Studies on 5-8 Fused Ring Compounds. IV. The Syntheses of 5-8-5 Fused Ring Compounds and the Conformations of Their Eight-Membered Rings

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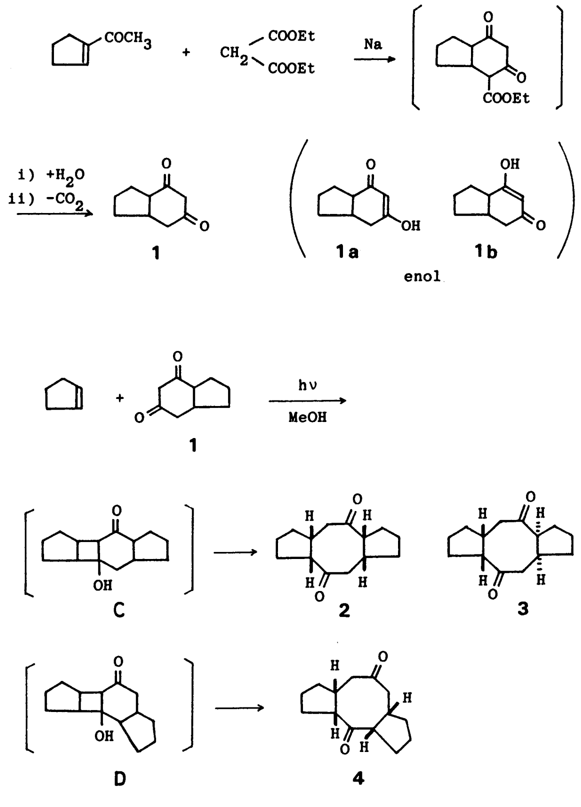
Synopsis. The isomers, *cis-cisoid-cis-* and *cis-transoid-cis*-tricyclo[9.3.0.0^{4,8}]tetradecane-2,9-dione (**2** and **3**) and *cis-cisoid-cis*-tricyclo[9.3.0.0^{3,7}]tetradecane-2,9-dione (**4**) were synthesized by the photocycloaddition of bicyclo[4.3.0]nonane-2,4-dione (**1**) to cyclopentene. X-Ray analyses of those compounds revealed that the conformations of the eight-membered rings are twist-boat in **2**, chair in **3**, and boat-chair form in **4**.

The 5-8-5 fused tricyclic systems have been found as the carbon skeletons of ophiobolin[1] sesterterpenes, and fusicoccin[2] and basmane[3] diterpenes. Although several reports[4] have appeared concerning the syntheses of 5-8-5 fused ring compounds, the synthetic and conformational studies on such compounds are still insufficient. In this paper we report the syntheses of some 5-8-5 fused ring compounds via the photocycloaddition of bicyclo[4.3.0]nonane-2,4-dione (**1**) to cyclopentene and their molecular structures and conformations.

The starting material, bicyclo[4.3.0]nonane-2,4-dione (**1**), was synthesized by Michael condensation between 1-acetylcyclopentene and diethyl malonate, accompanied by intramolecular cyclization and followed by decarboxylation, in an analogous synthetic procedure of dimedone.[5] The enolization of β-diketone (**1**) is feasible in two forms, **1a** and **1b**. For the photoadducts, therefore, two structural isomers (**C** and **D**) are possible.

The photocycloaddition was carried out in a methanol solution of **1** and cyclopentene by high-pressure mercury lamp, and yielded directly 5-8-5 fused ring compounds; *cis-cisoid-cis-* and *cis-transoid-cis*-tricyclo[9.3.0.0^{4,8}]tetradecane-2,9-dione (**2** and **3**) and *cis-cisoid-cis*-tricyclo[9.3.0.0^{3,7}]tetradecane-2,9-dione (**4**). The latter compound (**4**) has the same carbon ring skeleton as that of ophiobolin and fusicoccin. The ratio of **2**, **3**, and **4** was approximately 4 : 1 : 2.

The molecular structures of **2**, **3**, and **4** were determined by X-ray analyses.[6] Figure 1 shows perspective views of the molecules and Fig. 2 shows the side views of eight-membered rings. Molecules **3** has a center of symmetry. In these compounds, two five-membered rings are fused to eight-membered ring in a *cis-*



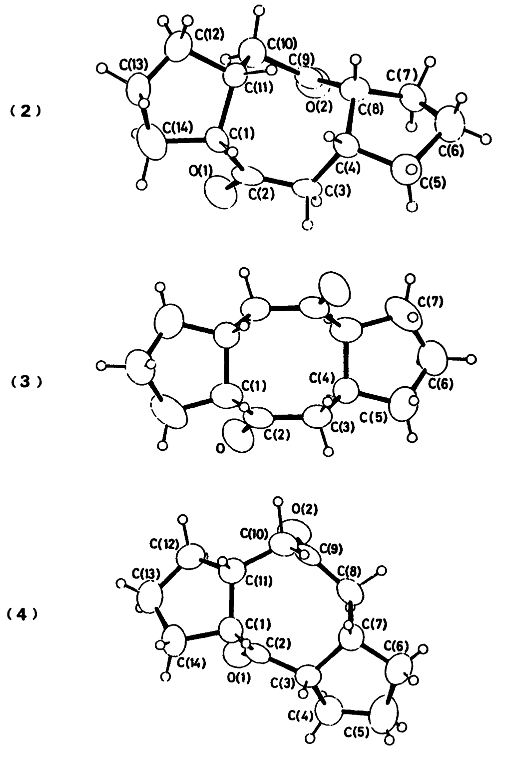


Fig. 1. Perspective views of the molecules **2**, **3**, and **4**.

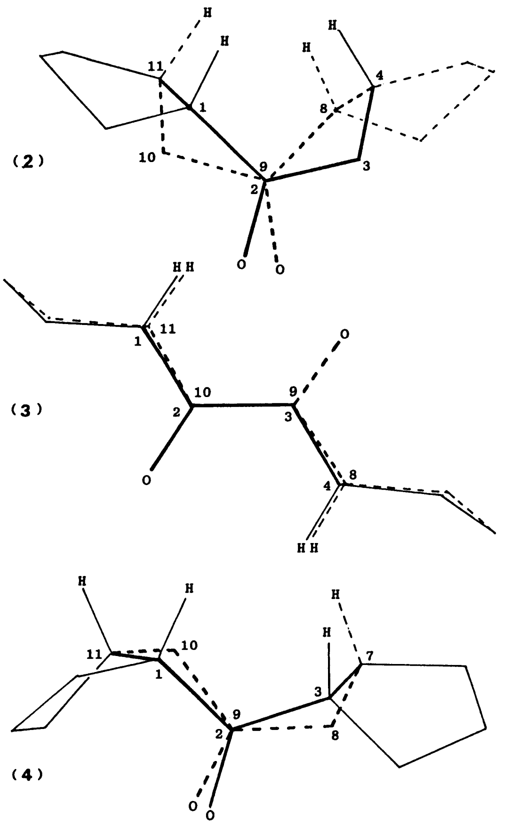


Fig. 2. The side views of the molecules **2**, **3**, and **4**. **2** and **4**: Projections along the C(2)···C(9) vectors. **3**: Projection along the C(2)···C(10) and C(3)···C(9) vectors.

configuration. Consequently, **2** and **4** have a *cis-cisoid-cis* configuration and **3** has a *cis-transoid-cis* configuration. Broadly speaking, two carbonyl groups in **2** and **4** are arranged in parallel orientation, whereas those in **3** take antiparallel orientation.

Cyclooctane, its simple derivatives, and 1,5-cyclooctanedione have been shown to exist predominantly in boat-chair(BC) form,[7] which is the most stable conformation predicted by the molecular mechanics calculations.[8] The X-ray analysis of *trans*-7-bromo-4,4-dimethylbicyclo[6.3.0]undecane-2,6-dione[9] and *trans*-5-bromobicyclo[6.3.0]undecane-2,6-dione[10] revealed that their eight-membered rings in the molecules are BC form. In this study the central eight-membered ring of **4** takes considerably distorted BC form. In contrast the conformations in **2** and **3** are a twist-boat and a chair forms, respectively, and these two conformations are quite unique in 5-8-5 fused ring systems.

Experimental

The IR spectra were recorded on a JASCO IR-G spectrometer. The mass spectra were measured with a Hitachi M-80B mass spectrometer. The GC-analyses were carried out on a 263-50 Hitach gas chromatograph.

Bicyclo[4.3.0]nonane-2,4-dione (1). Sodium (5 g) was dissolved in absolute ethanol (85 ml) with stirring under reflux. To the solution diethyl malonate (36 g) was added; then 1-acetylcyclopentene (22 g) was added dropwise. After being refluxed with stirring for 2 h., a solution of KOH (25 g) in water (140 ml) was added to the reaction mixture, which was refluxed with stirring for 8 h. The hot mixture was acidified with dilute HCl (4 M (1M=1 mol dm^{-3})), and then ethanol was evaporated. The residue was boiled with charcoal (3 g) until no more carbon dioxide was evolved, then again acidified with dil. HCl, and again boiled with charcoal (3 g). The hot mixture was finally acidified (pH<3) with dil. HCl, and boiled for a few minutes. In order to dissolve the resulting oily phase, acetone was added to the mixture, and then boiled and filtered. The filtrate was evaporated under reduced pressure and the residue was crystallized from carbon tetrachloride to give **1** (66% yield): Mp 95—96 °C (from CCl_4); IR (Nujol) 2600 (broad, enol OH), 1610 cm^{-1} (β-diketone C=O); MS *m/z* (rel intensity) 152 (M$^+$, 64), 124 (19), 111 (30), 95 (28), 83 (45), 82 (42), 67 (100), 54 (22), 43 (30). HRMS; Found: *m/z* 152.0845. Calcd for $C_9H_{12}O_2$: M, 152.0837.

Table 1. Mp, IR, and Mass Spectra of **2**, **3**, and **4**

	2	**3**	**4**
Mp θ_m/°C	204—204.5	142—143	96—97
IR (Nujol) $\nu_{C=O}$/cm^{-1}	1690	1690	1685 1700 (sh)
MS (*m/z*)	(rel intensity %)		
220 (M$^+$)	18	39	13
192 (M−28)	3	7	2
178 (M−42)	7	10	2
165 (M−55)	25	28	7
153 (M−67)	100	58	100
152 (M−68)	23	15	55
137 (M−83)	20	19	10
124	80	57	42
111	17	16	37
95	28	28	29
83	44	46	20
81	24	30	25
67	68	100	75
55	35	65	23
41	29	68	26
HRMS (*m/z*)			
Found	220.1461	220.1472	220.1457
Calcd for $C_{14}H_{20}O_2$: M, 220.1464			

***cis-cisoid-cis-* and *cis-transoid-cis*-Tricyclo[9.3.0.0^{4,8}]tetradecane-2,9-dione (2 and 3) and *cis-cisoid-cis*-Tricyclo[9.3.0.0^{3,7}]tetradecane-2,9-dione (4).** A solution of **1** (1 g) in methanol (150 ml) and cyclopentene (20 ml) was irradiated for 10 h.[11] through quartz filter[11] with a 100 W high-pressure mercury lamp at 5 °C in a nitrogen atmosphere. After the irradiation, the solvent was removed under reduced pressure, and a small amount of ether was added in the residue. Immediately, the photoadduct (**2**) was isolated as a crystalline solid, sparingly soluble in ether. **2** was recrystallized from ether-acetone. Subjecting to silica-gel column chromatography of the residual ether solution (eluted with hexane-ether), **3**, **4**, additional amount of **2** and also unreacted starting material (**1**) were obtained. Compounds of **3** and **4** were crystallized from ether-hexane. In a GC-analysis of the reaction mixture the ratio of **2**, **3**, **4**, and **1** was approximately 4 : 1 : 2 : 6. The yield of the photoadducts mixture (**2**, **3**, and **4**) was 40%, based on the starting material consumed. Mp, IR, and MS; (see Table 1).

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6) A full report will be published by S. Okumoto elsewhere. The crystal data and R values are as follows: (**2**) monoclinic, Cc, a=11.994(2), b=5.451(1), c=18.306(2) Å, β=91.49(2)°, V=1196.5(3) Å^3, Z=4, D_x=1.22, D_m=1.21(2) Mg m^{-3}, Mo $K\alpha$, λ=0.71073 Å, μ=0.07 mm^{-1}, R=0.033 for 745 observed unique reflections. (**3**) monoclinic, $P2_1/n$, a=11.761(3), b=9.208(1), c=5.594(1) Å, β=98.02(2)°, V= 599.8(2) Å^3, Z=2, D_x=1.22, D_m=1.19(2) Mg m^{-3}, μ=0.07 mm^{-1}, R=0.048 for 603 reflections. (**4**) monoclinic, $P2_1/n$, a=12.316(2), b=17.833(3), c=5.390(1) Å, β=90.06(2)°, V= 1183.9(4) Å^3, Z=4, D_x=1.24, D_m=1.23(2) Mg m^{-3}, μ=0.08 mm^{-1}, R=0.052 for 1293 reflections.

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11) Although in this period a considerable amount of starting material remained, the irradiation was discontinued because prolonged irradiation reduced the yield of **4**. In this photocycloaddition the rate of reaction through Pyrex filter is very slow, therefore quartz filter was used.