

# Photoreaction of Benzofuroxan

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Benzofuroxan **5**, upon irradiation using a high pressure mercury lamp with a Pyrex filter in acetonitrile containing a little water, afforded 1*H*-azepine-2,7-dione **6**. The initial stage of this reaction would be formation of a highly reactive intermediate possessing two nitrile oxide functions. On the other hand, when compound **5** was irradiated using a low pressure mercury lamp in acetonitrile containing a little water, it afforded 6*H*-furazano[4,5-*c*]carbazole 3-oxide **11** and compound **6**. The structure of compound **11** was determined by an X-ray structural analysis. In the presence of an aromatic hydrocarbon, the formation of compound **11** was decreased and that of compound **6** was increased. Mechanistic studies on the photoreaction suggest that the photosensitized formation of compound **6** with the aromatic hydrocarbon may be carried out by the reabsorption of the fluorescence of it near 365 nm and the presence of it may quench the formation of compound **11**.

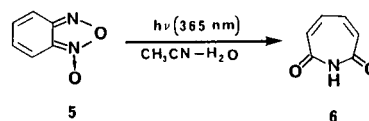
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As a part of benzofuroxan and benzofurazan chemistry, the photoreaction of benzofuroxan was examined using a high or a low pressure mercury lamp. We have already reported the reactions of benzofuroxan with 1,3-diketones to give the corresponding quinoxaline di-*N*-oxides catalyzed by silica gel [1] or molecular sieve [2] and the examination of the biological activity of benzofurazans using *Escherichia coli* [3]. It is known that benzofurazan **1** on irradiation with ultraviolet light gives a reactive nitrile oxide intermediate. The nitrile oxide reacts with triethyl phosphite to produce 1,4-dinitrile derivatives **2** [4]. Irradiation of **1** in benzene yields an azepine **3** and in methanol yields the corresponding *N*-substituted carbamate **4** [5]. The photoreaction of **1** and dimethyl acetylenedicarboxylate yields a mixture of isomeric isoxazoles [6].

The work reported here was undertaken in order to make clear the photochemical reactivity of compound **5**. Compound **5**, upon irradiation using a high pressure mercury lamp with a Pyrex filter in dry acetonitrile, reacted very little but the photolysis of **5** when it was carried out in the presence of acetonitrile containing a little water, we

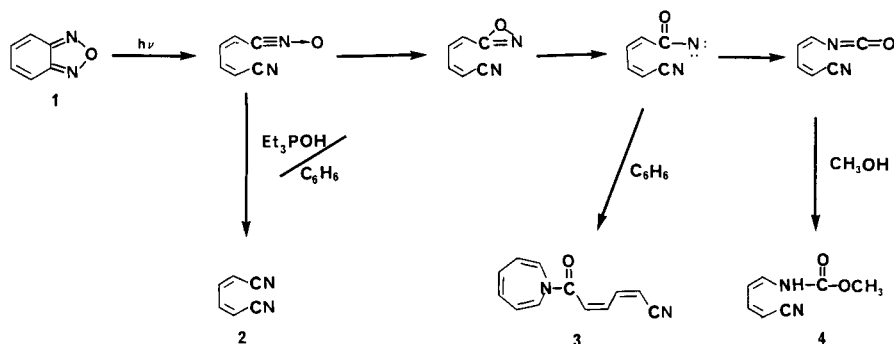
could isolate 1*H*-azepine-2,7-dione **6** from the photoproducts.

Scheme II

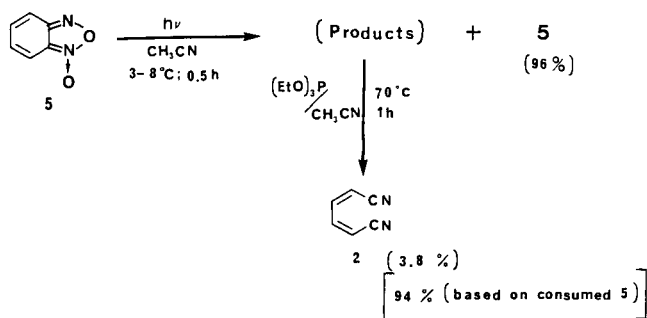


In order to make clear the formation mechanism of **6**, in the initial stage of the photoreaction, we examined the deoxygenation of the first-formed product. We allowed compound **5** to irradiate in acetonitrile without water at low temperature (3~8°), so that the photoreaction proceeds as slowly as possible to control a transformation of the first-formed product into another compound. After irradiation for 0.5 hour, we allowed it to heat at 70° for one hour, then an aliquot of the photoreaction mixture was placed in the presence of an oxygen-acceptor such as triethylphosphite, and *cis-cis*-1,4-dicyanobuta-1,3-diene **2** was obtained in 94% yield based on the amount of compound **5** consumed.

Scheme I

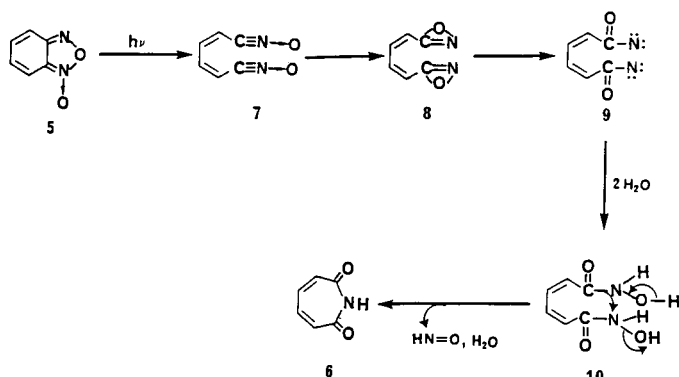


Scheme III



It can therefore be presumed that the irradiation of compound **5** gives probably buta-1,3-diene-1,4-dinitrile oxide **7** by initial N-O bond cleavage, such as compound **1**, and then it transforms into an intermediate of the type of dinitrene **9** via the dioxazirene **8**, which is added two molecules of water contained in the solvent to form **10**, followed by the elimination of nitroxyl and water. An instance of a reaction of carbonylnitrene with water has been reported. The photolysis of benzazide in the presence of water gave benzhydroxamic acid in 9% yield [7].

Scheme IV



On the other hand, the photolysis of **5** using a low pressure mercury lamp in acetonitrile:water (9:1, v/v) gave 6*H*-furazano[4,5-*c*]carbazole 3-oxide **11**, which must have formed by the condensation of two molecules of **5**, and compound **6** obtained by photolysis of **5** by 365 nm radiation.

Scheme V

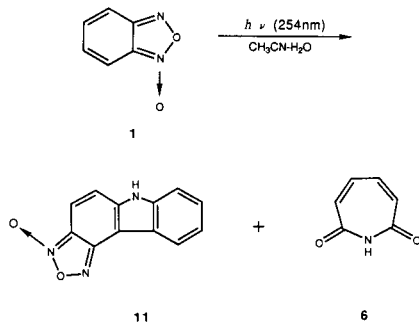


Table 1

Yields of Product on Photolysis of Compound **5** at 365 nm

Solvent	Reaction Time (h)	Yield of Product (%)	Conversion (%)
dry CH <sub>3</sub> CN	30	trace	6
CH <sub>3</sub> CN-H <sub>2</sub> O(95:5)	30	13	
	100	25	72
(Dark)			
CH <sub>3</sub> CN-H <sub>2</sub> O(95:5)	30	0	0

Table 2

Yields of Products on Photolysis of Compound **5** in a Merry-go-round Type Apparatus at 254 nm

Additive	Yield of product (%) [a]		Conversion (%)
	Compound <b>11</b>	Compound <b>6</b>	
—	0.7	trace	46
naphthalene	trace	8.6	45
fluorene	trace	9.2	58
phenanthrene	trace	8.8	45

[a] Yields based on consumed **5**.

Table 3

Yields of Products on Photolysis of Compound **5** in an Immersion Unit Type Apparatus at 254 nm

Additive	Yield of product (%) [a]		Conversion (%)
	Compound <b>11</b>	Compound <b>6</b>	
—	13.6	3.3	39
fluorene	trace	16.7	39

[a] Yields based on consumed **5**.

In the experiment of photolysis without any photosensitizer, the chief product was **11**. However, when the photoreaction of **5** in the presence of an aromatic hydrocarbon, such as naphthalene, fluorene or phenanthrene, was examined, the formation of **11** was decreased and that of **6** was increased. The total yield was little different under either of the conditions for photolysis of **5**, however, the formation ratio of product **11** and **6** was considerably different under the two sets of conditions, as shown in Table 3. In the reaction without any photosensitizer the ratio of formation between **11** and **6** was 4 to 1, while in the presence of an aromatic hydrocarbon the product was mostly **6**.

In order to make clear the effect of the aromatic hydrocarbon in the photoreaction, we measured the fluorescence spectra of phenanthrene to which **5** was added in various ratios. When phenanthrene absorbs light at 254 nm which is the same wave-length as the light from a low

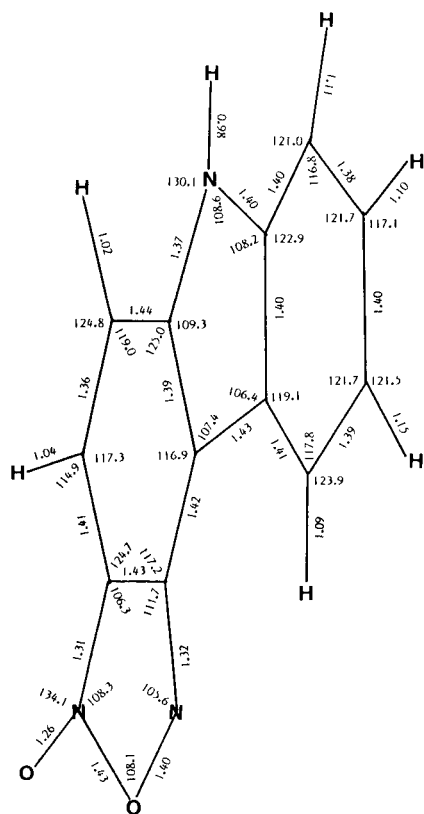


Fig. 1. X-ray crystal structure of 11

pressure mercury lamp, it fluoresces at 350, 366 and 383 nm. On the other hand, phenanthrene containing **5** exhibited its changed fluorescence spectrum. It is noteworthy that the fluorescence spectrum was particularly quenched at 365 nm. The wave length, 365 nm, agrees very closely with the absorption band in the ultraviolet spectrum of **5** (Figure 2).

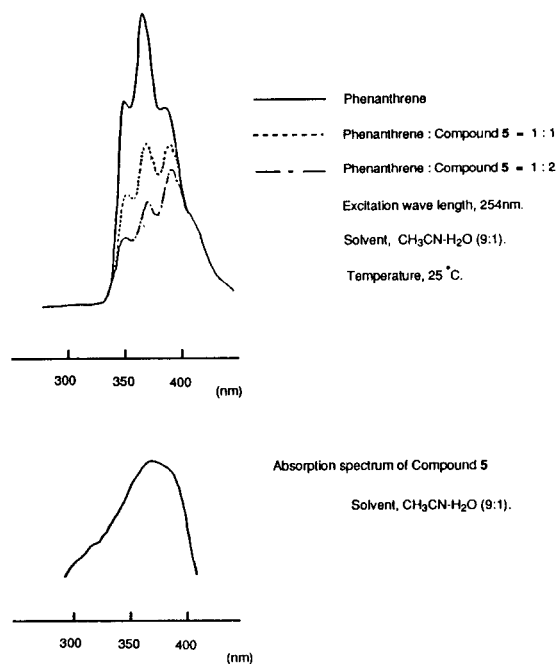


Fig. 2. Variation of the fluorescence of photosensitizer with compound 5

The following mechanism has been suggested to account for their interesting behavior on the fluorescence spectra. The photosensitized formation of **6** from **5** in the presence of the aromatic hydrocarbon was carried out by

## Scheme VI

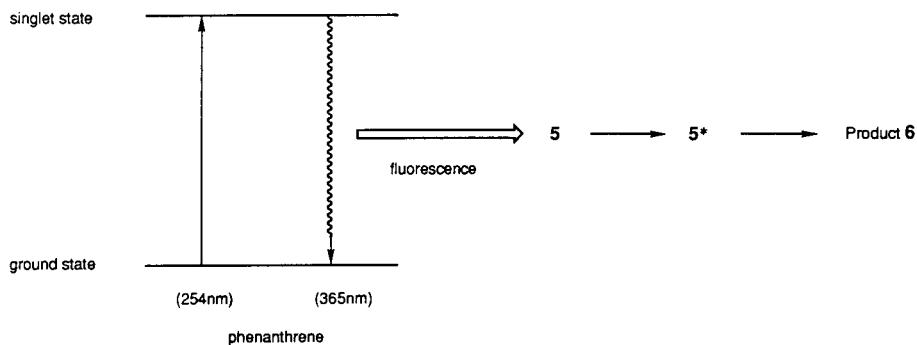
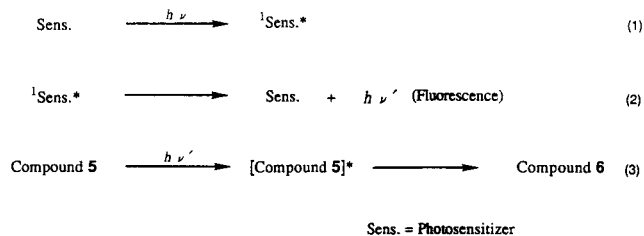


Fig. 3. Mechanism of the photosensitized formation of compound 6 by phenanthrene

the reabsorption of the fluorescence near 365 nm, and on the other hand the formation of compound **11** was quenched because of the absorption of light at 254 nm (Figure 3).

## EXPERIMENTAL

Compound **5** was obtained from Aldrich Chemical Company, Inc, U.S.A., and was purified by column chromatography and recrystallization from *n*-hexane. *Cis-cis*-1,4-dicyanobuta-1,3-diene was prepared as previously described [4]. The photoreactions were carried out with Nikko Sekiei Works photochemical reactor. Melting points were determined with a Yanagimoto micromelting point apparatus and are uncorrected. The ir spectra were recorded on a Jasco IR-810 spectrometer. The <sup>1</sup>H and <sup>13</sup>C nmr spectra were recorded on a JNM-EX 90 FT NMR instrument with TMS as the internal standard. The mass spectra were recorded on a Hitachi M-2000 spectrometer with an electron beam energy of 70 eV. The hplc was carried out with a Shimadzu LC-5A chromatograph. The single crystal X-ray analysis was performed at the X-ray analytical laboratory in Faculty of Pharmaceutical Sciences, University of Tokyo. Microanalyses were performed at the microanalytical laboratory of the Center for Instrumental Analysis in College of Science & Technology, Nihon University.

### Photolysis of Benzofuroxan (**5**) at 365 nm.

A solution of 5.00 g (0.037 mole) of compound **5** dissolved in 300 ml of acetonitrile:water (95:5, v/v) was irradiated using a 400-W high pressure mercury lamp with a Pyrex filter at room temperature. After irradiation for 30 and 100 hours, an aliquot was taken, and unreacted **5** or product **6** were determined with an hplc apparatus using the calibration curves.

### Deoxygenation in the Initial Stage of the Photolysis of Benzofuroxan (**5**) at 365 nm.

A solution of 61.0 mg of compound **5** dissolved in 15 ml of dry acetonitrile was irradiated using a 1k-W high pressure mercury lamp with a Pyrex filter at 3~8°. After 0.5 hour, an aliquot (0.5 ml) was taken and added to the acetonitrile solution contained excess triethylphosphite (300 mg), and the solution was allowed to heat at 70° for 1 hour. Unreacted **5** and *cis-cis*-1,4-dicyanobuta-1,3-diene **2** were determined with an hplc apparatus using the calibration curves. After irradiation for 0.5 hour, the recovery of compound **5** was 58.6 mg (96%), and the yield of dicyanide **2** was 1.7 mg [3.8% (yield based on consumed **5**, 94%)].

### 1*H*-Azepine-2,7-dione (**6**).

This compound was obtained as colorless needles (ethanol), mp 167~168°; ir (potassium bromide):  $\nu$  3180 (NH), 1685, 1655 (C=O), 1610 (C=C) cm<sup>-1</sup>; uv (pH 1):  $\lambda$  max nm (log  $\epsilon$ ) 208 (4.46), 237 (3.61), 281 (3.74), 291 (3.72); (pH 7):  $\lambda$  max nm (log  $\epsilon$ ) 208 (4.44), 237 (3.58), 281 (3.72), 291 (3.70); (pH 11):  $\lambda$  max nm (log  $\epsilon$ ) 234 (4.19), 254 (4.11); <sup>1</sup>H nmr (deuteriochloroform):  $\delta$  6.44-6.83 (m, 4H), 8.80 (s, 1H, NH, deuterium oxide-exchangeable); <sup>13</sup>C nmr

(DMSO-d<sub>6</sub>):  $\delta$  164.21 (C<sub>2,7</sub>), 134.21 (C<sub>3,6</sub>, J<sub>CH</sub> = 194 Hz), 132.27 (C<sub>4,5</sub>, J<sub>CH</sub> = 193 Hz); ms: (m/e) 123 (M<sup>+</sup>), 95 (M<sup>+</sup>-CO), 67 (M<sup>+</sup>-COCO), 52 (M<sup>+</sup>-COCONH); hrms: (m/z) 123.0319. Calcd. for C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>: M, 123.0319.

*Anal.* Calcd. for C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>: C, 58.53; H, 4.09; N, 11.38. Found: C, 58.78; H, 4.23; N, 11.46.

### Photolysis of Benzofuroxan (**5**) at 254 nm.

I. A solution of 136 mg (1 mmole) of compound **5** dissolved in 10 ml of acetonitrile:water (9:1, v/v) was placed in a merry-go-round type apparatus. The solution was irradiated using a 160 W low pressure mercury lamp at 11~15°. After irradiation for 200 hours, an aliquot was taken, and unreacted **5**, product **6** and **11** were determined with an hplc apparatus using the calibration curves.

II. A solution of 5.00 g (0.037 mole) of compound **5** dissolved in 300 ml of acetonitrile:water (9:1, v/v) was placed in an immersion unit type photochemical reactor. The solution was irradiated using a 160 W low pressure mercury lamp at room temperature. After irradiation for 140 hours, compound **5**, **6** and **11** were determined, such as the experiment I.

### Photolysis of Benzofuroxan (**5**) in the Presence of Fluorene at 254 nm.

A solution of 5.00 g (0.037 mole) of **5** and 3.325 g (0.02 mole) of fluorene in 300 ml of acetonitrile:water (9:1, v/v) was irradiated and compound **5**, **6** and **11** were determined, such as the experiment I.

### 6*H*-Furazano[4,5-*c*]carbazole 3-Oxide (**11**).

This compound was obtained as yellow prisms (methanol), mp 237~238°; ir (potassium bromide):  $\nu$  3335, 1610, 1578, 1530, 1460 cm<sup>-1</sup>; uv (methanol):  $\lambda$  max nm (log  $\epsilon$ ) 202 (4.54), 231 (4.52), 266 (4.18), 356 (4.02); <sup>1</sup>H nmr (DMSO-d<sub>6</sub>):  $\delta$  7.68-8.18 (m, 6H), 12.24 (s, 1H, deuterium oxide-exchangeable); hrms: (m/z) 225.0538. Calcd. for C<sub>12</sub>H<sub>7</sub>N<sub>3</sub>O<sub>2</sub>: M, 225.0538; X-ray analysis (Figure 1).

*Anal.* Calcd. for C<sub>12</sub>H<sub>7</sub>N<sub>3</sub>O<sub>2</sub>: C, 64.00; H, 3.13; N, 18.66. Found: C, 63.72; H, 2.95; N, 18.67.

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