Properties and Cage Lactone Synthesis of Diels-Alder Adducts from 2-Pyrones

Tetsuro Shimo*, Hideki Nagahama, Kiyotaka Yorozu and Kenichi Somekawa*

Department of Applied Chemistry and Chemical Engineering,
Faculty of Engineering, Kagoshima University,
Korimoto, Kagoshima 890, Japan

Received December 12, 1991

New cage lactones were synthesized by the photocyclization of the tricyclodienolactones **1a**, **1b**, **2** which were available from the Diels-Alder reactions of 2-pyrones with *p*-benzoquinones or norbornadiene. Retro-Diels-Alder reactions of cross-adducts between 2-pyrone-mono-adducts and *p*-benzoquinone were also described.

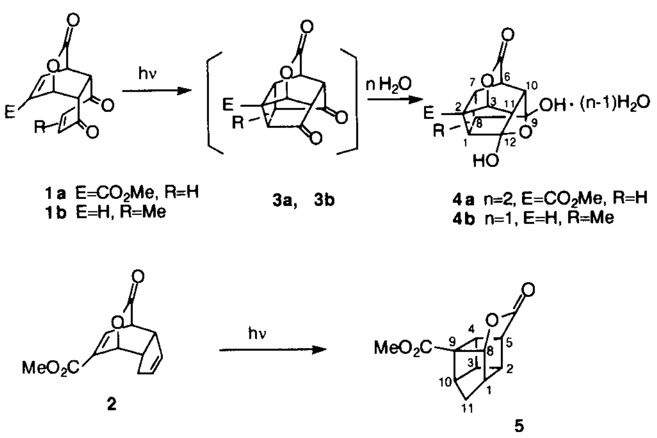
J. Heterocyclic Chem., **29**, 801 (1992).

Considerable interest in the synthesis and thermal cycloreversion of energetic cage compounds has increased during past decade [1]. Pentaprismane, one of them, has been synthesized by way of a cage lactone [2]. Although it is known that the Diels-Alder adducts derived from 2-pyrones are usually labile and susceptible to decarboxylation, methyl 2-pyrone-5-carboxylate (MP) gave rather stable Diels-Alder adducts [3,4]. It may thus open the route to synthesis of a new cage lactone from the stable Diels-Alder adduct derived from MP which carries suitably located two unsaturated bonds, *via* an intramolecular cyclization.

In this paper we report the synthesis of new cage lactones from photocyclization of tricyclodienolactones **1a** [3], **1b** [3], and **2** [5] which were prepared from Diels-Alder reactions of MP with *p*-benzoquinone, that of 2-pyrone with 2-methyl-*p*-benzoquinone, and that of MP with norbornadiene, respectively. In addition, retro-Diels-Alder reactions of cross-adducts, which were expected to give another type of cage compounds, between 2-pyrone-mono-adducts and *p*-benzoquinone are described.

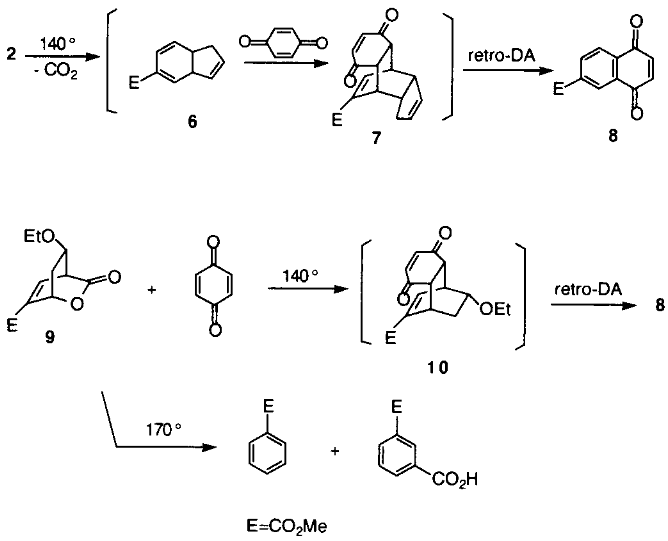
Irradiation of the tricyclodienolactone **1a** in dichloromethane with a 400W high-pressure mercury lamp at room temperature afforded a cage lactone **4a** in 89% yield (Scheme 1). The compound **4a** was assigned as a dihydrate of the initially formed cage lactone **3a**. Such high reactivity of cage compounds having γ-dicarbonyl moiety toward moisture are found in literature [7]. The structural elucidation of **4a** was accomplished on the basis of spectral data: ^{13}C nmr spectrum shows seven tertiary and three quaternary carbons in **4a**. The similar photoreaction of **1b** afforded a cage lactone **4b** in 75% yield. Similarly, tricyclodienolactone **2** gave a cage lactone **5** in 90% yield.

Scheme 1



Since tricyclodienolactones **1** and **2**, having dihydropentene or dihydroquinone moiety, gave cage lactones by the irradiation, we next investigated the synthesis of tetracyclic compound **7** and tricyclic compound **10**, which were also expected to produce the another type of cage compounds, by using diene equivalents **2** and **9** [3] with *p*-benzoquinone. The reaction of **2** with *p*-benzoquinone at 140° gave 6-methoxycarbonyl-1,4-naphthoquinone (**8**) *via* retro-Diels-Alder reaction of the tetracyclic compound **7** (Scheme 2). Similarly, the reaction of **9**, which decomposed at 170° to give methyl benzoate and *m*-methoxycarbonylbenzoic acid [4], with *p*-benzoquinone was hated at 140° to afford **8** *via* similar retro-reaction of **10**. These results sug-

Scheme 2



gest that intended compounds **7** and **10**, being tricyclo[6.2.2.$0^{2,7}$]dodecane-4,9-diene-3,6-diones, are susceptible to retro-Diels-Alder reaction by the ease of aromatization at 140°. The proper precursor of diene and dienophile, and suitable reaction conditions are required for the preparation of cage compounds.

EXPERIMENTAL

All melting points were determined using a Yanagimoto Mel-temp apparatus and are uncorrected. The ir and mass spectra were recorded with JASCO A-3 and JEOL JMS-OISG spectrometers. The ^{1}H and ^{13}C nmr spectra were obtained with JEOL JNM-MH-100 (100 MHz) and JEOL FX-100 (25 MHz) spectrometers using TMS as the internal reference.

Methyl 9,12-dihydroxy-5-oxo-4,13-dioxahexacyclo[6.4.$1^{9,12}$.0.$0^{2,7}$.$0^{3,11}$.$0^{6,10}$]tridecane-2-carboxylate (**4a**).

A solution of **1a** (200 mg, 0.76 mmole) in dichloromethane (20 ml) was irradiated with a Riko merry-go-round type 400W high-pressure mercury lamp for 1.5 hours. The solvent was removed under reduced pressure and the resulting solid was crystallized from ethyl acetate to give **4a** (202 mg, 89%).

Compound **4a** had mp 97-99°; ir (potassium bromide): 3550, 3250, 1780, 1760 cm^{-1}; ^{1}H nmr (acetone-d$_6$): δ = 2.8-3.04 (m, 5H, 1-, 7-, 8-, 10-, 11-H), 3.11 (s, 2H, H_2O), 3.41 (bt, 1H, 6-H, J = 4.0 Hz), 3.81 (s, 3H, Me), 5.22 (d, 1H, 3-H, J = 6.0 Hz), 6.06, 6.56 (each s, 1H, OH); ^{13}C nmr (acetone-d$_6$): δ = 50.8 (2-C), 41.5, 42.9, 45.8, 50.4, 50.8, 51.9 (1-, 6-, 7-, 8-, 10-, 11-C), 52.7 (Me), 80.4 (3-C), 107.1, 111.7 (9-, 12-C), 171.9, 172.0 (C=O); ms: m/z (relative intensity) 262 (M - 2H_2O, 100).

Anal. Calcd. for $C_{13}H_{14}O_8$: C, 52.55; H, 4.70. Found: C, 52.62; H, 4.79.

9,12-Dihydroxy-1(or 8)-methyl-4-,13-dioxahexacyclo[6.4.$1^{9,12}$.0.$0^{2,7}$.$0^{3,11}$.$0^{6,10}$]tridecan-5-one (**4b**).

A solution of **1b** (200 mg, 0.92 mmole) in dichloromethane (20 ml) was irradiated for 1.5 hours. The solvent was removed and the crude residue was crystallized from acetone to give **4b** (162 mg, 75%).

Compound **4b** had mp 175-178°; ir (potassium bromide): 3320, 1740 cm^{-1}; ^{1}H nmr (DMSO-d$_6$): δ = 1.00 (d, 3H, Me), 2.2-2.8 (m, 6H, 1 (or 8)-, 2-, 6-, 7-, 10-, 11-H), 4.90 (bt, 1H, 3-H, J = 6.0 Hz), 7.15, 7.25 (each s, 1H, OH); ms: m/z (relative intensity) 218 (M -H_2O, 100).

Anal. Calcd. for $C_{12}H_{12}O_5$: C, 61.01; H, 5.08. Found: C, 61.27; H, 5.24.

Methyl 6-Oxo-7-oxapentacyclo[6.3.0.$0^{2,5}$.$0^{3,11}$.$0^{4,9}$]undecane-9-carboxylate (**5**).

A solution of **2** (435 mg, 1.98 mmoles) in dry acetone (200 ml) under nitrogen was irradiated with a Riko immersion-type 400W high-pressure mercury lamp through a Pyrex vessel at room temperature for 16 hours. The solvent was removed under reduced pressure. The residue was chromatographed on a silica gel column with cyclohexane-ethyl acetate 5:1 v/v mixture to give **5** (390 mg, 90%).

Compound **5** was obtained as an oil; ir (neat): 1755, 1730 cm^{-1}; ^{1}H nmr (deuteriochloroform): δ = 1.68, 1.90 (each bd, 1H, CH_2), 2.76-3.3 (m, 6H, 1-, 2-, 3-, 4-, 5-, 10-H), 3.70 (s, 3H, Me), 5.06 (bs, 1H, 8-H); ^{13}C nmr (deuteriochloroform): δ = 34.4 (11-C), 36.5, 39.0, 39.3, 39.9, 40.5, 48.9 (1-, 2-, 3-, 4-, 5-, 10-C), 46.8 (9-C), 52.3 (Me), 84.5 (8-C), 170.5, 172.1 (C=O); ms: m/z (relative intensity) 220 (M$^+$, 11), 66 (100).

Anal. Calcd. for $C_{12}H_{12}O_4$: C, 65.45; H, 5.45. Found: C, 65.30; H, 5.45.

The Reaction of **2** with *p*-Benzoquinone and that of **9** with *p*-Benzoquinone.

A solution of **2** (0.44 g, 2.0 mmoles) and *p*-benzoquinone (0.26 g, 2.4 mmoles) in xylene (30 ml) was refluxed for 18 hours, and the usual workup afforded 39 mg (9%) of 6-methoxycarbonyl-1,4-naphthoquinone (**8**) (mp 98-100°) (lit [8], 97-98°). Similarly, the reaction of **9** (0.45 g, 2.0 mmoles) with *p*-benzoquinone (0.26 g, 2.4 mmoles in xylene (30 ml) under reflux for 20 hours gave **8** (117 mg, 27%).

REFERENCES AND NOTES

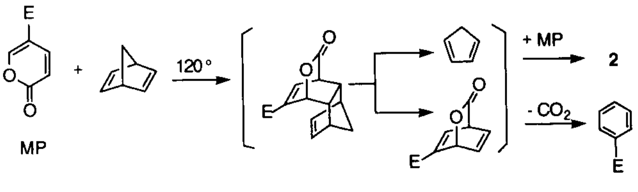
[1a] T. Hamada, H. Iijima, T. Yamamoto, N. Numao, K. Hirao and O. Yonemitsu, *J. Chem. Soc., Chem. Commun.*, 696 (1980); [b] A. P. Marchand and S. C. Suri, *J. Org. Chem.*, **49**, 2041 (1984); [c] Y. Yamashita and T. Mukai, *Chem. Letters*, 1741 (1984).

[2] P. Eaton, Y. S. Or and S. J. Branca, *J. Am. Chem. Soc.*, **103**, 2134 (1981).

[3] T. Shimo, K. Somekawa and S. Kumamoto, *Nippon Kagaku Kaishi*, 1927 (1982); *Chem. Abstr.*, **98**, 125817b (1983).

[4] T. Shimo, K. Somekawa, M. Sato and S. Kumamoto, *Nippon Kagaku Kaishi*, 1927 (1984); *Chem. Abstr.*, **102**, 149041w (1985).

[5] The tricyclodienolactone **2** (mp 121-123°) (lit [6], 123-124°) was previously prepared by the Diels-Alder reaction of MP with cyclopentadiene. We have also found that the reaction of MP with norbonadiene gave **2** in 37% yield, together with methyl benzoate in 47% yield. The formation of **2** can be explained *via* novel retro-Diels-Alder reaction of initially formed Diels-Alder adduct, followed by the Diels-Alder reaction of MP with generated cyclopentadiene as depicted below. These facts mean MP is a very reactive diene moiety, whose feature was also suggested from the fact that 4,6-dimethyl-2-pyrone did not reacted with norbonadiene at 160°, and this adduct from norbornadiene is labile.



E=CO$_2$Me

[6] T. Imagawa, N. Sueda and M. Kawanishi, *Tetrahedron*, **30**, 2227 (1974).

[7] Y. Okamoto, K. Harano, M. Yasuda, E. Osawa and K. Kanematus, *Chem. Pharm. Bull.*, **31**, 2526 (1983).

[8] M. U. Akpuaka, R. L. Beddoes, J. M. Bruce, S. Fitzjohn and O. S. Mills, *J. Chem. Soc., Chem. Commun.*, 686 (1982).