HETEROCYCLES, Vol. 6, No. 8, 1977

PHOTOLYSIS OF AMINO-SUBSTITUTED 1,4-NAPHTHOQUINONES
A NOVEL SYNTHESIS OF HETEROCYCLIC QUINONES

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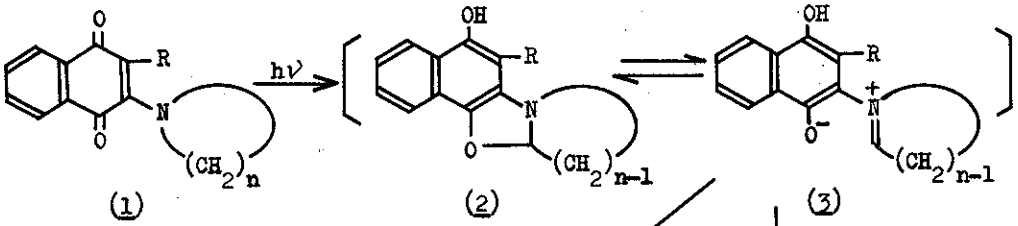
Irradiation of the 2-amino-substituted 1,4-naphthoquinones (1c and 1d) having an active methylene group at the 3-position with high-pressure mercury lamp resulted in the formation of 11,11-bis-ethoxycarbonyl-1,2,5,10,11,11a-hexahydro-5,10-dioxo-3H-pyrrolo[1,2-a]benz[f]indole (6c) or 12,12-bisethoxycarbonyl-1,2,3,4,6,11,12,12a-octahydro-6,11-dioxopyrido[1,2-a]benz[f]indole (6d) via the oxazoline (2).

The solvent effects were also examined.

1,4-Benzoquinones bearing certain secondary amino substituents have been shown to photoisomerise readily in the sunlight to the benzoxazoline and benzoxazole derivatives.[1,2,3] Recently we have observed the results of photolysis of aminonaphthoquinones (1a) and (1b) in hydroxylic solvents.[4,5] These investigations pointed to the formation of a zwitter ion intermediate (3) followed by the intermolecular nucleophilic attack to give the ring-opened aminoquinones (4a) and (4b) or (5a) and (5b) as the main products. Therefore, photolysis of the substituted aminoquinones possessing sufficient nucleophilic character followed by its intramolecular ring closure would provide a versatile pathway to a number of heterocyclic quinones (6).

We now wish to report an example of this novel type of the photoinduced intramolecular cyclization of (1c) and (1d) in various solvents.



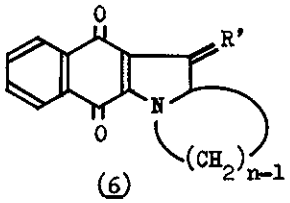
(1)

(1a): R=H, n=4
(1b): R=H, n=5
(1c): R=CH(COOEt)$_2$, n=4
(1d): R=CH(COOEt)$_2$, n=5

(2)

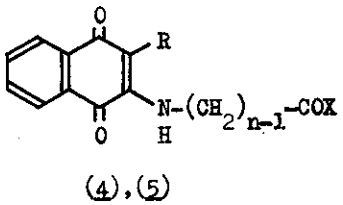
(3)

H_2O or EtOH+H_2O



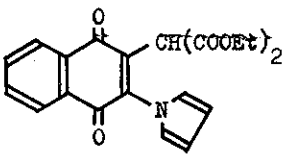
(6)

R'=(COOEt)$_2$

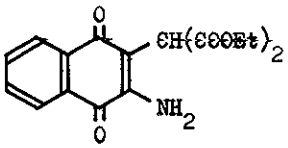


(4),(5)

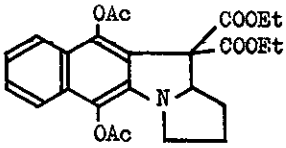
(4a): R=X=H, n=4
(4b): R=X=H, n=5
(5a): R=H, X=OEt, n=4
(5b): R=H, X=OEt, n=5



(7)



(8)



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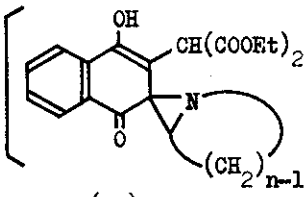

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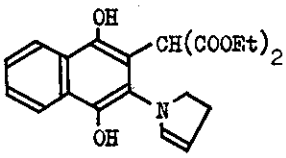

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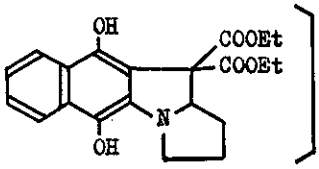

(12)

The aminoquinones (1) [(1c), mp. 121-122°; ir. 1743, 1735 (ester), and 1676 (CO) cm^{-1}; nmr. ($CDCl_3$) τ 2.00-2.33 (4H, m, Ar-H), 5.26 (1H, s, C<u>H</u>$(COOEt)_2$), 5.73 (4H, q, $2COOC\underline{H}_2CH_3$), 6.23 (4H, m, $2N-CH_2$), 8.09 (4H, m, $2CH_2$), and 8.73 (6H, t, $2COOCH_2C\underline{H}_3$); ms. m/e 385 (M^+); (1d), oil; ir. 1740, 1720 (ester), and 1665 (CO) cm^{-1}; nmr. ($CDCl_3$) τ 1.94-2.32 (4H, m, Ar-H), 5.20 (1H, s, C<u>H</u>$(COOEt)_2$), 5.72 (4H, q, $2COOC\underline{H}_2CH_3$), 6.70 (4H, m, $2N-CH_2$), 8.32 (6H, m, $3CH_2$), and 8.72 (6H, t, $2COOCH_2C\underline{H}_3$); ms. m/e 399 (M^+)] were readily prepared from 3-chloro-2-bisethoxycarbonylmethyl-1,4-naphthoquinone[6] and found to be exceedingly photosensitive.

Photolysis of (1c), a violet-red compound, in benzene using a high pressure mercury lamp through Pyrex glass gave a colorless photoisomer. However, the product could not be isolated owing to the instability. Monitoring of the photoreaction of (1c) in $CDCl_3$ by nmr. spectroscopy suggested that the intermediate, the oxazoline (2c), would be first formed and then degradated into several compounds by lapse of time. [(2c), nmr. ($CDCl_3$) τ 1.42 (1H, s, OH, disappeared upon the addition of D_2O), 1.70-2.60 (4H, m, Ar-H), 3.88 (1H, t, O-CH-N), 4.95 (1H, s, C<u>H</u>$(COOEt)_2$), 5.70 (4H, q, $2COOC\underline{H}_2CH_3$), 6.48-6.92 (2H, m, $N-CH_2$), 7.60-8.00 (4H, m, $2CH_2$), and 8.72 (6H, q, $2COOCH_2C\underline{H}_3$)].

After standing the irradiated solution of (1c) for 12 hr at room temperature, three new products were obtained. The major product (8.3%), a red crystalline compound, was assigned as (6c) [mp. 153-155°; ir. 1745, 1719 (ester), and 1679 (CO) cm^{-1}; nmr. ($CDCl_3$) τ 2.06-2.46 (4H, m, Ar-H), 5.21 (1H, d,d, N-CH), 5.76 (4H, q, $2COOC\underline{H}_2CH_3$), 6.36 (2H, t, $N-CH_2$), 8.00 (4H, m, $2CH_2$), and 8.72 (6H, t, $2COOCH_2C\underline{H}_3$); ms. m/e 383 (M^+)]. The second product (4%), a yellow oil, was shown to be the pyrroloquinone (7) [ir. 1735 (ester) and 1670 (CO) cm^{-1}; nmr. ($CDCl_3$) τ 1.84-2.22 (4H, m, Ar-H), 3.20-3.64 (4H, ABq, N-CH=CH), 5.32 (1H, s, C<u>H</u>$(COOEt)_2$), 5.80 (4H, q, $2COOC\underline{H}_2CH_3$), and 8.73 (6H, t, $2COOCH_2$-

CH_3); ms. m/e 381 (M^+)]. The third product (3.5%), a yellow crystal, was assigned as the aminoquinone (8) [mp. 143-145°; ir. 3440, 3330 (NH_2), 1739, 1705 (ester), and 1680 (CO); nmr. ($CDCl_3$) τ 1.88-2.30 (4H, m, Ar-H), 3.76 (2H, broad, NH_2, exchanged in D_2O), 4.38 (1H, s, $CH(COOEt)_2$), 5.78 (4H, q, $2COOCH_2$-CH_3), 8.72 (6H, t, $2COOCH_2CH_3$); ms. m/e 331 (M^+)]. The structures of (7) and (8) were also confirmed by their syntheses which were achieved by ready nucleophilic displacement of 3-chloro-2-bisethoxycarbonylmethyl-1,4-naphthoquinone by Δ^3-pyrroline and aqueous ammonia, respectively. We have also examined the photolysis of (1c) in various solvents. The results are summarized in Table I.

Table I. Influence of Solvent on the Photolysis of the Aminoquinone (1c)

Solvents	Reaction Time (min)	Products (%) (6c)	(7)	(8)
benzene	40	8.3	4	3.5
chloroform	40	10	3	5.8
ethanol	30	23	-	-
acetic acid	30	45	-	-
ethanol-acetic acid	30	30	-	-

In polar and acidic media, which favour the formation of a zwitter ionic species (3) and the subsequent intramolecular cyclization reaction, the only product isolated was (6c) as shown in Table I. Similar arguments may be applied to the piperidinoquinone (1d). Photolysis of (1d) in benzene gave a number of products; the starting material (1d) (3.7%), the ring closed quinone (6d) (2.9%) [mp. 155-157°; ir. 1752, 1718 (ester), and 1679 (CO) cm^{-1}; nmr. ($CDCl_3$)

τ 2.10-2.50 (4H, m, Ar-H), 5.00 (1H, d, N-CH), 5.84 (4H, q, 2COOC$\underline{H}_2$CH$_3$), 5.70-6.92 (2H, m, N-CH$_2$), 8.06-8.40 (6H, m, 3CH$_2$), and 8.80 (6H, t, 2COOCH$_2$C$\underline{H}_3$); ms. m/e 397 (M^+)], and the aminoquinone (8) (6.5%) were isolated. Photolysis in ethanol gave (1d) (19%) and (6d) (49.7%). The piperidinoquinone (1d) isolated might be resulted from the photoreduction of (1d) followed by oxidation.

From these experiments, the following mechanism appears reasonable for the formation of (6), (7), and (8). The reaction proceeds through γ-hydrogen abstraction on photo-excitation of the aminoquinone (1c) and (1d) leading to a cycloaziridinoketone intermediate (10),[7] which affords the naphthoxazoline (2). In non-polar solvents, under conditions which might be expected to favour (2), (2) undergoes hydrogen-transfer (the formation of (11)) and presumably photo-oxidation to form (7). (6) and (8) presumably arise from the intramolecular cyclization of (3) and the nucleophilic attack of water present in the solvents on (3), respectively. A zwitter ion (3) affords the intermediates (12) and (4), the latter of which may undergo re-photolysis to form (8).

In an attempt to trap an intermediate (12) in the photoreaction, (1c) was photolysed in acetic anhydride-pyridine. (6c) and the diacetate (9) were obtained (5% and 56.7% respectively). [(9), mp. 160-162°; ir. 1765 and 1720 (ester) cm^{-1}; nmr. ($CDCl_3$) τ 2.46 (4H, m, Ar-H), 5.18 (1H, d,d, N-CH), 5.70 (2H, q, COOC$\underline{H}_2$CH$_3$), 5.78 (2H, q, COOC$\underline{H}_2$CH$_3$), 6.34-6.74 (2H, m, N-CH$_2$), 7.56 (3H, s, OCOCH$_3$), 7.60 (3H, s, OCOCH$_3$), 8.02 (4H, m, 2CH$_2$), 8.66 (3H, t, COOCH$_2$C$\underline{H}_3$), and 8.74 (3H, t, COOCH$_2$C$\underline{H}_3$); ms. m/e 469 (M^+)].

We believe that this photo-induced reaction of the amino-substituted quinones may be of great utility in the simple synthesis of heterocyclic quinones. Further study on the intra- and inter-molecular nucleophilic substitution and its implications in the photolysis of the aminotoluquinones are being carried out.

Acknowledgement Our sincere thanks are offered to Prof. S. Ohki for his continuous interest and encouragement on this work.

References and Notes

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5 While our studies on the irradiation of (1a) and (1b) in nonpolar and polar media were in progress, a report from other laboratory appeared on the same subject. K. Marujama and T. Kozuka, the 36th Spring Annual Meeting of the Chemical Society of Japan, April, 1977, Osaka; Abstracts of papers, II, p. 883.

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7 S. Farid, Chem. Commun., 1970, 303. The concept of the spirocyclopropane intermediates, such as diradicals, zwitter ions, or ketones, which have arisen particularly in connection with the systems of the tert-butyl-1,4-benzoquinones, may well be applicable to a much wider range of quinones possessing an abstractable hydrogen atom at the β-position of the side-chain. However, the factors governig many of the reactions are still far from clear. Therefore, it is suggested that the formation of the oxazolines (2) proceeds by a mechanism analogous to the spirocyclopropane intermediates mentioned above.

Received, 23rd April, 1977