PHOTOLYSIS OF AMINO-SUBSTITUTED 1,4-NAPHTHOQUINONES

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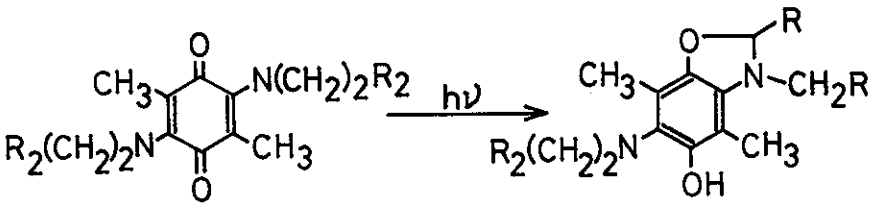
Photolysis of pyrrolidino- (3a), piperidino- (3b), and morpholino-1,4-naphthoquinone (3c) has been studied in non-polar and polar solvents. Besides the corresponding dehydro compounds (4), a number of products with degradation of the side ring via an oxazoline (16) and the zwitter ion intermediate (17) were obtained.

Several reactions involving the abstraction of a hydrogen atom from the side chains of the quinones have been reviewed previously[1] and the interest in the photochemistry of these and related systems has been continued. Considerable progress has been made in some areas, particularly in that of the tert-butyl-1,4-benzoquinones.[2] However, there are only a few examples for the amino-substituted quinones. 1,4-Benzoquinones bearing certain secondary amino-substituents (1) have been shown to photoisomerise readily in the sunlight to the benzoxazolines (2).[3] The related 2-piperidino- (3b) and 2-morpholino-1,4-naphthoquinone (3c) have been reported[4] to yield the corresponding dehydro compounds (4b and 4c), but, in view of the isolation[3] of the oxazolines from analogously-substituted 1,4-benzoquinones, further investigation is needed. We now wish to report the reinvestigation of the photolysis of amino-substituted 1,4-naphthoquinones.

Photolysis of pyrrolidino-1,4-naphthoquinone (3a)

The irradiation with a high pressure mercury lamp through a Pyrex glass of a dilute solution of 3a in benzene produced a mixture of at least five components, which were identified as the mixture (70%) of the aminoaldehyde (5a) and the



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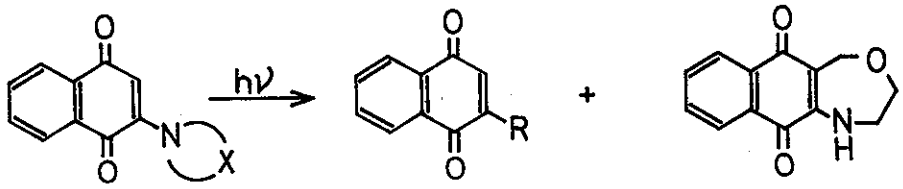
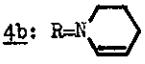


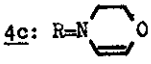
3a: X=$(CH_2)_4$

3b: X=$(CH_2)_5$

3c: X=$(CH_2)_2O(CH_2)_2$

4a: R= 

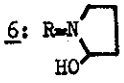
4b: R= 

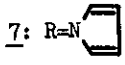
4c: R= 

5a: R=$NH(CH_2)_3CHO$

5b: R=$NH(CH_2)_4CHO$

5c: R=$NH(CH_2)_2OCH_2CHO$

6: R= 

7: R= 

8: R=NH_2

9: R=$NH(CH_2)_3COOEt$

10: R=$N=CH(CH_2)_2COOEt$

11: R=$NHCO(CH_2)_2COOEt$

12: R=$NHCO(CH_2)_3CHO$

13: R=$NH(CH_2)_2OCHO$

14: R=$NH(CH_2)_2OH$

15

carbinolamine (6), 2-(2-pyrrolinyl)-1,4-naphthoquinone (4a) (4%), 2-pyrrolyl-1,4-naphthoquinone (7) (2%), and 2-amino-1,4-naphthoquinone (8)[5] (<1%). The IR spectrum of the mixture of 5a and 6 showed the amino, hydroxy, and aldehyde absorptions, and the NMR spectrum indicated the presence of two olefinic protons, an amino, and an aldehyde group. Furthermore, the MS showed the molecular ion peak at m/e 243. 4a was unstable to acids. On treatment with SiO_2, 4a afforded the mixture of two components. 4a was also obtained in a good yield on warming the chlorobenzene solution of the components for a few minutes. Therefore, it was postulated that the one component of the mixture had the structure (5a) and the other the structure (6) in 1:1 ratio. The structures of 4a and 7 were confirmed by microanalysis and the following spectral data: [4a: mp 148-151°; IR 1660 (CO), and 1620 (C=C) cm^{-1}; NMR (C_6D_6) δ 7.02-8.30 (4H, m, Ar-H), 7.74-7.82 (1H, m, N-C<u>H</u>=CH), 5.55 (1H, s, C=CH-CO), 4.82-4.90 (1H, m, N-CH=C<u>H</u>), 2.77 (2H, t, N-CH_2), and 1.73-1.95 (2H, m, N-$CH_2C\underline{H}_2$); MS m/e 225 (M^+). 7: mp 195-196°; IR 1670, 1650 (CO), and 1610 (C=C) cm^{-1}; NMR ($CDCl_3$) δ 7.73-8.26 (4H, m, Ar-H), 7.31 (2H, s, 2N-C<u>H</u>=CH), 6.84 (1H, s, N-C=CH-CO), and 6.41 (2H, s, 2N-CH=C<u>H</u>); MS m/e 223 (M^+)].

While our studies on the irradiation of 3a in nonpolar media were in progress, a report from other laboratory appeared on the same subject. Maruyama, et al.[6] obtained the same products, 4a, 5a, and 7, by the photolysis of 3a.

Photolysis of 3a in ethanol followed by preparative layer chromatography afforded 2-(3-ethoxycarbonylpropylamino)-1,4-naphthoquinone (9) (30.8%) [mp 123-124°; IR 3340 (NH), 1710 (ester), 1660, and 1620 (CO) cm^{-1}; NMR ($CDCl_3$) δ 7.41-8.18 (4H, m, Ar-H), 6.10 (1H, s, NH, disappeared with D_2O), 5.76 (1H, s, N-C=CH-CO), 4.18 (2H, q, $COOC\underline{H}_2CH_3$), 3.25 (2H, q, N-CH_2), 2.43 (2H, t, CH_2CO), 1.98-2.16 (2H, m, $CH_2C\underline{H}_2CH_2$), and 1.25 (3H, t, $COOCH_2C\underline{H}_3$); MS m/e 287 (M^+)], 2-(3-ethoxycarbonylpropylideneamino)-1,4-naphthoquinone (10) (5.9%) [oil; IR 1720 (ester), 1685, and 1670 (CO) cm^{-1}; NMR ($CDCl_3$) δ 7.78-8.24 (4H, m, Ar-H), 7.38 (1H, s, N-C=CH), 5.94

(1H, m, N=CH), 3.51 (2H, q, $COOCH_2CH_3$), 2.13-2.83 (4H, m, $COCH_2CH_2$), and 1.17 (3H, t, $COOCH_2CH_3$); MS m/e 285 (M^+)], and 2-(3-ethoxycarbonylpropionylamino)-1,4-naphthoquinone (11) (10.8%) [mp 142-144°; IR 3250 (NH), 1721 (ester), 1670, and 1638 (CO) cm^{-1}; NMR ($CDCl_3$) δ 8.65 (1H, broad, NH, disappeared with D_2O), 7.73-8.21 (4H, m, Ar-H), 7.87 (1H, s, N-C=CH), 4.18 (2H, q, $COOCH_2CH_3$), 2.77 (4H, s, $COCH_2CH_2CO$), and 1.27 (3H, t, $COOCH_2CH_3$); MS m/e 301 (M^+)] along with a trace of 7 and 8. 9 was alternatively prepared from 1,4-naphthoquinone and ethyl γ-aminobutyrate.

Photolysis of piperidino-1,4-naphthoquinone (3b)

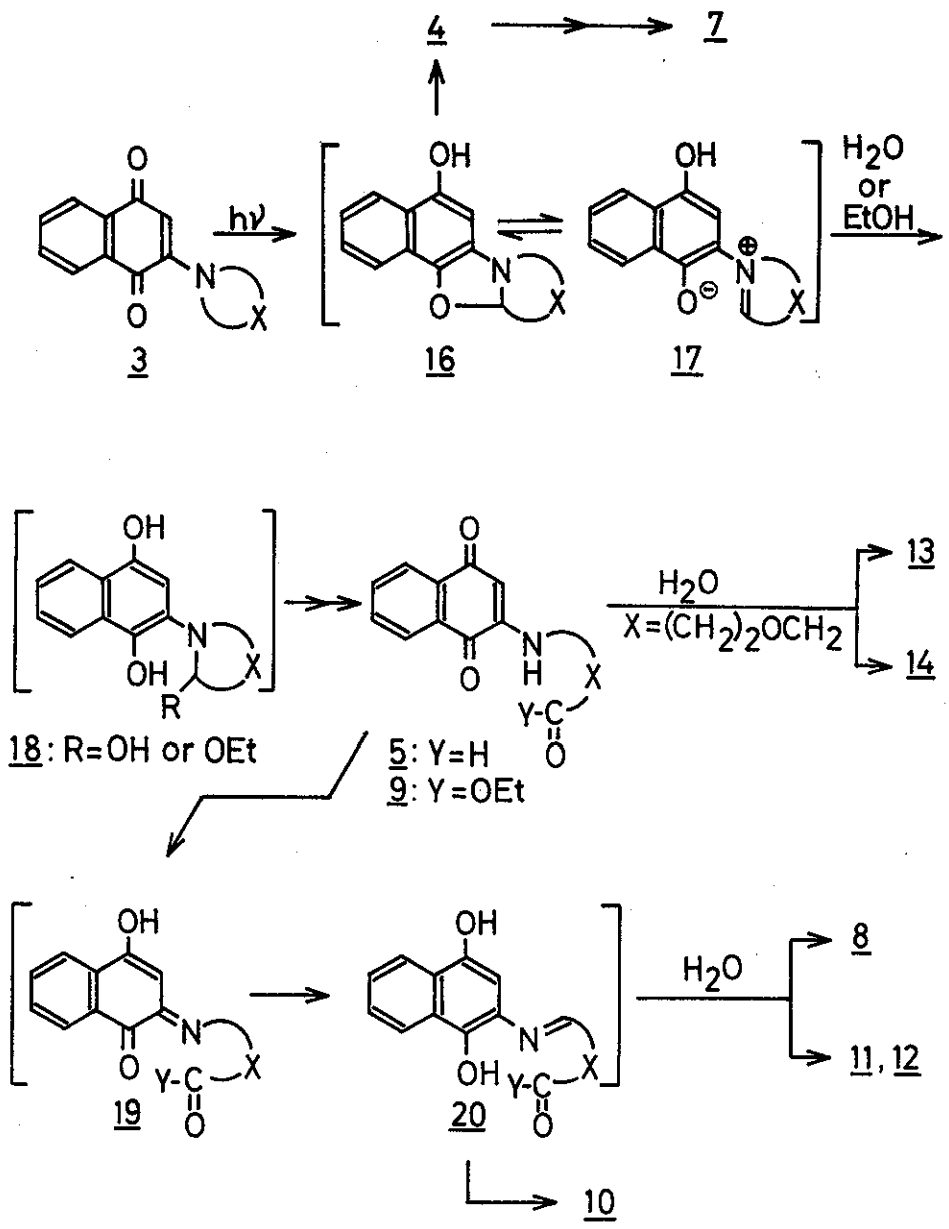
The irradiation of a solution of 3b in benzene produced a number of products, four of which were identified as 2-(2,3-dehydropiperidino)-1,4-naphthoquinone (4b)[4] (6.5%), 2-(4-formylbutylamino)-1,4-naphthoquinone (5b) (15.1%) [mp 118-119°; IR 3340 (NH), 2865, 1720 (CHO), 1660, and 1620 (CO) cm^{-1}; NMR (C_6D_6) δ 9.19 (1H, s, CHO), 7.81-8.31 (4H, m, Ar-H), 5.66 (1H, s, N-C=CH), 5.39 (1H, broad, NH, disappeared with D_2O), 2.29 (2H, q, NCH_2), 1.53-1.67 (2H, m, CH_2CHO), and 0.80-1.04 (4H, m, CH_2CH_2); MS m/e 257 (M^+)], 2-(4-formylbutyrylamino)-1,4-naphthoquinone (12) (4.5%) [mp 119-121°; IR 3350 (NH), 2850, 1710 (CHO), 1662, and 1635 (CO) cm^{-1}; NMR ($CDCl_3$) δ 9.76 (1H, s, CHO), 8.32 (1H, broad, NH, disappeared with D_2O), 7.46-8.12 (4H, m, Ar-H), 7.79 (1H, s, N-C=CH), 2.57 (4H, q, $COCH_2CH_2$), and 1.96-2.05 (2H, m, $CH_2CH_2CH_2$); MS m/e 271 (M^+)], and 8 (2.8%).

Photolysis of morpholino-1,4-naphthoquinone (3c)

Irradiation of a solution of 3c in absolute benzene afforded only one product (4c) in 11.6% yield, which corresponds to the substance obtained by Fokin, et al.[4] On the other hand, when aqueous benzene was used as the solvent, a number of products were formed including 4c (6.8%) and 8 (trace). The irradiated solution was subjected to high performance l.c. on a silicagel column[7]; Five products, in order of A, B, C, D, and E, and traces of other products including 8 were obtained. The product A was found to be 4c. The products C (1.1%), D (6.7%), and E (4.0%)

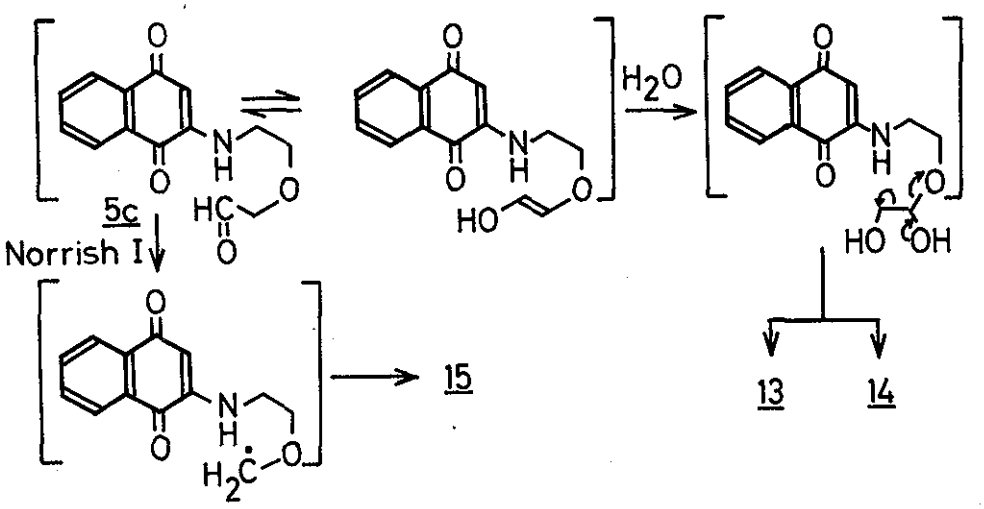
were identified as 2-(2-formoxyethylamino)-1,4-naphthoquinone (13), 2-(2-formylmethoxyethylamino)-1,4-naphthoquinone (5c), and 2-(2-hydroxyethylamino)-1,4-naphthoquinone (14) on the basis of the microanalysis and the following spectral data. [5c: oil; IR 3310 (NH), 2850, 1718 (CHO), and 1665 (CO) cm^{-1}; NMR (CD_3COCD_3) δ 9.74 (1H, s, CHO), 7.52-8.17 (4H, m, Ar-H), 6.80 (1H, broad, NH, disappeared with D_2O), 5.80 (1H, s, N-C=CH), 3.89 (4H, m, CH_2OCH_2), and 3.50 (2H, m, NCH_2); MS m/e 259 (M^+). 13: mp 168-170°; IR 3310 (NH), 1700 (CHO), and 1662 (CO) cm^{-1}; NMR ($CDCl_3$) δ 7.52-8.15 (4H, m, Ar-H), 8.11 (1H, s, CHO), 5.78 (1H, s, N-C=CH), 6.07 (1H, broad, NH, disappeared with D_2O), 4.43 (2H, t, OCH_2), and 3.50 (2H, q, NCH_2); MS m/e 245 (M^+). 14: mp 158-160°; IR 3330 (NH and OH) and 1674 (CO) cm^{-1}; NMR (CD_3COCD_3) δ 7.71-8.14 (4H, m, Ar-H), 6.68 (1H, broad, NH), 5.81 (1H, s, N-C=CH), 4.17 (1H, broad, OH), 3.90 (2H, m, OCH_2), and 3.44 (2H, m, $N-CH_2$); MS m/e 217 (M^+)]. The structure of 14 was also confirmed by an independent synthesis of 1,4-naphthoquinone with ethanolamine. Compound B (mp 154-155°, obtained in 2.2% yield), which indicated the absence of olefinic protons and the presence of six methylene protons in the NMR spectrum and displayed the secondary amine absorption in the IR spectrum and the molecular weight of 222 (MS), was deduced to be 1,4-perhydrooxazepino[3,4-b]-1,4-naphthoquinone (15).

The interrelationship of the products obtained in the photochemical sequence may be depicted in Scheme I. These results are best explained by considering 16 and 17 as the intermediates. The first step is an intramolecular hydrogen abstraction. Subsequently the diradical may lead to the naphthoxazoline (16) via spiroaziridine species[3b] *by hydrogen transfer, ring closure, and aromatisation.* 16 undergoes hydrogen transfer followed by oxidation to form 4. Further, 4a affords 7 by the re-oxidation. Whereas, the presence of polar solvents such as ethanol and a small amount of water in the solvent allows the formation of an equilibrium mixture of 16 and the zwitter ion intermediate (17). The nucleophilic


4
7
hν
3
16
17
H2O
or
EtOH
18: R=OH or OEt
5: Y=H
9: Y=OEt
H2O
X=(CH2)2OCH2
13
14
19
20
H2O
8
11, 12
10

Scheme I

attack of the water present in the solvent or ethanol on 17 forms 18, which leads to 5 followed by oxidation (the formation of 6) competing with degradation of the ring or 9 followed by oxidation and re-photolysis. The formation of 10, 8, and the oxidation product (11 or 12) may be explained by the intervention of the quinol 20[8] via 19. Intermolecular substitution of water and photo-oxidation yield 11 or 12 and trans-alkylidenation followed by oxidation gives 8. 13, 14, and 15 presumably arise from the reaction course as shown in Scheme II.



Scheme II

These investigations pointed to the formation of a zwitter ion intermediate (17) followed by the intermolecular nucleophilic attack to give the ring-opened aminoquinones (5 and 9) as main products. Therefore, the photolysis of the substituted aminoquinones possessing sufficient nucleophilic character followed by its ring closure would provide a versatile pathway to a number of heterocyclic quinones.

For the purpose of the simple synthesis of heterocyclic quinones, its implication is being carried out and will be reported elsewhere.

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References and Notes

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