 δ (7H) and 7.95 δ (5H). Of these the multiplet around 6.83 δ is assigned to the most shielded protons of the pyridine ring namely, the H_3 and H_5 protons. The multiplets at 7.35 δ and 7.95 δ are assigned to the aromatic protons of the two benzoyl groups and also the H_4 and H_6 protons of the pyridine ring. The broad band around 12.87 δ in the spectrum of **15** is assigned to the NH proton and it has been observed that this proton is exchangeable with D_2O.

A probable route to the formation of the adducts **14**


m/e 272(100)
12
-CO
m/e 244(12)
12b
-C6H5CN
C10H7N
m/e141(2)
12d
-H•
-H•
m/e 271(14)
12a
-CO
m/e 243(12)
12c
-H•
C17H10N2
m/e 242(3)
12e
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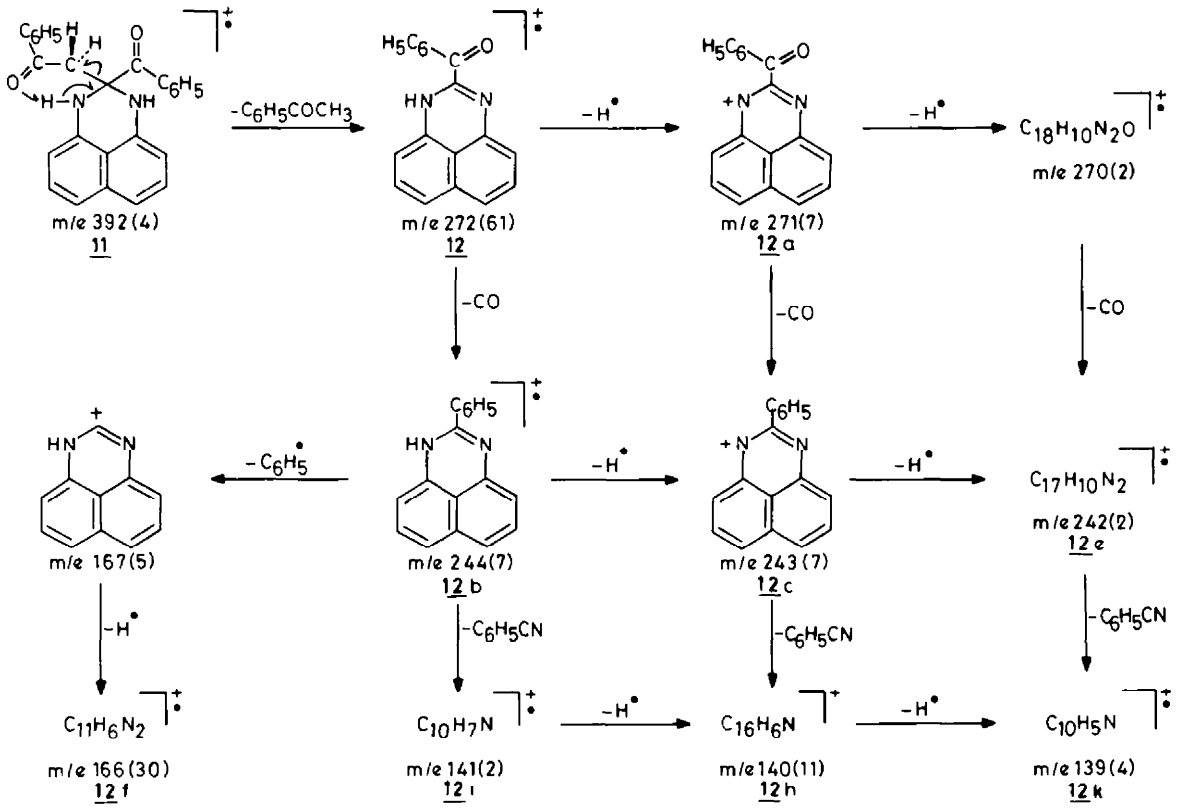
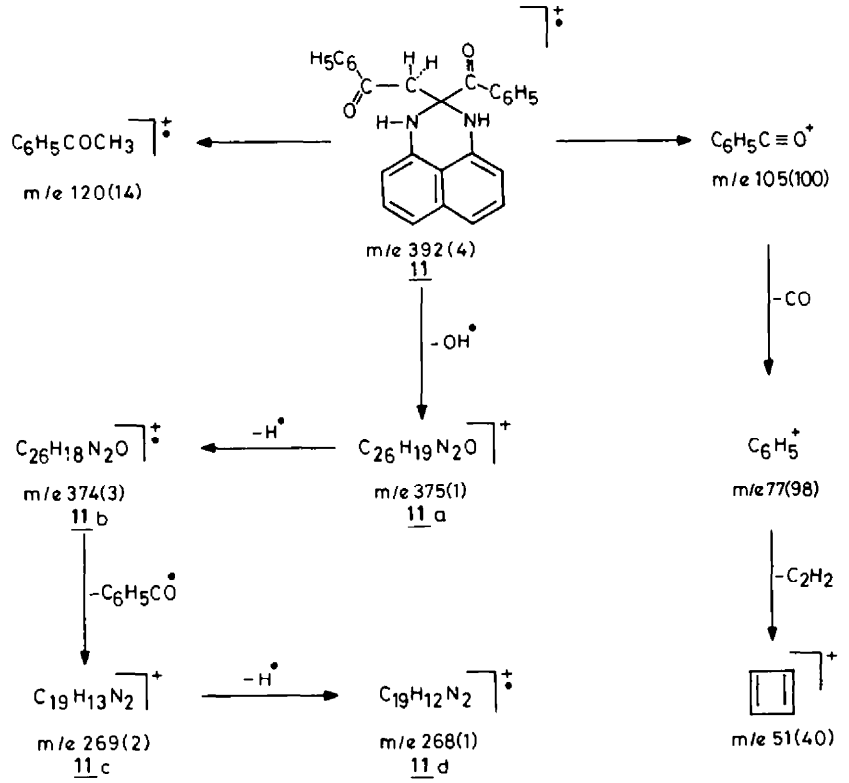
C11H5N2
m/e 165(3)
12g
-H•
C11H6N2
m/e166(56)
12f
-CN•
C10H6N
m/e140(19)
12h
m/e 272(100)
12
C6H5-C≡O+
m/e 105(41)
-CO
C6H5+
m/e 77(71)
-C2H2
m/e 51(6)
-C6H5CO
-CN
C10H7N
m/e141(2)
12i
-H•
C10H6N
m/e 140(19)
12j
-H•
C10H5N
m/e 139(6)
12k
-C2H2
-C2H2
-C2H2
C8H5N
m/e 115(1)
12l
-H•
C8H4N
m/e 114(3)
12m
-H•
C8H3N
m/e 113(5)
12n

Scheme 5.


m/e 392(4)
11
-C6H5COCH3
m/e 272(61)
12
-H•
m/e 271(7)
12a
-H•
C18H10N2O
m/e 270(2)
-CO
-CO
-CO
m/e 167(5)
-C6H5•
m/e 244(7)
12b
-H•
m/e 243(7)
12c
-H•
C17H10N2
m/e 242(2)
12e
-H•
-C6H5CN
-C6H5CN
C11H6N2
m/e 166(30)
12f
C10H7N
m/e 141(2)
12i
-H•
C16H6N
m/e 140(11)
12h
-H•
C10H5N
m/e 139(4)
12k


C6H5COCH3
m/e 120(14)
m/e 392(4)
11
C6H5C≡O+
m/e 105(100)
-OH•
-CO
C26H18N2O
m/e 374(3)
11b
-H•
C26H19N2O
m/e 375(1)
11a
C6H5+
m/e77(98)
-C6H5CO•
-C2H2
C19H13N2
m/e 269(2)
11c
-H•
C19H12N2
m/e 268(1)
11d
m/e 51(40)

Scheme 6.

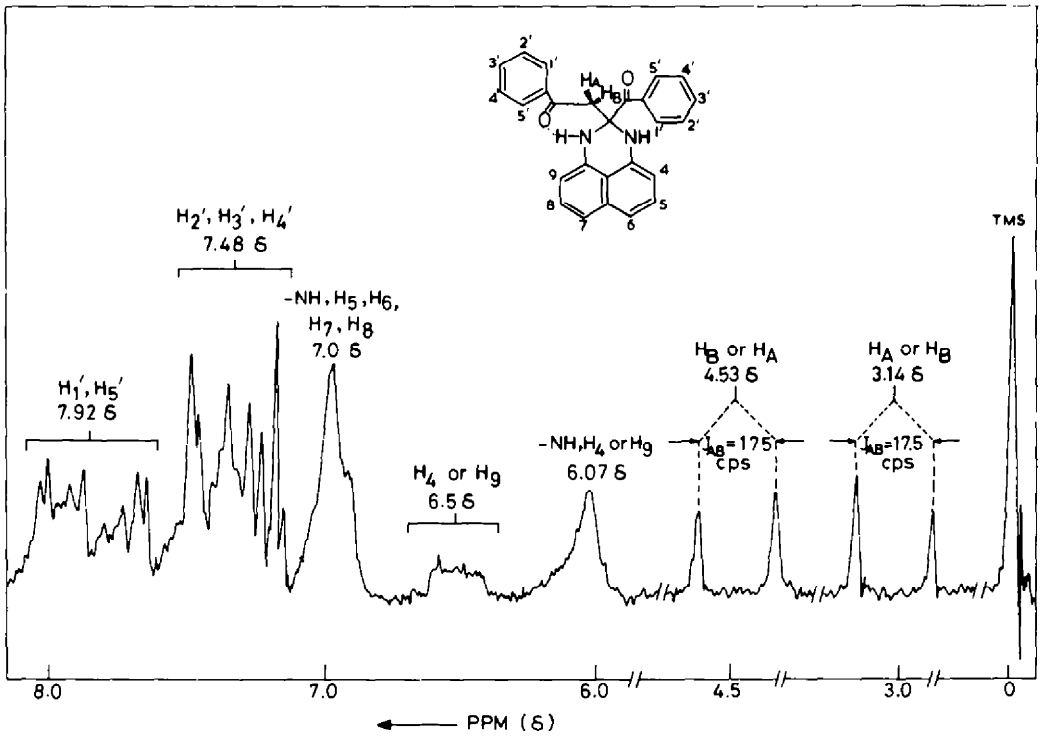
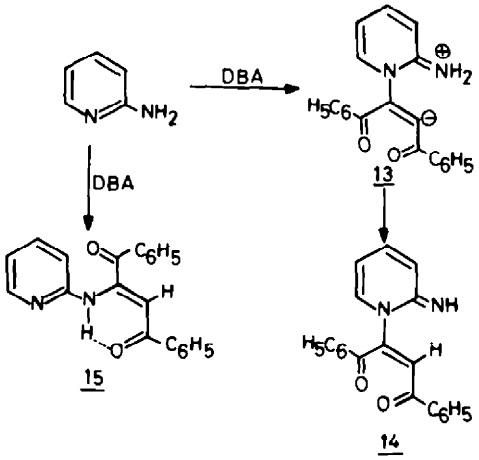


Fig. 1. NMR spectrum (60 MHz) of 2-benzoyl-2-phenacyl-2,3-dihydroperimidine (11).



Scheme 7.

and **15** in the reaction of 2-aminopyridine with DBA is shown in Scheme 7. In the reaction of a bifunctional nucleophile like 2-aminopyridine, two modes of reaction are possible. In one case, the primary amine centre can initiate the nucleophilic attack and lead to the formation of the adduct **15**. Such a reaction is analogous to the reaction of aniline and other primary amines with DBA. In the alternative mode of reaction, the tertiary amine centre of the pyridine nucleus initiates the nucleophilic attack, leading to the formation of the zwitterionic intermediate **13**, which can then undergo an intramolecular transfer of a proton to give rise to the adduct **14** (Scheme 7). It might be pointed out in this connection that the reactions of 2-aminopyridine with acrylic ester[20] and methyl propiolate[21-23] are known to proceed in a similar manner.

EXPERIMENTAL

All m.ps are uncorrected and were recorded on a Mel-Temp m.p. apparatus. The IR spectra were recorded on Perkin–Elmer, Model 137 and Model 521 IR Spectrometers. The electronic spectra were recorded on a Beckman DB Spectrophotometer. NMR traces were recorded on either Varian A-60 or XL-100 NMR Spectrometer, using TMS as internal standard. The mass spectra were recorded on a Varian Mat CH7 Mass Spectrometer at 70 eV.

Starting materials

Dibenzoylacetylene, m.p. 110–111°, was prepared by a reported procedure.[24]

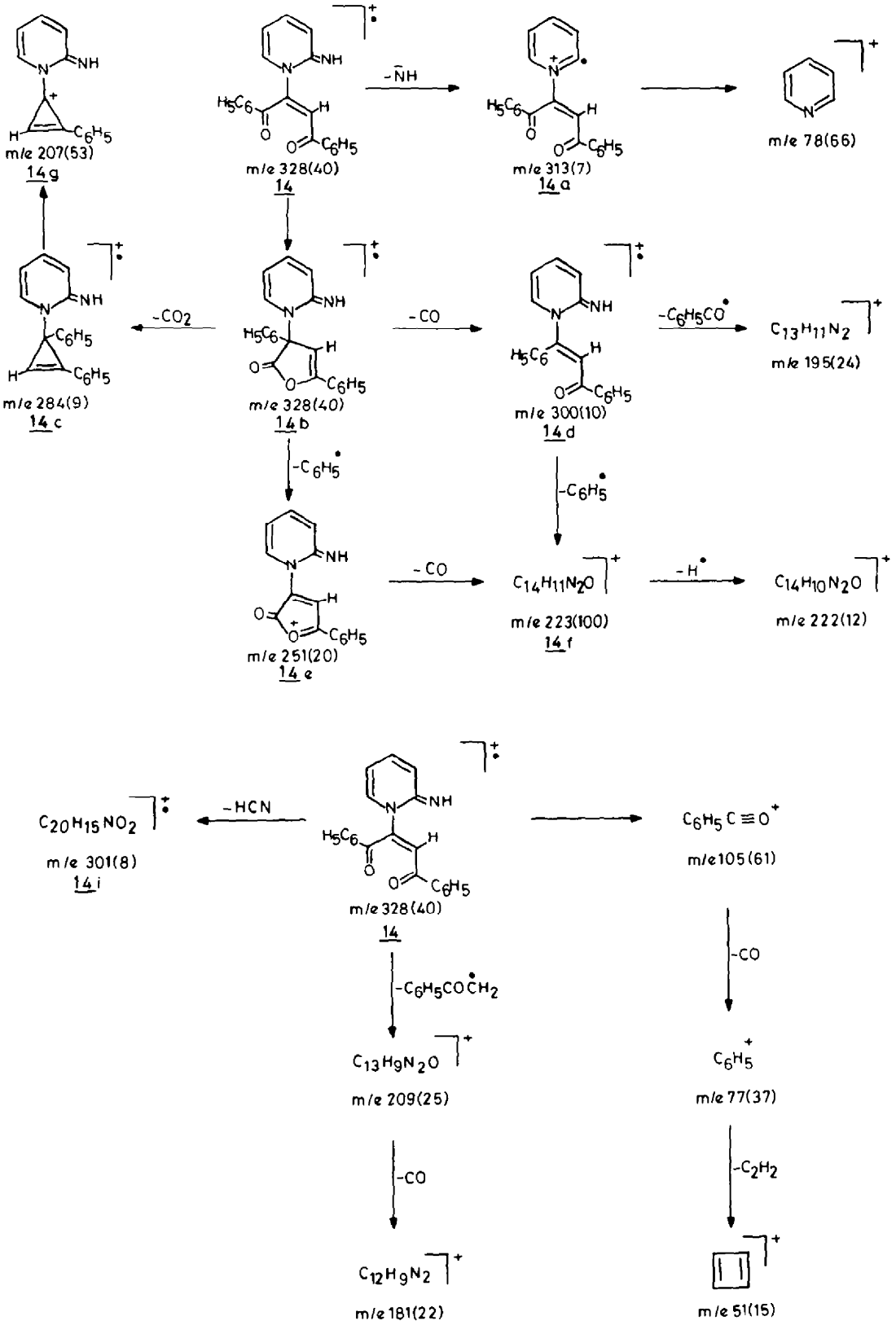
Commercial grades of aniline, piperidine and N-phenylbenzylamine were freshly distilled before use. Phenacylaniline, m.p. 98°, was prepared in a 69% yield by a reported procedure.[25]

Reaction of aniline with dibenzoylacetylene

A soln of DBA (234 mg, 1 mmol) in THF (10 ml) was added to a THF soln of aniline (93 mg, 1 mmol in 50 ml) at room temp. and with constant stirring, over a period of 30 min. The stirring was continued for an additional period of 30 min and afterwards the solvent was removed under vacuum to give a yellow solid. Recrystallization from a mixture (2:1) of MeOH and $CHCl_3$ gave 290 mg (89%) of bright yellow needle shaped crystals of **1**, m.p. 130° (lit.[2] m.p. 131°). (Found: C, 80.58, H, 5.03, N, 3.80; Mol. wt., 327 (Mass spectrometry). $C_{22}H_{17}NO_2$ requires: C, 80.73, H, 5.19, N, 4.13, Mol. wt., 327). IR spectrum (KBr) ν_{max}: 3120 cm^{-1} (ν_{N-H}, H-bonded), 3095, 2945, 2845 cm^{-1} (ν_{C-H}), 1670 and 1615 cm^{-1} ($\nu_{C=O}$), 1600, 1580 and 1570 cm^{-1} ($\nu_{C=C}$).

Reaction of piperidine with dibenzoylacetylene

A soln of DBA (936 mg, 4 mmol) in THF (15 ml) was added to a THF soln of piperidine (340 mg, 4 mmol in 80 ml) at room temp. and with constant stirring. After 1 hr, the stirring was stopped and the solvent was removed under vacuum. The residue was recrystallized from a mixture (2:1) of MeOH and $CHCl_3$ to give


m/e 207(53)
14g
m/e 328(40)
14
-NH
m/e 313(7)
14a
m/e 78(66)
-CO2
m/e 284(9)
14c
m/e 328(40)
14b
-CO
m/e 300(10)
14d
-C6H5CO•
C13H11N2
m/e 195(24)
-C6H5•
m/e 251(20)
14e
-CO
C14H11N2O
m/e 223(100)
14f
-H•
C14H10N2O
m/e 222(12)
C20H15NO2
m/e 301(8)
14i
-HCN
m/e 328(40)
14
C6H5C≡O+
m/e105(61)
-C6H5COCH2•
C13H9N2O
m/e 209(25)
-CO
C6H5+
m/e 77(37)
-CO
C12H9N2
m/e 181(22)
-C2H2
m/e 51(15)

Scheme 8.

1.25 g (98%) of pale yellow needles of **6**, m.p. 179° (lit.[2] m.p. 181°). (Found: C, 78.50, H, 6.49, N, 4.29; Mol. wt., 319 (Mass spectrometry). $C_{21}H_{21}NO_2$ requires: C, 78.99, H, 6.58, N, 4.39, Mol. wt., 319). IR spectrum (KBr) ν_{max}: 3031, 3020, 2956 and 2876 cm^{-1} (ν_{C-H}), 2926 and 2855 cm^{-1} (ν_{CH_2}, asymmetric and symmetric), 1670 cm^{-1} ($\nu_{C=O}$), 1612, 1599 and 1585 cm^{-1} ($\nu_{C=C}$).

Reaction of N-*phenylbenzylamine with dibenzoylacetylene*

Treatment of a soln of DBA (500 mg, 2.1 mmol) in THF (10 ml) with a THF-soln of N-phenylbenzylamine (554 mg, 2.1 mmol in 80 ml) at room temp. for 1 hr and work-up of the mixture as in the earlier cases gave a product mixture. Recrystallization of this product from a mixture (2:1) of MeOH and $CHCl_3$ gave 850 mg (81%) of colourless needle shaped crystals of **5**, m.p. 133°. (Found: C, 83.45, H, 5.41, N, 3.50, Mol. wt., 417 (Mass spectrometry). $C_{29}H_{23}NO_2$ requires: C, 83.45, H, 5.51, N, 3.36, Mol. wt., 417). IR spectrum (KBr) ν_{max}: 3016 and 2996 cm^{-1} (ν_{C-H}), 1674 cm^{-1} ($\nu_{C=O}$), 1625, 1599 and 1584 cm^{-1} ($\nu_{C=C}$).

Reaction of o-*aminophenol with dibenzoylacetylene*

A soln of DBA (500 mg, 2.1 mmol) in THF (10 ml) was gradually added to a THF-soln of *o*-aminophenol (229 mg, 2.1 mmol in 60 ml), at room temp., over a period of 1 hr. The mixture was stirred continuously during the addition. Removal of the solvent under vacuum gave an impure product, which was treated with animal charcoal and subsequently recrystallized from a mixture (1:1) of petroleum ether and $CHCl_3$ to give 560 mg (77%) of **3**, m.p. 184–185°. (Found: C, 76.88, H, 4.86, N, 4.10, Mol. wt., 343 (Mass spectrometry). $C_{22}H_{17}NO_3$ requires: C, 76.96, H, 4.95, N, 4.08, Mol. wt., 343). IR spectrum (KBr) ν_{max}: 3170 cm^{-1} (ν_{N-H}, H-bonded), 3070 cm^{-1} (ν_{C-H}), 1625 cm^{-1} ($\nu_{C=O}$), 1620, 1605 and 1584 cm^{-1} ($\nu_{C=C}$).

Reaction of N-*phenacylaniline with dibenzoylacetylene*

A mixture of DBA (702 mg, 3 mmol) and N-phenacylaniline (633 mg, 3 mmol) in THF (80 ml) was refluxed for 3 hr on a steam-bath. Removal of the solvent under vacuum gave an oily mass which solidified on treatment with a small amount of MeOH. Recrystallization of this product from a mixture (5:1) of petroleum ether and $CHCl_3$ gave 1 g (78%) of **5**, m.p. 110°. (Found: C, 83.52, H, 4.89, N, 3.13, Mol. wt., 427 (Mass spectrometry). $C_{30}H_{21}NO_2$ requires: C, 83.83, H, 4.91, N, 3.27, Mol. wt., 427). IR spectrum (KBr) ν_{max}: 2993, 2987 and 2985 cm^{-1} (ν_{C-H}), 1655 cm^{-1} ($\nu_{C=O}$), 1635, 1605 and 1584 cm^{-1} ($\nu_{C=C}$). UV spectrum (MeOH) λ_{max}: 258 nm (ϵ, 26,000) and 326 (6,600).

Reaction of 1,8-*diaminonaphthalene with dibenzoylacetylene*

A soln of DBA (1.17 g, 5 mmol) in THF (20 ml) was added to a THF soln of 1,8-diaminonaphthalene (0.79 g, 5 mmol in 100 ml), at room temp. over a period of 1 hr. Removal of the solvent under vacuum gave a product which was chromatographed over silica-gel.

Elution of the column with a mixture (5:1) of petroleum ether and benzene gave a violet compound which was recrystallized from hot $CHCl_3$ to give 1.15 g (86%) of **12**, m.p. 203–204°. (Found: C, 79.59, H, 4.70, N, 10.10, Mol. wt., 272 (Mass spectrometry). $C_{18}H_{12}N_2O$ requires: C, 79.41, H, 4.41, N, 10.29, Mol. wt., 272). IR spectrum (KBr) ν_{max}: 3360 cm^{-1} (ν_{N-H}), 3065, 2946 and 2866 cm^{-1} (ν_{C-H}), 1658 cm^{-1} ($\nu_{C=O}$), 1624, 1590 and 1520 cm^{-1} ($\nu_{C=C}$). UV spectrum (MeOH) λ_{max}: 237 nm (ϵ, 23,000), 260 (18,000), 285 (14,000), 338 (10,000) and 508 (1100).

Further elution of the silica-gel column with a mixture (4:1) of petroleum ether and benzene gave 230 mg of a mixture of products which was rechromatographed over silica-gel. Elution with a mixture (5:1) of petroleum ether and benzene gave 50 mg of 2-benzoylperimidine, m.p. 203–204° (mixture m.p.).

Further elution of the column with a mixture (4:1) of petroleum ether and benzene gave 180 mg (9%) of yellow needle shaped crystals of **11**, m.p. 146–147°. (Found: C, 79.32, H, 5.42, N, 7.29, Mol. wt., 392 (Mass spectrometry). $C_{26}H_{20}N_2O_2$ requires: C, 79.59, H, 5.10, N, 7.14, Mol. wt., 392). IR spectrum (KBr) ν_{max}: 3276 cm^{-1} (ν_{N-H}, H-bonded), 3065 and 2926 cm^{-1} (ν_{C-H}), 1650 cm^{-1} ($\nu_{C=O}$), 1638, 1610 and 1593 cm^{-1} ($\nu_{C=C}$). UV spectrum (MeOH) λ_{max}: 235 nm (ϵ, 52,500) and 335 (17,000).

Thermolysis of 2 - *benzoyl* - 2 - *phenacyl* - 2,3 - *dihydroperimidine*

A sample of 2 - benzoyl - 2 - phenacyl - 2,3 - dihydroperimidine (60 mg, 0.15 mmol) was heated for 30 min around 150–155° in a sealed tube. The mixture was chromatographed over silica-gel. Elution with a mixture (5:1) of petroleum ether and benzene gave 30 mg (73%) of 2-benzoylperimidine, m.p. 203–204° (mixture m.p.).

Further elution of the column with the same solvent mixture gave 15 mg (25%) of the unchanged starting material, m.p. 146–147° (mixture m.p.).

Reaction of 2-*aminopyridine with dibenzoylacetylene*

To a soln of DBA (2.34 g, 0.01 mol) in ether (300 ml) was added an ether soln of 2-aminopyridine (0.94 g, 0.01 mol in 80 ml) with constant stirring over a period of 45 min. On leaving the mixture overnight, a deep red solid compound separated out, which was recrystallized from hot benzene to give 2 g (61%) of **14**, m.p. 168°. (Found: C, 76.76, H, 5.04, N, 8.45, Mol. wt., 328 (Mass spectrometry). $C_{21}H_{16}N_2O_2$ requires: C, 76.82, H, 4.87, N, 8.53, Mol. wt., 328). IR spectrum (KBr) ν_{max}: 3115 cm^{-1} (ν_{N-H}, H-bonded), 3085 and 3055 cm^{-1} (ν_{C-H}), 1668 and 1653 cm^{-1} ($\nu_{C=O}$), 1613, 1588 and 1578 cm^{-1} ($\nu_{C=N}$ and $\nu_{C=C}$). UV spectrum (MeOH) λ_{max}: 260 nm (ϵ, 19,500), 295 (15,000) and 452 (7200).

Removal of the solvent from the mother liquor gave a residual product which was chromatographed over silica-gel. Elution with petroleum ether gave a product which was recrystallized from a mixture (1:1) of benzene and MeOH to give 400 mg (12%) of yellow crystals of **15**, m.p. 165°. (Found: C, 76.90, H, 4.73, N, 8.66, Mol. wt., 328 (Mass spectrometry). $C_{21}H_{16}N_2O_2$ requires: C, 76.82, H, 4.87, N, 8.53, Mol. wt., 328). IR spectrum (KBr) ν_{max}: 3160 cm^{-1} (ν_{N-H}, H-bonded), 3100 and 3060 cm^{-1} (ν_{C-H}), 1710 cm^{-1} ($\nu_{C=O}$), 1630 cm^{-1} ($\nu_{C=N}$), 1600, 1580, 1530 cm^{-1} ($\nu_{C=C}$). UV spectrum (MeOH) λ_{max}: 258 nm (ϵ, 22,000) and 380 (29,000).

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