The Intramolecular Hydrogen Abstraction Reaction in the Photolysis of Aminated 1,4-Naphthoquinones

Kazuhiro MARUYAMA, Tadashi KOZUKA, and Tetsuo OTSUKI

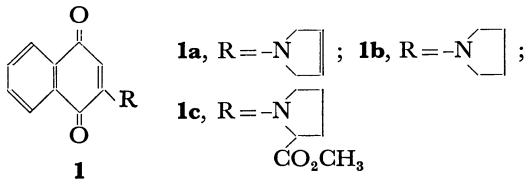
Department of Chemistry, Faculty of Science, Kyoto University, Kyoto 606

(Received February 14, 1977)

Photolysis of aminated 1,4-naphthoquinones **1a**—**c** in liquid phase was investigated. After photolysis and successive autoxidation, 2-(3-pyrrolin-1-yl)-1,4-naphthoquinone **1a** gave 2-(1-pyrrolyl)-1,4-naphthoquinone **3** quantitatively. However, in the reaction, 2-(1-pyrrolydinyl)-1,4-naphthoquinone **1b** and 2-(2-methoxycarbonyl-1-pyrrolidinyl)-1,4-naphthoquinone **1c** afforded the corresponding hetero-ring opened products; 2-(4-oxobutylamino)-1,4-naphthoquinone **5** and 2-(4-methoxycarbonyl-4-oxobutylamino)-1,4-naphthoquinone **8** in good yields. Possible mechanisms for the formation of **3**, **5**, and **8** are presented.

The photochemistry of aminoquinones having a β-aminoenone grouping (–N–C=C–C=O) in the molecule is of interest from the synthetic viewpoint of antibiotics such as mytomycin and streptrigrin, but only a few investigations have been made.[1-3]

We describe herewith the synthesis and photochemistry of quinones **1**.

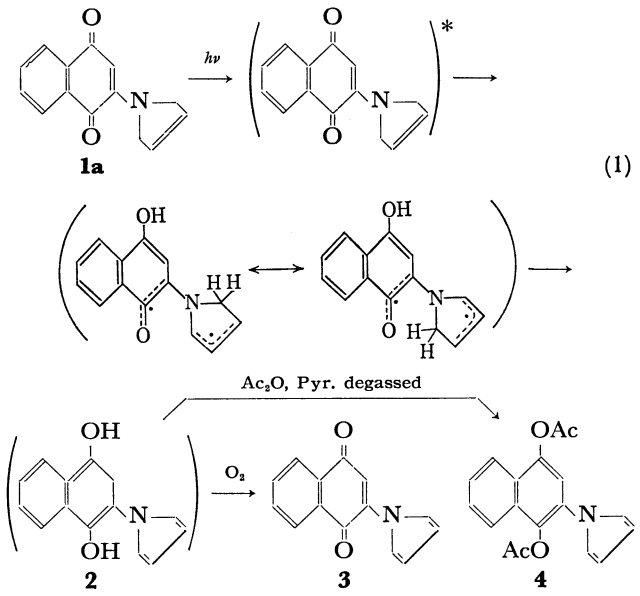


Results and Discussion

Compounds **1a**—**c** were prepared from the corresponding amines and 1,4-naphthoquinone by standing overnight in methanol. After purification by column chromatography and recrystallization, the spectral data of all the aminated 1,4-naphthoquinones were found to be consistent with the assigned structures.

Photolysis of 2-Aminated 1,4-Naphthoquinones ***1a—c.*** Irradiation of a solution of the quinone **1a** (8.88×10^{-3} M) in benzene for 1 h and bubbling the resulting solution with air for several minutes gave quinone **3** quantitatively. The ^{1}H-NMR spectrum ($CDCl_3$) of **3** showed two characteristic triplets, centered at 7.31(2H) and 6.42(2H) ppm. The quinone vinyl singlet, 6.84(1H) ppm, shifted to the lower field, suggesting the presence of 1-substituted pyrrole ring. Compound **3** was identified by comparison with the authentic sample prepared by dehydrogenation of **1a** with Pd–C.

The photochemical process was followed by measuring the UV spectrum of degassed benzene solution of **1a** during the course of irradiation. As the reaction proceeds the absorbance of the peak at 276 and 460 nm diminishes and the peak at 318 and 332 nm increases, exhibiting isosbestic points at 302 and 342 nm (Fig. 1). On the other hand, we examined the same reaction by ^{1}H-NMR spectrometry irradiating of a degassed C_6D_6 solution of **1a**. The examination revealed that the reaction proceeded quite smoothly. As the methylene and olefinic protons of 3-pyrroline ring diminish, two characteristic triplets due to the pyrrole ring protons and phenolic hydroxy protons (2H) grow. This indicates that an unstable compound **2** is produced in the reaction. Unstable **2** was trapped as its diacetate **4** by treatment with acetic anhydride in pyridine under degassed conditions. It was confirmed that the change in concentration of reactant **1a** (<0.2 M) gave no essential change on the course of reaction. Thus, the reaction of **1a** to **2** can be explained by a mechanism involving initial intramolecular hydrogen abstraction by carbonyl, followed by subsequent free rotation of C–N bond and secondary intramolecular hydrogen transfer as shown by Eq. 1.



Aminated quinone **1b** dissolved in benzene (2.20×10^{-3} M, for 1.5 h) is also highly photosensitive. After the usual work-up **1c** gave **5** (78%), together with small amount of **3** (2%) and **6** (3%). The structure of **5** was compatible with its spectral data; ν_{NH}: 3340, ν_{CO}: 1720 cm^{-1}; ^{1}H-NMR: 6.00 (br s, 1H, NH), 9.77 (s, 1H, CHO) ppm. Treatment of **5** with methanolic hydrogen chloride yielded acetal **7**. Structure **3** was confirmed by the spectral data and comparison with the authentic sample. The structure **6** was assigned on the basis of the spectral data, but compound **6** is unstable against light in solution. When the solution, after UV irradiation of **6** in chloroform, was left to stand overnight under contact with air, the color of solutions turned light yellow from purple red, the absorption spectrum of **6**

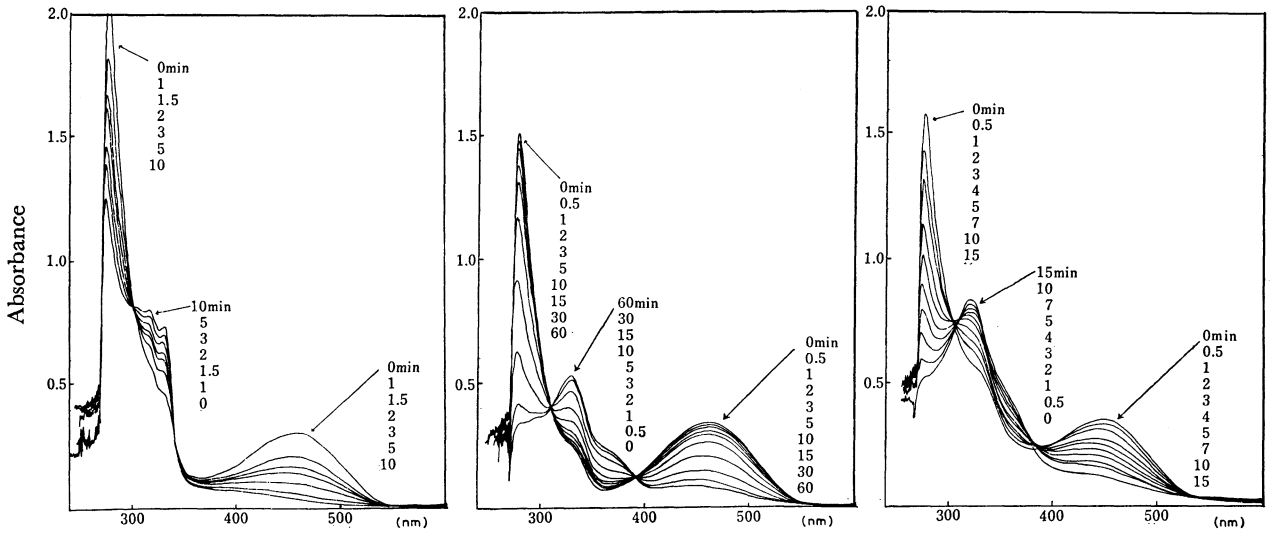
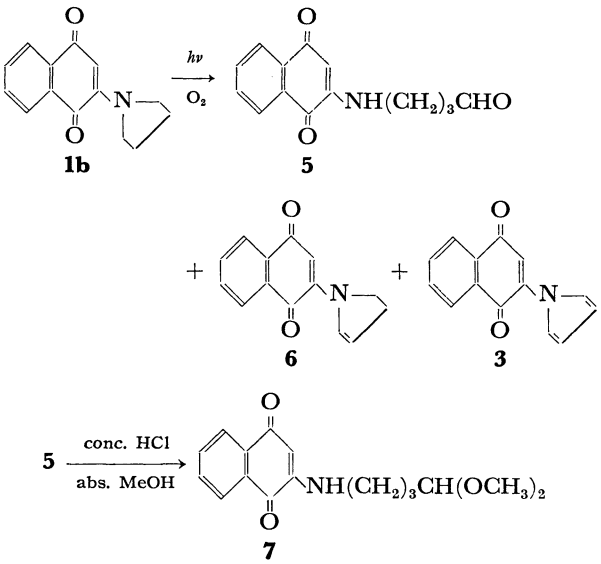


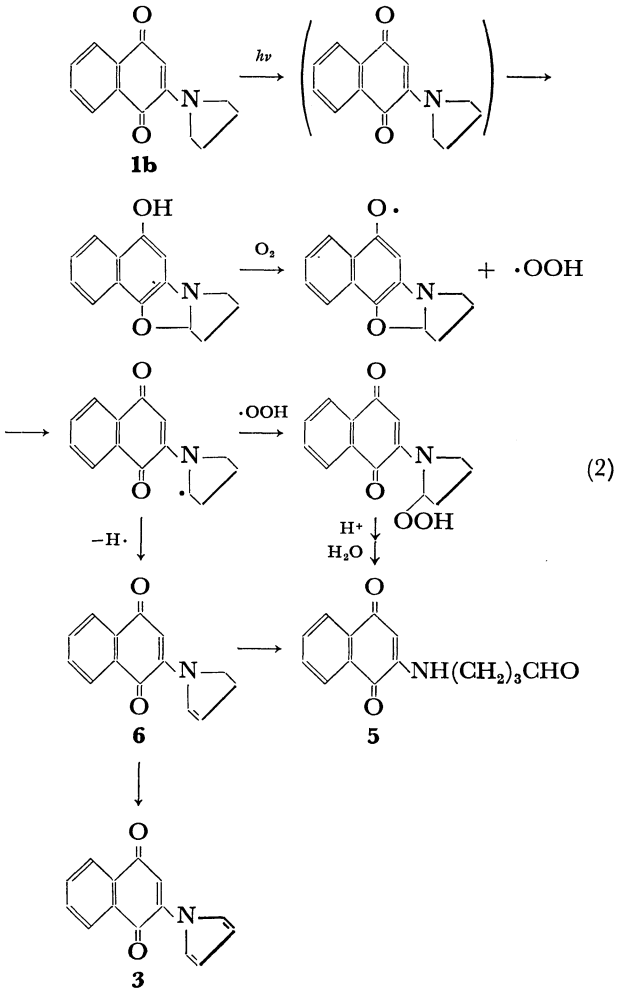
Fig. 1. Fig. 2. Fig. 3.

UV spectra of **1a**—**c**(benzene), before irradiation and during irradiation. A strictly degassed solution of **1a**—**c** was irradiated in a UV cell (1 cm × 1 cm) by high pressure Hg arc lamp (300 W) through VY-42 glass filters (1 cm × 3). In this experiment a glass filter was employed to eliminate the light of wavelength shorter than 400 nm.

(λ_{max}: 520 nm) disappearing, and new peaks corresponding to **3** and **5** appearing at 256, 270, and 441 nm. Presumably compound **6** changes to **3** and **5** by photolysis followed by air oxidation.



Photolysis of **1b** in degassed benzene was followed by UV spectroscopy. The orange yellow solution finally became colorless. Two isosbestic points at 309 and 392 nm appeared, indicating that the reaction is simple and clean (Fig. 2). The first order kinetic plot of the reaction showed a straight line (Fig. 4). When the reaction vessel was opened and aerated with bubbling of air, the solution turned yellow. The UV spectrum of the resulting solution was essentially the same as that of the benzene solution of **5**, λ_{max} (benzene): 278 and 440 nm (log ε: 4.24 and 3.52). Apparent maximum absorption of UV spectrum of the final solution is at



(2)

λ_{max} (benzene): 330 nm (log ε: *ca.* 3.8). From the results the photolysis of **1b** and successive air-oxidation

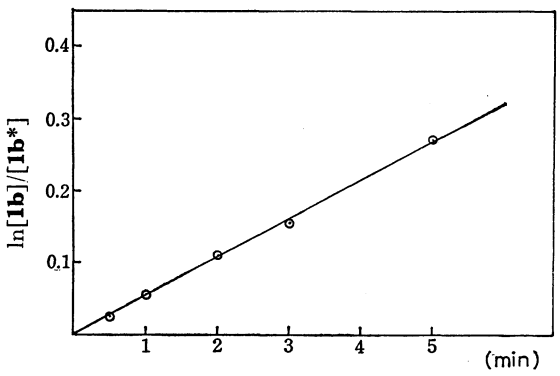
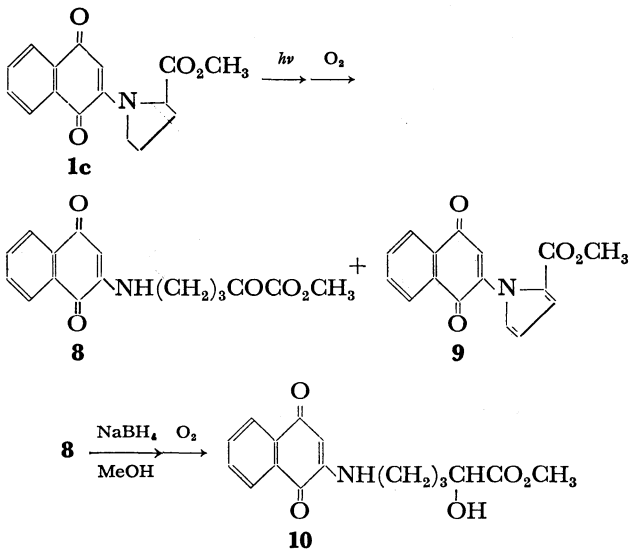


Fig. 4. First order kinetic plot in the photolysis of **1b** (solvent: benzene).
[**1b**]; absorbance(at 460 nm) before irradiation of **1b**.
[**1b***]; absorbance(at 460 nm) during irradiation of **1b**.

can be formulated as shown in Eq. 2. However, the detailed mechanism for the hetero-ring opening still remains unclarified.

Compounds **8** and **9** were obtained in 30 and 6%, respectively, after irradiation of **1c** (2.50×10^{-3} M) in benzene for 3 h and subsequent aeration. Structures **8** and **9** were assigned on the basis of their spectral data. Compound **8** was reduced to **10** by treatment with sodium borohydride in methanol.

Photolysis of **1c** in deaerated benzene was also followed by UV spectroscopy. No isosbestic point was observed during the course of reaction, suggesting that the reaction is complex (Fig. 3). This is in line with the lower yield of the identified products.



Experimental

Photolysis of ***1a***. A benzene solution of 2-(2-pyrrolin-1-yl)-1,4-naphthoquinone **1a**[4] (8.88×10^{-3} M) was irradiated without degassing with a high pressure Hg arc lamp through water layer. Aeration of the solution after 1 h gave 2-(1-pyrrolyl)-1,4-naphthoquinone **3** quantitatively; mp 164.5—164.7 °C. IR (KBr); 1670 cm^{-1}. Mass: *m/e*=223 (M^+). ^{1}H-NMR ($CDCl_3$); 6.43 (t, 2H), 6.84 (s, 1H), 7.31 (t, 2H), 7.71, 8.08 (m, 4H) ppm. UV max ($CHCl_3$); 256, 305, 395 nm (log ε: 4.31, 3.95, 3.54). Found: C, 75.03; H, 3.87; N, 6.09%. Calcd for $C_{14}H_9O_2N$: C, 75.32; H, 4.06; N, 6.28%.

During the course of irradiation the ^{1}H-NMR spectra of **1a** in degassed C_6D_6 indicated the formation of single product; *i.e.*, highly oxygen-sensitive compound **2**, which was identified by the subsequent acetylation with acetic anhydride–pyridine under degassed conditions as diacetate **4** (86%); mp 138—139 °C. IR (KBr); 1755 cm^{-1}. Mass: *m/e*=309 (M^+). ^{1}H-NMR ($CDCl_3$): 2.30 (s, 3H), 2.46 (s, 3H), 6.32 (t, 2H), 6.95 (t, 2H), 7.37, 7.57, 7.91 (m, 5H) ppm. Found: C, 69.61; H, 4.94; N, 4.68%. Calcd for $C_{18}H_{15}O_4N$: C, 69.89; H, 4.89; N, 4.53%.

Photolysis of ***1b***. By irradiating (1.5 h) of dry benzene solution of 2-(1-pyrrolidinyl)-1,4-naphthoquinone **1b**[5] (2.20×10^{-3} M) with a high pressure Hg arc lamp through a filter solution of 5,7-dimethyl-2*H*-3,6-dihydro-1,4-diazepine perchlorate, three products **5**, **6**, and **3** were isolated: 2-(4-oxobutylamino)-1,4-naphthoquinone **5** (78%): mp 146—147 °C. IR (KBr); 3340, 2825, 2725, 1680 cm^{-1}. Mass: *m/e*=243 (M^+). ^{1}H-NMR ($CDCl_3$); 2.04 (m, 2H), 2.63 (t, 2H), 3.23 (m, 2H), 5.69 (s, 1H), 6.00 (br s, 1H), 7.64, 8.02 (m, 4H), 9.77 (s, 1H) ppm. UV max ($CHCl_3$); 243, 270, 337, 441 nm (log ε: 4.07, 4.33, 3.50, 3.51). Found: C, 68.60; H, 5.33; N, 5.30%. Calcd for $C_{14}H_{13}O_3N$: C, 69.12; H, 5.39; N, 5.76%. 2-(2-Pyrrolin-1-yl)-1,4-naphthoquinone **6** (3%); mp 141—143 °C. IR (KBr); 1660, 1613, 1586, 1550 cm^{-1}. Mass: *m/e*=225 (M^+). ^{1}H-NMR ($CDCl_3$); 2.72 (tdd, 2H), 3.79 (t, 2H), 5.46 (m, 1H), 5.73 (s, 1H), 7.88 (m, 1H), 7.68, 8.01 (m, 4H) ppm. UV max ($CHCl_3$); 243, 250, 273, 520 nm (log ε: 4.08, 4.09, 4.29, 3.67). 2-(1-Pyrrolyl)-1,4-naphthoquinone **3** (2%): *vide supra*.

Acetalization of **5** gave 2-(4,4-dimethoxybutylamino)-1,4-naphthoquinone **7** (75%): mp 91—93 °C. IR (KBr); 3330, 1685 cm^{-1}. ^{1}H-NMR ($CDCl_3$); 1.74 (m, 4H), 3.22 (m, 2H), 3.35 (s, 6H), 4.38 (t, 1H), 5.71 (s, 1H), 6.06 (br s, 1H), 7.66, 8.05 (m, 4H) ppm. UV max ($CHCl_3$); 242, 271, 330, 440 nm (log ε 3.79, 4.06, 3.23, 3.20).

Photolysis of ***1c***. A chloroform solution of 2-(2-methoxycarbonyl-1-pyrrolydinyl)-1,4-naphthoquinone **1c**[6] (2.50×10^{-3} M) was irradiated with a high pressure Hg arc lamp through a filter solution of copper(II) sulfate. After irradiation for 3 h, two products, **8** and **9**, were isolated: 2-(4-Methoxy carbonyl-4-oxobutylamino)-1,4-naphthoquinone **8** (30%) mp 181—183 °C. IR (KBr); 3330, 1730, 1676 cm^{-1}. Mass: *m/e*=301 (M^+). ^{1}H-NMR ($CDCl_3$); 2.01 (m, 2H), 3.04 (t, 2H), 3.30 (q, 2H), 3.92 (s, 3H), 5.78 (s, 1H), 6.00 (br s, 1H), 7.07, 8.08 (m, 4H) ppm. UV max ($CHCl_3$); 242, 270, 331, 444 nm (log ε: 4.11, 4.35, 3.53, 3.49). Found: C, 63.91; H, 4.87; N, 4.69%. Calcd for $C_{16}H_{15}O_2N$: C, 63.78; H, 5.02; N, 4.65%. 2-(2-Methoxycarbonyl-1-pyrrolyl)-1,4-naphthoquinone **9** (6%): mp 116—120 °C. IR (KBr); 1708, 1687 cm^{-1}. Mass: *m/e*=281 (M^+). ^{1}H-NMR ($CDCl_3$); 3.74 (s, 3H), 6.40 (m, 1H), 6.90 (m, 1H), 7.12 (m, 1H), 6.86 (s, 1H), 7.79, 8.14 (m, 4H) ppm. UV max ($CHCl_3$); 248, 254, 298 (log ε: 4.20, 4.20, 3.63).

The reduction of **8** with sodium borohydride gave 2-(4-hydroxy-4-methoxycarbonylbutylamino)-1,4-naphthoquinone **10** (74%): mp 126—127 °C. IR (KBr); 3515, 3345, 1735, 1725, 1680 cm^{-1}. Mass: *m/e*=303 (M^+). ^{1}H-NMR ($CDCl_3$); 1.86 (m, 4H), 3.26 (q, 2H), 3.81 (s, 3H), 4.24 (br s, 1H), 5.72 (s, 1H), 6.06 (br s, 1H), 3.05 (br s, 1H), 7.65, 8.04 (m 4H) ppm. UV max ($CHCl_3$); 242, 271, 330, 445 (log ε: 4.19, 4.42, 3.69, 3.63).

References

1) E. P. Fokin and E. P. Prudchenko, *Izv. Sib. Otd. Akad.*

Nauk. SSSR, Ser. Khim. Nauk, **1966**, (2), 98; *Chem. Abstr.*, **66**, 37809 (1967). E. P. Fokin and A. M. Detsina, *ibid.*, **1969**, (3), 95; *Chem. Abstr.*, **72**, 12500n (1970).

2) D. W. Cameron and R. G. F. Giles, *J. Chem. Soc., C*, **1968**, 1461.

3) R. G. F. Giles, *Tetrahedron Lett.*, **1972**, 2253.

4) Mp 180.5—181.5 °C.

5) Mp 164—165 °C.

6) Mp 149.5—150.0 °C.