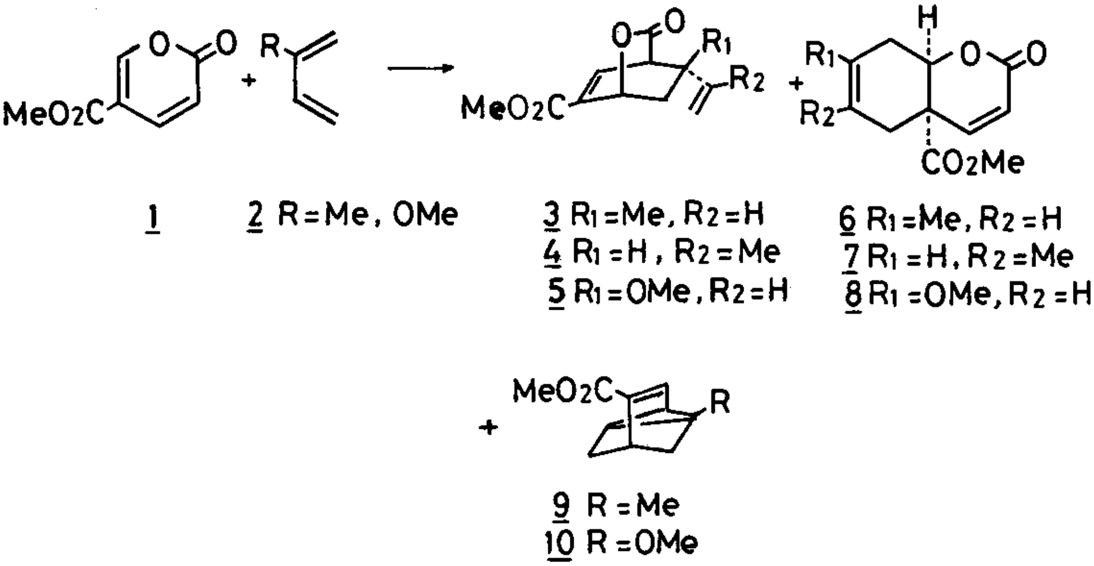
THERMAL CONVERSION OF METHYL 8-VINYL-3-OXO-2-OXABICYCLO[2.2.2]-OCT-5-EN-6-CARBOXYLATES TO TETRAHYDROCOUMARINS AND METHYL BENZOATES

Takanao Matsui,* Yoh-ichi Matsushita, and Mitsuru Nakayama+
Faculty of Engineering, Miyazaki University, Gakuen-Kibanadai,
Miyazaki 889-21, Japan
+Department of Agricultural Chemistry, University of Osaka
Prefecture, Sakai, Osaka 591, Japan

Abstract — Methyl 8-methyl- and 8-methoxy-8-vinyl-3-oxo-2-oxabicyclo[2.2.2]oct-5-en-6-carboxylates (3 and 5), prepared by the Diels-Alder reaction of methyl 2-oxo-2*H*-pyran-5-carboxylate with 2-methyl- and 2-methoxy-1,3-butadienes, were converted into methyl 9-methyl- and 9-methoxy-3-oxo-2-oxabicyclo[4.4.0]deca-4,8-diene-6-carboxylates (tetrahydrocoumarins) by a Cope rearrangement at about 140°C, respectively. On the other hand, 3 and 5 were transformed into methyl 4-isopropyl- and 4-acetylbenzoates *via* the reaction of methyl tricyclo[3.2.1.0^{2,7}]oct-3-en-4-carboxylates at about 257°C in the presence of Pd-C, respectively.

In a previous paper,[1] we reported that the Diels-Alder reaction of methyl 2-oxo-2*H*-pyran-5-carboxylate (1) with 2-methyl- and 2-methoxy-1,3-butadienes afforded three types of the products such as 3-oxo-2-oxabicyclo[2.2.2]octenes (3-5), 3-oxo-2-oxabicyclo[4.4.0]decadienes (tetrahydrocoumarins) (6-8), and tricyclo[3.2.1.0^{2,7}]octenes (9-10) (Scheme 1). However, the combined yields and the ratio between the the products were seriously changed with reaction temperature since

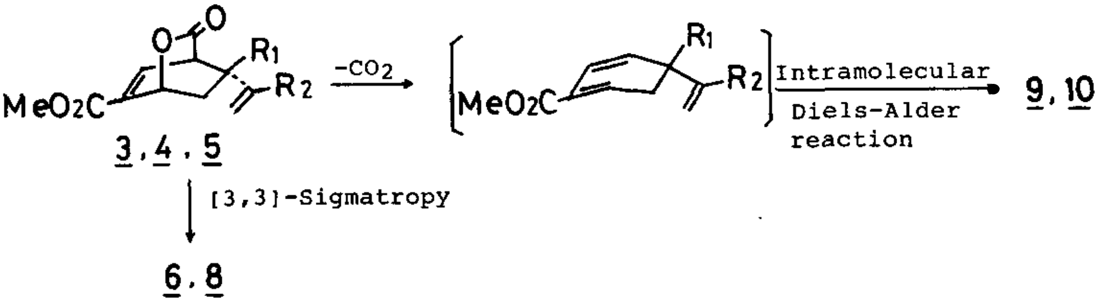


Scheme 1

further conversion of these initial adducts occurred under applied conditions. From the viewpoint of the molecular structure and the thermal conversion, our interests were focused on the transformation of 3-5 into 6-8 by [3,3]-sigmatropic reaction since these compounds involve a strained structure bearing two allyl moieties. Herein, we report the conversion reactions of 3-5 such as intramolecular sigmatropic rearrangement and pericyclic decarboxylation followed by cycloaddition reaction to give 6, 8, 9, and 10 and further conversion of 9 and 10 to methyl benzoates.

RESULTS AND DISCUSSION

A mixture of regioisomers (6) and (7) was prepared by the Diels-Alder reaction of 1 with isoprene,[1,2a,3] but the each single compound has not, hitherto, been obtained. When a *m*-xylene solution of 3 was heated at ca. 140°C for 4 h, two compounds (6) and (9) [2a] were produced and then separation of this mixture by column chromatography afforded 6 as pure crystals in 21% yield and 9 as colorless oil in 26% yield. Likewise, the reaction of 5 provided 8 in 14% yield, together with 10 in 28% yield. But attempts to obtain the desired tetrahydrocoumarin (7) from 4 were unsuccessful, leading to most of 9 and/or the starting material. A pathway for the formation of 9 from 3 or 4 and of 10 from 5 can be explained on the basis of that for the conversion reaction of methyl 8-vinyl-3-oxo-2-oxabicyclo[2.2.2]oct-5-en-6-carboxylate to the corresponding tricyclo[3.2.1.0^{2,7}]octene compound proposed by Imagawa (Scheme 2).[2] On the other hand, the formation of 6 from 3 and of 8 from 5 is considered that it was likely produced through [3,3]-sigmatropic rearrangement. A poor yield or no formation of tetrahydrocoumarin via the [3,3]-sigmatropy in 3-5 may be due to a severe ring strain and the steric hindrance of the methyl group in the case of 4 in the transition state, as depicted in Figure 1; the transition state leading to the product must be boat-like form which is generally less favorable than chair-like form, as can be judged from a symmetry-allowed [3,3]-sigmatropic shift.[4] The earlier report demonstrated that the thermal reaction of di-



Scheme 2

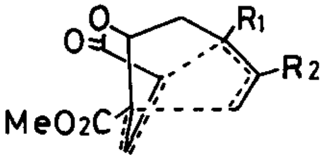


Figure 1

methyl tricyclo[3.2.1.$0^{2,7}$]oct-3-en-2,4-dicarboxylate over Pd-C gave dimethyl 4-ethylisophthalate.[2b] We similarly treated 9 and 10 with 10% Pd-C in diphenyl ether at ca. 257°C for 4 h and obtained methyl 4-isopropylbenzoate in 32% yield and methyl 4-acetylbenzoate in 27% yield, respectively. Thus, we have observed that methyl 4-substituted benzoates are accessible from methyl 8-vinyl-3-oxo-2-oxabicyclo[2.2.2]-oct-5-en-6-carboxylates *via* methyl tricyclo[3.2.1.$0^{2,7}$]oct-3-en-4-carboxylates.

EXPERIMENTAL SECTION

Melting points are uncorrected. Ir spectra were measured in $CHCl_3$ on a Hitachi 270-30 spectrophotometer. Nmr spectra were recorded on a Hitachi R-1500 spectrometer for ^1H and a Bruker AC 250P spectrometer for ^{13}C in $CDCl_3$ with TMS as an internal standard unless otherwise specified.

Conversion of 3 and 5.

From 3: A solution containing 100 mg (0.45 mmol) of 3 in 20 ml of *m*-xylene was stirred at 139-140°C for 4 h under a nitrogen atmosphere. The solvent was removed in vacuo, and the residue was chromatographed on silica gel with hexane-ethyl acetate (95:5) as an eluent to give 6 (21 mg; 21% yield) and 9[2a] (21 mg; 26% yield), along with the recovered 3 (31 mg). 6: mp 61.5-62.5°C (acetone-hexane); ir 1730 cm^{-1}; ^1H nmr δ=1.69 (3H, d, J=1.2 Hz, $-CH_3$), 1.8-3.0 (4H, m, $-CH_2-$ x2), 3.76 (3H, s, $-CO_2CH_3$), 5.00 (1H, t, J=4.3 Hz, $-\overset{|}{C}H-$), 5.3-5.7 (1H, m, $-CH=\overset{|}{C}-$), 6.03 and 6.93 (each 1H, d, J=10.0 Hz, $-CH=CH-$); ^{13}C nmr δ=22.91, 31.14, 33.67, 45.75, 52.97, 76.01, 117.68, 120.89, 131.20, 149.73, 163.42, 171.84; ms m/z 222 (M^+); Found: m/z 222.0887. Calcd for $C_{12}H_{14}O_4$: M, 222.0892. 9: Colorless oil; ir 1700, 1620 cm^{-1}; ^1H

nmr (CCl_4) δ=0.68 (2H, d, J=11 Hz, methylene-H_{ex} x2), 1.30 (3H, s, CH_3), 1.4-1.9 (4H, m, methylene- and methyne-H), 3.06 (1H, dd, J=8 and 2 Hz, $-\overset{|}{C}H-$), 3.52 (3H, s, $-CO_2CH_3$), 6.76 (1H, dd, J=6 and 2 Hz, $-CH=\overset{|}{C}-$) ; ^{13}C nmr δ=18.12, 25.00, 25.17, 26.18, 28.59, 32.64, 34.37, 51.28, 130.26, 137.23, 165.68; ms m/z 178 (M^+); Found: m/z 178.1004. Calcd for $C_{11}H_{14}O_2$: M, 178.0994. These were almost identical with the reported spectral data.[2a]

From 5: A similar procedure as described above [5 200 mg (0.84 mmol), *m*-xylene 20 ml, 139-140° C, 4 h] gave 8[1] (28 mg; 14% yield) and 10 (45 mg; 28% yield) together with 1 (60 mg). 10: Colorless viscous oil; ir 1700, 1620 cm^{-1}; ^1H nmr δ=0.72 and 1.19 (each 1H, d, J=13 Hz, methylene-H_{ex}), 1.73 and 1.9-2.2 (each 1H and 3H, m, methylene- and methyne-H), 3.2-3.3 (1H, m, $-\overset{|}{C}H-$), 3.33 (3H, s, $-OCH_3$), 3.83 (3H, s, $-CO_2CH_3$), 7.20 (1H, dd, J=5 and 2 Hz, $-CH=\overset{|}{C}-$); ^{13}C nmr δ=24.04, 24.56, 26.38, 27.03, 32.10, 51.33, 56.40, 72.90, 130.99, 135.92, 165.42; ms m/z 194 (M^+); Anal. Calcd for $C_{11}H_{14}O_3$: C, 68.02; H, 7.27. Found: C, 68.03; H, 7.23.

Conversion of 9 and 10.

From 9: A mixture of 175 mg (0.98 mmol) of 9 and 18 mg of 10% Pd-C in 1.5 g of diphenyl ether was heated at reflux for 4 h under a nitrogen atmosphere. Removal of the Pd-C by filtration followed by column chromatography on silica gel using hexane-benzene (70:30 and 40:60) as an eluent afforded methyl 4-isopropylbenzoate (56 mg; 32% yield); colorless oil; ir 1710, 1600 cm^{-1}; ^1H nmr (CCl_4) δ=1.26 (6H, d, J=8 Hz, $-CH(CH_3)_2$), 2.91 (1H, sept, J=8 Hz, $-CH(CH_3)_2$), 3.82 (3H, s, $-CO_2CH_3$), 7.16 and 7.86 (each 2H, d, J=9 Hz, Ar-H). These were identical with the spectral data of the compound derived from commercially available 4-isopropylbenzoic acid.

From 10: A similar procedure as described above [10 192 mg (1.0 mmol), 10% Pd-C 100 mg, diphenyl ether 2.1 g, reflux, 4 h] afforded 52 mg (27% yield) of methyl 4-acetylbenzoate; mp 95-97°C (aqueous methanol); ir 1730, 1700, 1620, 1580 cm^{-1}; ^1H nmr δ=2.65 (3H, s, $-COCH_3$), 3.96 (3H, s, $-CO_2CH_3$), 7.98 and 8.16 (each 2H, d, J=9 Hz, Ar-H). These were identical with the spectral data of the compound (mp 100-101°C) derived from commercially available 4-acetylbenzoic acid.

ACKNOWLEDGEMENTS

We are grateful to the Research Center for Material Analysis in Miyazaki University for the use of ^{13}C nmr apparatus, and to Mr. Yoshinori Minami, Taiho Pharmaceutical Co., Ltd., for the mass measurement.

REFERENCES

1. T. Matsui, S. Kitajima, and M. Nakayama, Bull. Chem. Soc. Jpn., 1988, 61, 316.
2. a) T. Imagawa, N. Sueda, and M. Kawanisi, Tetrahedron, 1974, 30, 2227.
   b) T. Imagawa, T. Nakagawa, M. Kawanisi, and K. Sisido, Bull. Chem. Soc., Jpn., 1979, 52, 1506.
3. G. A. Kraus and K. Frazier, J. Org. Chem., 1980, 45, 4820; B. A. Brown and E. W. Colvin, J. Chem. Soc., Chem. Commun., 1984, 1514.
4. R. B. Woodward and R. Hoffmann, "The Conservation of Orbital Symmetry," Verlag Chemie, Weinheim, 1970.

Received, 2nd December, 1991