Benzofuran Derivatives. Part 3 [1]. On the Reactivities of the Intermediates in Benzofuran Synthesis

Takaaki Horaguchi*, Shinichi Matsuda and Kiyoshi Tanemura

Department of Chemistry, Faculty of Science, Niigata University, Ikarashi, Niigata 950-21, Japan

Tsuneo Suzuki

School of Dentistry at Niigata, The Nippon Dental University, Niigata, Hamaura-cho, Niigata 951, Japan

Received December 11, 1986

3-Methyl-5-nitrobenzofuran (**2**) and 3-methyl-5-nitrobenzofuran-2-carboxylic acid (**3**) were obtained by heating 2-acetyl-4-nitrophenoxyacetic acid (**1**) with various bases in acetic anhydride. It appeared that 3-hydroxy-3-methyl-5-nitro-2,3-dihydrobenzofuran-2-carboxylic acid (**4**) was the intermediate in the benzofuran synthesis. The properties of **4** were examined under various conditions. Using strong bases such as triethylamine in place of sodium acetate, 3-methyl-5-nitrobenzofuran-2-carboxylic acid (**3**) was obtained exclusively. However, in the presence of acetic acid in the reaction mixture 3-methyl-5-nitrobenzofuran (**2**) was obtained in good yield. The reaction pathways for the formation of **2** and **3** are discussed.

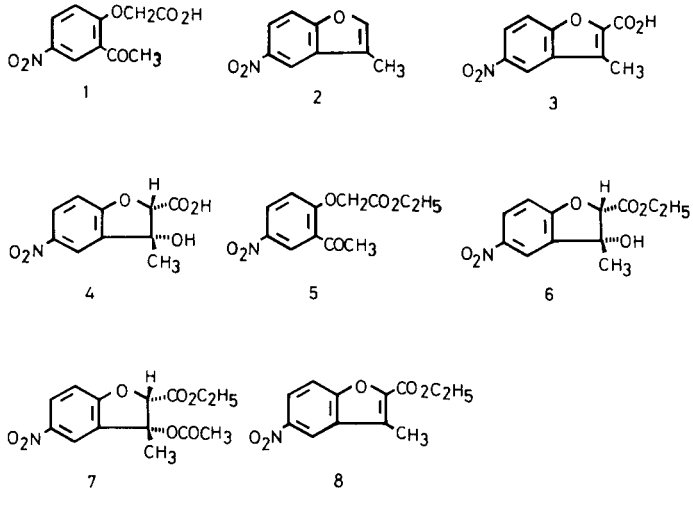
J. Heterocyclic Chem., **24**, 965 (1987).

Introduction.

Benzofurans may be readily synthesized by the treatment under reflux with sodium acetate in acetic anhydride of 2-acylphenoxyacetic acids [2]. In the reactions both benzofurans and benzofuran-2-carboxylic acids are produced. However, the latter compounds have not been noticed because of their poor yields. When 2-formylphenoxyacetic acid [3], 2-formyl-4-nitrophenoxyacetic acid [4], or 2-acetyl-4-nitrophenoxyacetic acid [4] were used as the starting materials, benzofuran-2-carboxylic acids were obtained in considerable yields. In contrast, in the presence of acetic acid 2-formylphenoxyacetic acid gave exclusively benzofuran [3]. Thus, the product distribution varied according to reaction conditions. In the benzofuran synthesis, 3-alkyl-3-hydroxy-2,3-dihydrobenzofuran-2-carboxylic acids or their analogues have been considered to be intermediates [5,6]. We attempted to prepare the corresponding intermediates and clarify their properties since mechanisms in the benzofuran synthesis were not well enough examined.

Results and Discussion.

In the previous paper [4], we reported that 2-acetyl-4-nitrophenoxyacetic acid (**1**) gave 3-methyl-5-nitrobenzofuran (**2**) and 3-methyl-5-nitrobenzofuran-2-carboxylic acid (**3**) in 57 and 34% yields respectively. The considerable yield of **3** was attributed to the strongly electron-withdrawing effect of a nitro group and was convenient to examine properties of the intermediates in the benzofuran synthesis. Therefore, we attempted to prepare 3-hydroxy-3-methyl-5-nitro-2,3-dihydrobenzofuran-2-carboxylic acid (**4**) as the intermediate in the benzofuran synthesis. When ethyl 2-acetyl-4-nitrophenoxyacetate (**5**) was heated with sodium hydroxide in dioxane, 3-hydroxy-3-methyl-5-nitro-2,3-dihydrobenzofuran-2-carboxylate (**6**) was obtained in 58% yield [1]. The corresponding diasteromer was produced in a small amount. The *cis* relationship concerning the hydrogen and the methyl group in **6** was confirmed by consideration of a molecular model and determination of the NOE [1]. The ester **6** was hydrolyzed with sodium hydroxide to the desired acid **4** in 61% yield.



Formula 1

Initially, the reactions of acids **4** and **1** with various bases were examined in acetic anhydride. The results are shown in Table 1. In the absence of bases the acid **4** gave benzofuran **2** and benzofuran-2-carboxylic acid **3** in 72 and 17% yields respectively. When the acid **4** was reacted with sodium acetate, the benzofuran **2** and the benzofuran-2-carboxylic acid **3** were obtained in 56 and 32% yields respectively. Similarly, the acid **1** afforded **2** and **3** in 60 and 33% yields respectively. In both reactions of **4** and **1** with sodium acetate the product ratios of **2** and **3** were almost the same. Using sodium formate as the base

the product ratios of **2** and **3** were analogous to those in the case of sodium acetate. As the bases were changed from sodium acetate or sodium formate to pyridine, α-picoline, or γ-collidine (stronger bases), formation of the benzofuran-2-carboxylic acid **3** became much more favorable. In the case of the acid **4** the yields of **2** ranged from 7 to 20% and those of **3** from 81 to 72%. In the reactions of the acid **1** similar results were obtained. Furthermore, when much stronger bases such as *N*-ethylmorpholine, triallylamine, and triethylamine were used the benzofuran-2-carboxylic acid **3** was produced exclusively in both the reactions of the acids **4** and **1**. Therefore, the stronger the basicity of the bases, the more the formation of the benzofuran-2-carboxylic acid **3** became favorable. Thus, the results in Table 1 strongly suggest that the benzofuran-2-carboxylic acid **4** is the intermediate in the reactions of the acid **1** with bases in acetic anhydride.

Table 1

Reactions of Carboxylic Acids **4** and **1** with Various Bases in Acetic Anhydride [a]

Run	Compound	Base (PK_a/25°C) [b]	Product (yield, %) **2**	**3**
1	**4**	sodium acetate (4.75)	56	32
2	**1**	sodium acetate (4.75)	60	33
3	**4**	sodium formate (3.74)	63	29
4	**1**	sodium formate (3.74)	64	25
5	**4**	pyridine (5.17)	20	72
6	**1**	pyridine (5.17)	25	65
7	**4**	α-picoline (5.97)	11	74
8	**1**	α-picoline (5.97)	14	76
9	**4**	γ-collidine (9.57)	7	81
10	**1**	γ-collidine (9.57)	9	82
11	**4**	*N*-ethylmorpholine (7.70)	6	87
12	**1**	*N*-ethylmorpholine (7.70)	12	82
13	**4**	Triallylamine (8.31)	5	85
14	**1**	Triallylamine (8.31)	10	80
15	**4**	Triethylamine (10.67)	5	87
16	**1**	Triethylamine (10.67)	8	89
17	**4**	none	72	17

[a] A mixture of **4** or **1** (120 mg, 0.50 mmole), base (1.00 mmole), and acetic anhydride (6.5 ml) was heated at 110° for 3 hours. [b] Values in aqueous solution.

Secondly, the reactions of the acids **4** and **1** under acidic conditions were examined. The results are summarized in Table 2. When the acid **4** reacted with sodium acetate in acetic anhydride in the presence of acetic acid the products **2** and **3** were obtained in 85 and 9% yields respectively. The acid **1** gave almost the same results under similar conditions. In the presence of formic acid the acid **4** gave **2** and **3** in 88 and 8% yields respectively, however, the reaction of the acid **1** under the same conditions did not afford products and the starting material **1** was recovered unchanged. This is attributed to the stronger acidity of formic acid compared with acetic acid. The acid **4** reacted in acetic acid to give **2** and **3** in 90 and 7% yields respectively. Thus in the presence of acetic acid or formic acid, **4** afforded the benzofuran **2** in good yields in spite of the coexistence of sodium acetate. The results suggest that the reaction pathways in the presence of acetic acid differ from those in the absence of acetic acid.

Table 2

Reactions of Carboxylic Acids **4** and **1** Under Acidic Conditions

Run	Compound	Conditions	Product (yield, %) **2**	**3**
1 [a]	**4**	sodium acetate acetic anhydride acetic acid	85	9
2 [a]	**1**	sodium acetate acetic anhydride acetic acid	88	9
3 [b]	**4**	sodium acetate acetic anhydride formic acid	88	8
4 [b]	**1**	sodium acetate acetic anhydride formic acid	no reaction	
5[c]	**4**	acetic acid	90	7

[a] A mixture of **4** or **1** (120 mg, 0.5 mmole), sodium acetate (82 mg, 1.00 mmole), acetic anhydride (3.25 ml), and acetic acid (3.25 ml) was heated at 110° for 3 hours. [b] A mixture of **4** or **1** (120 mg, 0.50 mmole), sodium acetate (68 mg, 1.00 mmole), acetic anhydride (3.25 ml), and formic acid (3.25 ml) was heated at 110° for 3 hours. [c] Compound **4** (120 mg, 0.50 mmole) was heated in acetic acid (6.5 ml) or acetic anhydride (6.5 ml) at 110° for 3 hours.

Thirdly, the reactions of the ester **6** and acetic anhydride were examined [7]. The results are summarized in Table 3. The reaction of the ester **6** and acetic anhydride proceeded slowly to give **7** in 77% yield after 40 hours, but the elimination reaction of **7** to the corresponding furan **8** was very slow. In contrast, in the presence of sodium acetate the yield of **7** and **8** was increased. Heating of the ester **6** in acetic acid afforded **8** in good yield. The results in Table 3 show that the bases accelerate acetylation of the hydroxyl group in **6** and the following elimination of acetic acid. This acetylation of the hydroxyl group would occur in the reactions of acids **4** and **1** with various bases in acetic anhydride.

Finally, properties of the acetate **7** under various conditions were examined. The results are shown in Table 4. In the presence of bases such as sodium acetate or triethylamine the acetate **7** reacted readily to give the elimination product **8**. In contrast, the elimination was very slow in the absence of bases. The reaction of **7** in acetic acid proceeded very fast to afford **8**, indicating a different reaction mechanism.

Table 3

Reactions of the Ester **6** under Various Conditions

Run	Conditions	Time, hours	Product (yield, %) **6** (recovery)	**7**	**8**
1 [a]	acetic anhydride	5	82	13	0
2 [a]	acetic anhydride	10	63	29	trace
3 [a]	acetic anhydride	20	46	49	2
4 [a]	acetic anhydride	40	21	77	6
5 [b]	sodium acetate acetic anhydride	4	10	31	56
6 [b]	triethylamine acetic anhydride	4	48	8	43
7 [c]	acetic acid	4	11	0	81

[a] A mixture of **2** (200 mg, 0.75 mole) and acetic anhydride (10 ml) was heated at 110°. [b] A mixture of **2** (130 mg, 0.49 mmole), base (2.00 mmoles), and acetic anhydride (6.5 ml) was heated at 110°. [c] A mixture of **2** (130 mg, 0.49 mmole) and acetic acid (6.5 ml) was heated at 110°.

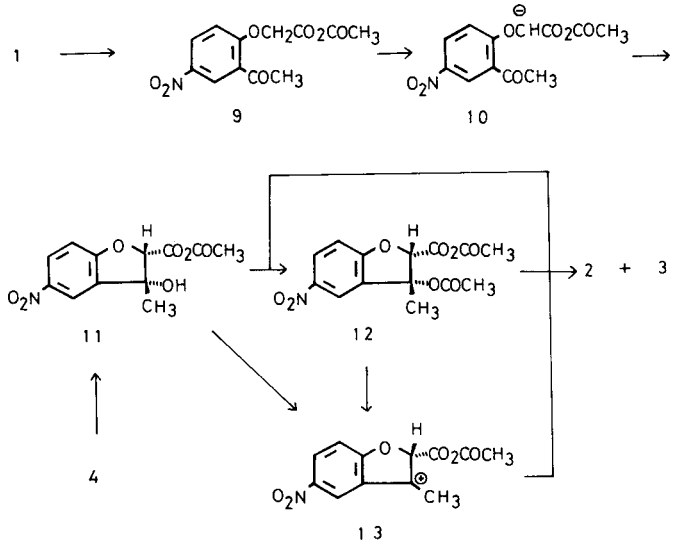
Table 4

Reactions of the Acetate **7** under Various Conditions

Run	Conditions	Time, hours	Product (yield, %) **7** (Recovery)	**8**
1 [a]	sodium acetate acetic anhydride	4	8	92
2 [a]	triethylamine acetic anhydride	2	2	95
3 [b]	acetic anhydride	10	96	3
4 [c]	acetic acid	1	6	94

[a] A mixture of **7** (80 mg, 0.25 mmole), base (1.00 mmole), and acetic anhydride (3.25 ml) was heated at 110°. [b] A mixture of **7** (80 mg, 0.25 mmole), and acetic anhydride (3.25 ml) was heated at 110°. [c] A mixture of **7** (80 mg, 0.25 mmole), and acetic acid (3.25 ml) was heated at 110°.

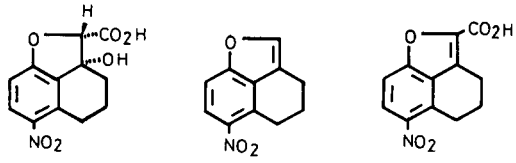
From the results of Tables 1-4 the possible reaction pathways in the benzofuran synthesis are as follows [4-8]. The 2-acetylphenoxyacetic acid **1** is initially acetylated with acetic anhydride to the corresponding anhydride **9** because benzofurans are not produced in the absence of acetic anhydride. The anhydride **9** is deprotonated by the weak base of sodium acetate to give an anion **10**. Formation of **10** is attributed to the strongly electron-withdrawing property of the acetoxycarbonyl group in **9**. For example, when the ester **5** is used instead of the acid **1**, the starting material is recovered unchanged because the acidity of the methylene group in **5** is too weak for deprotonation by sodium acetate. The anion **10** attacks the carbonyl carbon atom to afford dihydrofuran **11**. Though two diastereomers are possible for **11** the main product would have a *cis* relationship between the hydrogen and the methyl group judging from the results in Table 1 and the favorable configuration of **11**. The sterically unfavorable diastereomer would not play an important role in the benzofuran synthesis [1]. Similarly, the acid **4** would be acetylated with acetic anhydride to give the anhydride **11**. The anhydride **11** is the common intermediate compound for acids **1** and **4**. Next the hydroxyl group in **11** is acetylated to afford **12**. The elimination of the methyne hydrogen and the acetoxyl group in **12** would be promoted by bases (E2 elimination). In contrast, the elimination of the acetoxycarbonyl group and the acetoxyl group affords benzofuran **2**. The reaction mechanisms are not clear as yet, however, the elimination would not be so affected by the bases. Therefore, the ratios of the benzofuran **2** and the benzofuran-2-carboxylic acid **3** are controlled by the facility of the elimination of the hydrogen and the acetoxyl group from **12**. Using the strong bases such as triethylamine the benzofuran-2-carboxylic acid **3** is produced in high yield. There is an alternative possible route that the anhydride **11** gives directly the benzofuran **2** and the benzofuran-2-carboxylic acid **3** without acetylation of the hydroxyl group in **11**. At the present time it is not clear which pathway is dominant. When acetic acid or formic acid are present in the reaction mixture, protonation occurs on the hydroxyl group or the acetoxyl group in **11** or **12** to give a cation **13**. The benzofuran **2** and the benzofuran-2-carboxylic acid **3** are produced from **13** by elimination of the acetoxycarbonyl group or the hydrogen respectively. The reaction of the acid **4** in acetic acid would proceed through such a cation mechanism.



Scheme 1

As mentioned above the reactions of the acid **4** with various bases in acetic anhydride gave a considerable amount of the benzofuran-2-carboxylic acid **3**. However,

the reaction of an acid **14** which was similar to **4** with sodium acetate in acetic anhydride gave only naphtho[1,8-*bc*]furan **15**. Using triethylamine as the base the yield of the naphtho[1,8-*bc*]furan **15** was 83% and that of naphtho[1,8-*bc*]furan-2-carboxylic acid **16** was only 13%. The results suggest that the molecule of the acid **14** has a rigid structure and is not easy to take a conformation favorable for *trans* elimination (E2 elimination of acetic acid) [9]. In contrast, it seems that the molecule of **3** is not so rigid.



14 15 16

Formula 2

EXPERIMENTAL

The melting points were uncorrected. Column chromatography was performed on silica gel (Wakogel C-200). Unless otherwise stated anhydrous sodium sulfate was employed as the drying agent. The ir spectra (ir) were determined on a Hitachi EPI-grating infrared spectrophotometer. The nmr spectra (^{1}H and ^{13}C nmr) were determined at 90 MHz on a JEOL JNM-FX 90Q FT NMR spectrometer, using tetramethylsilane as the internal standard. Ether refers to diethyl ether.

Ethyl 3-Hydroxy-3-methyl-5-nitro-2,3-dihydrobenzofuran-2-carboxylate (**6**).

A mixture of **5** (1.00 g, 3.75 mmoles), powdered potassium hydroxide (0.70 g, 12.5 mmoles), and anhydrous dioxane (100 ml) was refluxed for 1 hour. After removal of the insoluble materials by filtration the dioxane was evaporated. The residue was chromatographed and eluted with benzene (9)-ether (1) to give **6** [1]; it formed colorless needles (0.58 g, 58%) from benzene, mp 156-158°; ir (potassium bromide): 3420 (OH), 1735 cm^{-1} ($COOC_2H_5$); ^{1}H nmr (deuteriochloroform): δ 1.34 (t, J = 7 Hz, 3H, CH_2CH_3), 1.86 (s, 3H, CH_3), 2.70 (broad s, 1H, OH), 4.32 (q, J = 7 Hz, 2H, $COOCH_2$), 4.97 (s, 1H, CHCOO), 7.00 (d, J = 10 Hz, 1H, C_7-H), 8.21 (d, J = 2 Hz, 1H, C_4-H), 8.23 (dd, J = 2 and 10 Hz, 1H, C_6-H); ^{13}C nmr (deuterioacetone): δ 14.5 (q), 26.4 (q), 61.7 (t), 78.9 (s), 91.6 (d), 111.5 (d), 120.9 (d), 127.7 (d), 134.4 (s), 143.5 (s), 164.8 (s), 167.0 (s).

Anal. Calcd. for $C_{12}H_{13}NO_6$: C, 53.93; H, 4.90; N, 5.24. Found: C, 54.00; H, 5.02; N, 5.21.

3-Hydroxy-3-methyl-5-nitro-2,3-dihydrobenzofuran-2-carboxylic Acid (**4**).

A 0.5 *M* sodium hydroxide solution (200 ml) was gradually added to an ethanolic solution (250 ml) of **6** (2.00 g, 7.50 mmoles) under cooling with ice and stirring. The solution was poured into ice-water and acidified with 2*M* hydrochloric acid. The resulting precipitate was extracted with ether. The ethereal layer was washed, dried, and evaporated to give **4** (1.09 g, 61%); it formed colorless needles from acetone-benzene, mp 161-162° (after drying at 70° for 10 hours under reduced pressure); ir (potassium bromide): 3510 (OH), 1740, 1720 cm^{-1} (COOH); ^{1}H nmr (deuterioacetone): δ 1.93 (s, 3H, CH_3), 2.09 (s, 1H, OH), 5.18 (s, 1H, CHCOO), 7.08 (d, J = 9 Hz, 1H, C_7-H), 8.23 (dd, J = 2 and 9 Hz, 1H, C_6-H), 8.25 (d, J = 2 Hz, 1H, C_4-H); ^{13}C nmr (deuterioacetone): δ 26.3 (q), 78.8 (s), 91.6 (d), 111.5 (d), 120.9 (d), 127.7 (d), 134.6 (s), 143.5 (s), 164.9 (s), 167.7 (s).

Anal. Calcd. for $C_{10}H_9NO_6$: C, 50.22; H, 3.79; N, 5.86. Found: C, 50.28; H, 4.03; N, 5.65.

General Procedure for the Reactions of **4** and **1** with Various Bases in Acetic Anhydride.

A mixture of **4** or **1** (120 mg, 0.50 mmole), base (1.00 mmole), and acetic anhydride (6.5 ml) was heated at 110° for 3 hours. The mixture was poured into ice-water, stirred for 1 hour and extracted with ether. The ethereal layer was washed with a 5% potassium carbonate solution (30 ml × 3), then with water, dried, and evaporated. The residue was chromatographed and eluted with benzene (5)-hexane (1) to give **2** [4]; it formed pale yellow needles from benzene, mp 89-90°; ir (potassium bromide): 890 cm^{-1} (furan H); ^{1}H nmr (deuteriochloroform): δ 2.29 (s, 3H, CH_3), 7.48 (d, J = 9 Hz, 1H, C_7-H), 7.54 (s, 1H, C_2-H), 8.20 (dd, J = 2 and 9 Hz, 1H, C_6-H), 8.43 (d, J = 2 Hz, 1H, C_4-H); ^{13}C nmr (deuteriochloroform): δ 7.6 (q), 111.6 (d), 116.1 (d), 116.9 (s), 120.0 (s), 121.5 (s), 144.0 (s), 144.5 (d), 151.8 (s).

Anal. Calcd. for $C_9H_7NO_3$: C, 61.01; H, 3.98: N, 7.91. Found: C, 61.02; H, 4.04; N, 7.72.

The alkaline solution was acidified with 6*M* hydrochloric acid and the resulting precipitate was extracted with ether. The ethereal layer was washed, dried, and evaporated to give **3** [4]; it formed colorless needles from acetone, mp 285-286° dec; ir (potassium bromide): 1700 cm^{-1} (COOH); ^{1}H nmr (deuterioacetone): δ 2.70 (s, 3H, CH_3), 7.82 (d, J = 9 Hz, 1H, C_7-H), 8.42 (dd, J = 2 and 9 Hz, 1H, C_6-H), 8.72 (d, J = 2 Hz, 1H, C_4-H).

Anal. Calcd. for $C_{10}H_7NO_5$: C, 54.30; H, 3.19; N, 6.33. Found: C, 54.32; H, 3.23; N, 6.21.

Reactions of **4** and **1** under Acidic Conditions.

A mixture of **4** or **1** (120 mg, 0.50 mmole), base (1.00 mmole), acetic anhydride (3.25 ml), and acetic acid(or formic acid) (3.25 ml) was heated at 110° for 3 hours. The mixture was treated by the method similar to general procedure for the reactions of **4** and **1** with bases in acetic anhydride. The reaction of **4** in acetic acid (6.5 ml) or acetic anhydride (6.5 ml) was carried out similarly by heating at 110° for 3 hours.

Reactions of **6** under Various Conditions.

A mixture of **6** (130 mg, 0.49 mmole), base (2.00 mmoles), and acetic anhydride (6.5 ml) was heated at 110° for 4 hours. The mixture was poured into ice-water, stirred for 1 hour, and extracted with ether. The ethereal layer was washed with a 5% potassium carbonate solution, then with water, dried, and evaporated. The residue was chromatographed and eluted with benzene to give **8** [1]; it formed colorless needles from benzene, mp 146-147°; ir (potassium bromide): 1710 cm^{-1} ($COOC_2H_5$); ^{1}H nmr (deuteriochloroform): δ 1.47 (t, J = 7 Hz, 3H, CH_2CH_3), 2.64 (s, 3H, CH_3), 4.49 (q, J = 7 Hz, 2H, $COOCH_2$), 7.62 (d, J = 9 Hz, 1H, C_7-H), 8.35 (dd, J = 2 and 9 Hz, 1H, C_6-H), 8.58 (d, J = 2 Hz, 1H, C_4-H); ^{13}C nmr (deuteriochloroform): δ 9.3 (q), 14.4 (q), 61.7 (t), 112.7 (d), 117.9 (d), 123.0 (d), 125.8 (s), 129.5 (s), 143.9 (s), 144.5 (2), 156.8 (s), 159.6 (s).

Anal. Calcd. for $C_{12}H_{11}NO_5$: C, 57.83; H, 4.45; N, 5.62. Found: C, 57.87; H, 4.53; N, 5.50.

Elution with benzene (9)-ether (1) afforded **7**; it formed colorless needles from benzene, mp 134-135°: ir (potassium bromide): 1745, 1730 cm^{-1} (COOC); ^{1}H nmr (deuteriochloroform): δ 1.39 (t, J = 7 Hz, 3H, CH_2CH_3), 1.93 (s, 3H, CH_3), 2.19 (s, 3H, $OCOCH_3$), 4.41 (q, J = 7 Hz, 2H, CH_2CH_3), 4.99 (s, 1H, CH_2COO), 7.05 (d, J = 9 Hz, 1H, C_7-H), 8.24 (dd, J = 3 and 9 Hz, 1H, C_6-H), 8.56 (d, J = 3 Hz, 1H, C_4-H); ^{13}C nmr (deuteriochloroform): δ 14.3 (q), 21.5 (q), 22.0 (q), 61.9 (t), 84.9 (s), 90.4 (d), 111.2 (d), 124.2 (d), 127.9 (d), 128.2 (s), 142.6 (s), 164.1 (s), 165.4 (s), 168.9 (s).

Anal. Calcd. for $C_{14}H_{15}NO_7$: C, 54.37: H, 4.89; N, 4.53. Found: C, 54.65; H, 4.86: N, 4.62.

Further elution with benzene (9)-ether (1) gave the starting material **6**.

Reactions of **7** under Various Conditions.

A mixture of **7** (80 mg, 0.25 mmole), base (1.00 mmole), and acetic anhydride (3.25 ml) was heated at 110°. The mixture was poured into ice-water, stirred for 1 hour, and extracted with ether. The ethereal layer was washed with a 5% potassium carbonate solution, then with water, dried, and evaporated. The residue was chromatographed and eluted with benzene to give **8**. Further elution with benzene (9)-ether (1) afforded the

starting material **7**. The reaction of **7** (80 mg, 0.25 mmole) in acetic anhydride (3.25 ml) or acetic acid (3.25 ml) was carried out by the same method.

Reactions of **14** with Sodium Acetate or Triethylamine in Acetic Anhydride.

The reactions were carried out by a method similar to the reactions of **4** and **1** with various bases in acetic anhydride.

3a-Hydroxy-6-nitro-2a,3,4,5-tetrahydro-2*H*-naphtho[1,8-*bc*]furan-2-carboxylic Acid (**14**).

Ethyl 3a-hydroxy-6-nitro-2a,3,4,5-tetrahydro-2*H*-naphtho[1,8-*bc*]furan-2-carboxylate (1.00 g, 3.77 mmoles, obtained from ethyl 4-nitro-8-oxo-5,6,7,8-tetrahydro-1-naphthoxyacetate and potassium hydroxide) was dissolved in ethanol (35 ml) and hydrolyzed by adding a 1*M* sodium hydroxide solution (4.56 ml). The alkaline solution was acidified with 2*M* hydrochloric acid and the resulting precipitate was filtered, washed with water and then with ether to give **14** (0.85 g, 94%); it formed colorless needles from acetone-hexane, mp 141-145° dec; ir (potassium bromide): 3510 (OH), 1720 cm^{-1} (COOH); ^1H nmr (deuterioacetone): δ 1.78-3.50 (m, 6H, C_3-H_2, C_4-H_2, C_5-H_2), 4.31 (broad s, 1H, OH), 5.10 (s, 1H, OCHCOO), 6.89 (d, J = 9 Hz, 1H, C_8-H), 8.16 (d, J = 9 Hz, 1H, C_7-H).

Anal. Calcd. for $C_{12}H_{11}NO_6$: C, 54.34; H, 4.18; N, 5.28. Found: C, 54.08; H, 4.28; N, 5.04.

6-Nitro-4,5-dihydro-3*H*-naphtho[1,8-*bc*]furan (**15**).

Colorless needles were obtained from methanol, mp 108-109°; ir (potassium bromide): 880 cm^{-1} (furan H); ^1H nmr (deuteriochloroform): δ 1.90-2.16 (m, 2H, C_4-H_2), 2.81 (dt, J = 1 and 6 Hz, 2H, C_3-H_2), 3.31 (t, J = 6 Hz, 2H, C_5-H_2), 7.26 (d, J = 6 Hz, 1H, C_8-H), 7.43 (t, J = 1 Hz, 1H, C_2-H), 8.07 (d, J = 6 Hz, 1H, C_7-H); ^{13}C nmr (deuteriochloroform): δ 19.4 (t), 23.5 (t), 26.1 (t), 109.1 (d), 118.4 (s), 121.9 (d), 128.9 (s), 131.2 (s), 140.3 (d), 141.6 (s), 155.2 (s).

Anal. Calcd. for $C_{11}H_9NO_3$: C, 65.02; H, 4.46: N, 6.89. Found: C, 64.81; H, 4.62; N, 6.98.

6-Nitro-4,5-dihydro-3*H*-naphtho[1,8-*bc*]furan-2-carboxylic Acid (**16**).

Colorless needles were obtained from acetone, mp 250°; ir (potassium bromide): 1700 cm^{-1} (COOH); ^1H nmr (deuterioacetone): δ 2.00-2.28 (m, 2H, C_4-H_2), 3.15 (t, J = 6 Hz, 2H, C_3-H_2), 3.37 (t, 2H, C_5-H_2), 7.55 (d, J = 9 Hz, 1H, C_8-H), 8.24 (d, J = 9 Hz, 1H, C_7-H).

Anal. Calcd. for $C_{12}H_9NO_5$: C, 58.30; H, 3.67; N, 5.67. Found: C, 58.55; H, 3.68; N, 5.47.

Acknowledgement.

The authors wish to thank Mr. Yoshiaki Matsuda for the elemental analyses.

REFERENCES AND NOTES

[1] Part 2, T. Suzuki, *Bull. Chem. Soc. Japan*, **58**, 2821 (1985).

[2] W. B. Whalley, *J. Chem. Soc.*, 3229 (1951); G. H. Phillip, A. Robertson, and W. B. Whalley, *J. Chem. Soc.*, 4951 (1952); F. M. Dean, P. Halewood, S. Mongholsuk, A. Robertson, and W. B. Whalley, *J. Chem. Soc.*, 1250 (1953); G. Lloyd and W. B. Whalley, *J. Chem. Soc.*, 3209 (1956); L. R. Worden, K. D. Kaufman, J. A. Weis, and T. K. Schaaf, *J. Org. Chem.*, **34**, 2311 (1969).

[3] A. W. Burgstahler and L. R. Worden, *Org. Synth.*, **46**, 28 (1966).

[4] T. Suzuki, T. Horaguchi, T. Shimizu and T. Abe, *Bull. Chem. Soc. Japan*, **56**, 2762 (1983).

[5] P. Cagniant and D. Cagniant, "Advances in Heterocyclic Chemistry", Vol **18**, A. R. Katritzky and A. J. Boulton, eds, Academic Press, London, 1975, p 418.

[6] S. Kawai, T. Nakamura and N. Sugiyama, *Proc. Imp. Acad. (Tokyo)*, **15**, 45 (1939); S. Tanaka, *J. Am. Chem. Soc.*, **73**, 872 (1951); A. B. Sen and M. S. Saxen, *J. Indian Chem. Soc.*, **36**, 283 (1952); T. Matsumoto and K. Fukui, *Bull. Chem. Soc. Japan*, **30**, 3 (1957); Y. Tanaka, *Bull. Chem. Soc. Japan*, **30**, 575 (1957); Y. Kawase and S. Nakamoto, *Bull. Chem. Soc. Japan*, **35**, 1624 (1962); S. P. Pappas and J. E. Blackwell Jr, *Tetrahedron Letters*, 1171 (1966); M. Ghelardoni, V. Pestellini and C. Munste, *Gazz. Chim. Ital.*, **99**, 1273 (1969); *Chem. Abstr.*, **73**, 24801v (1970); G. N. Walker and R. T. Smith, *J. Org. Chem.*, **36**, 305 (1971); K. Schofield, R. S. Ward and A. M. Choudhury, *J. Chem. Soc. C*, 2834 (1971); T. Horaguchi, H. Narita and T. Suzuki, *Bull. Chem. Soc. Japan*, **56**, 184 (1983).

[7] L. H. Zalkow and M. Ghosal, *J. Org. Chem.*, **34**, 1646 (1969).

[8] T. Horaguchi, H. Yagoh, K. Tanemura, and T. Suzuki, *J. Heterocyclic Chem.*, **23**, 657 (1986); T. Horaguchi, S. Tamura, N. Hiratsuka and T. Suzuki, *J. Chem. Soc., Perkin Trans. 1*, 1001 (1985).

[9] C. H. Depuy, R. D. Thurn, and G. F. Morris, *J. Am. Chem. Soc.*, **84**, 1314 (1962); H. Kwart, T. Takeshita, and J. L. Nyce, *J. Am. Chem. Soc.*, **86**, 2606 (1964); N. A. LeBell, P. D. Beirne, E. R. Karger, J. C. Powers, and P. M. Subramanian, *J. Am. Chem. Soc.*, **85**, 3199 (1963).