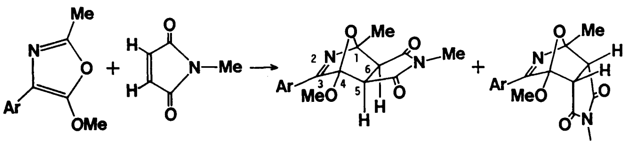
Molecular Structure of the exo-Diels-Alder-Adduct of 5-Methoxy-2-methyl-4-(*p*-nitrophenyl)oxazole with *N*-Methylmaleimide

Toshikazu Ibata,* Jiro Toyoda, Hatsue Tamura, and Kazuhide Ogawa
Institute of Chemistry, College of General Education, Osaka University,
Toyonaka, Osaka 560

(Received June 24, 1986)

Synopsis. The molecular structure of the exo-Diels–Alder adduct of 5-methoxy-2-methyl-4-(*p*-nitrophenyl)oxazole with *N*-methylmaleimide was determined by X-ray analysis. The crystals are triclinic, space group $P\bar{1}$, with a=9.160(2), b=11.182(2), c=8.816(1) Å, α=92.39(1), β=116.47(1), γ=100.60(1)°, Z=2, D_x=1.455 Mg m^{-3}, D_m=1.458 Mg m^{-3}, μ(Cu $K\alpha$)=9.76 cm^{-1}. The configuration of the exo-adduct is consistent with that predicted on the basis of the NMR data.

The Diels–Alder reaction is one of the most useful reactions in organic synthesis, and widely studied for the preparation of six-membered compounds.[1] Oxazoles have a conjugate azadiene system and are available for the diene component of the Diels–Alder reaction to prepare nitrogen-containing bicyclic compounds.[2,3] In these cycloadditions, the determination of the stereochemistry of the adducts is indispensable from the synthetic and mechanistic view points. However, because of the extreme unstability of the Diels–Alder adducts of oxazoles, no structural determination has been studied yet. The authors have reported that the reaction of 5-methoxy-2-methyl-4-(*p*-nitrophenyl)oxazole (**1**) and *N*-methylmaleimide (**2**) gave two adducts, **3** and **4**, in 32 and 58% yields, respectively.[3] The structures of **3** and **4** were determined tentatively to exo- and endo-adducts on the basis of NMR spectra. The high-field shift of N-CH_3 signal of the adduct (**4**) at δ 2.55, in comparison with that of **3** at δ 3.04, was attributed to the shielding effect of *p*-nitrophenyl group located near the N-CH_3. In this manner **4** was assumed to have endo-structure and **3** to have exo-structure.[3] In order to confirm the above assumption we performed X-ray analysis of the adduct. Of these two adducts endo-adduct (**4**) was found difficult to obtain good crystals for X-ray analysis because of its unstability owing to the retro-Diels–Alder reaction.



1 **2** **3** (exo) **4** (endo)

Ar=p-$NO_2C_6H_4$

Experimental

The Diels–Alder reaction of **1** and *N*-methylmaleimide was carried out by the method previously described.[3] Colorless crystals of the exo-adduct (**3**) were obtained by the several recrystallizations from a mixed solvent of benzene and hexane after the separation of the reaction products by silica-gel column chromatography.

The cell dimensions and diffraction intensities were measured on a Rigaku four-circle diffractometer with Ni-filtered Cu $K\alpha$ radiation. Among 2338 independent reflections with 2θ values up to 120°, 2294 with $|F_o|>0$ were used for the structure determination. No correction was made for absorption.

The structure was solved by the MULTAN 80 program.[4] The positions of the hydrogen atoms were obtained from the difference Fourier synthesis. The structural parameters were obtained by the block-diagonal least-squares method. Anisotropic thermal parameters were applied to the non-hydrogen atoms and isotropic parameters, to the hydrogen atoms. The final R values was 0.046. The function minimized was $\sum w(|F_o|-|F_c|)^2$ with the following weighting scheme: $w=(\sigma^2(F_o)+0.0072|F_o|+0.0009|F_o|^2)^{-1}$.

All the atomic scattering factors were taken from the "International Tables for X-Ray Crystallography".[5] The computations were carried out on an ACOS-850 computer at the Crystallographic Research Center, Institute for Protein Research Laboratory, Osaka University, using "The

Table 1. Atomic Positional (× 10^4) and Thermal Parameters for exo-Adduct (**3**)

Atom	x	y	z	B_{eq}/Å^2
O1	766(1)	3878(1)	1337(2)	3.3
O2	−139(2)	1766(1)	365(2)	3.9
O3	3962(2)	6123(1)	325(2)	5.1
O4	880(2)	2330(2)	−2425(2)	5.7
O5	4924(2)	−954(2)	8595(2)	6.1
O6	3582(3)	−2242(2)	6325(2)	7.9
N1	2962(2)	3846(1)	3967(2)	3.5
N2	2205(2)	4346(2)	−1370(2)	4.0
N3	4018(2)	−1209(2)	7061(2)	4.5
C1	2417(2)	4563(2)	2510(2)	3.2
C2	3456(2)	4289(2)	1573(2)	3.2
C3	3277(2)	5060(2)	168(2)	3.7
C4	1734(2)	3121(2)	−1224(2)	4.0
C5	2518(2)	2977(2)	657(2)	3.4
C6	1201(2)	2709(2)	1331(2)	3.3
C7	2250(2)	2733(2)	3277(2)	3.3
C8	2456(3)	5871(2)	2981(3)	4.0
C9	1707(3)	4825(3)	−2995(3)	5.4
C10	−1409(3)	1570(2)	929(3)	5.2
C11	2609(2)	1681(2)	4223(2)	3.3
C12	3478(2)	1902(2)	6008(2)	3.7
C13	3925(3)	957(2)	6945(2)	3.8
C14	3489(2)	−212(2)	6066(2)	3.6
C15	2604(3)	−474(2)	4309(3)	4.2
C16	2157(3)	488(2)	3383(2)	4.0

Universal Crystallographic Computing System-Osaka".[6] Table 1 lists the final atomic coordinates with equivalent isotropic temperature factors.[7]

Results and Discussion

Molecular Structure. The perspective view of the adduct (**3**) determined by the X-ray analysis is depicted in Fig. 1. The molecule has the exo-structure as has

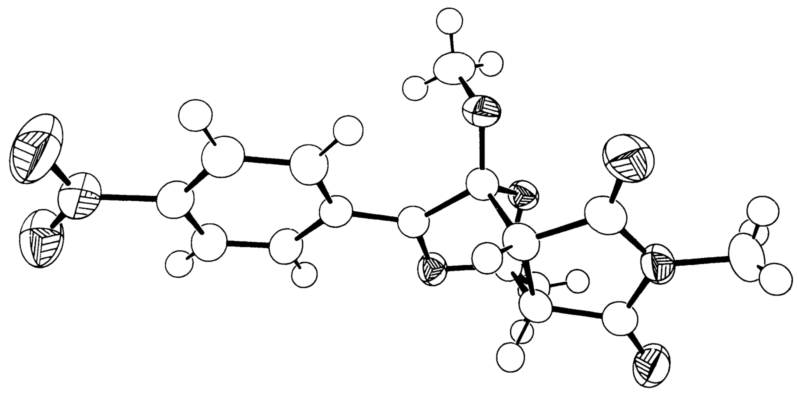
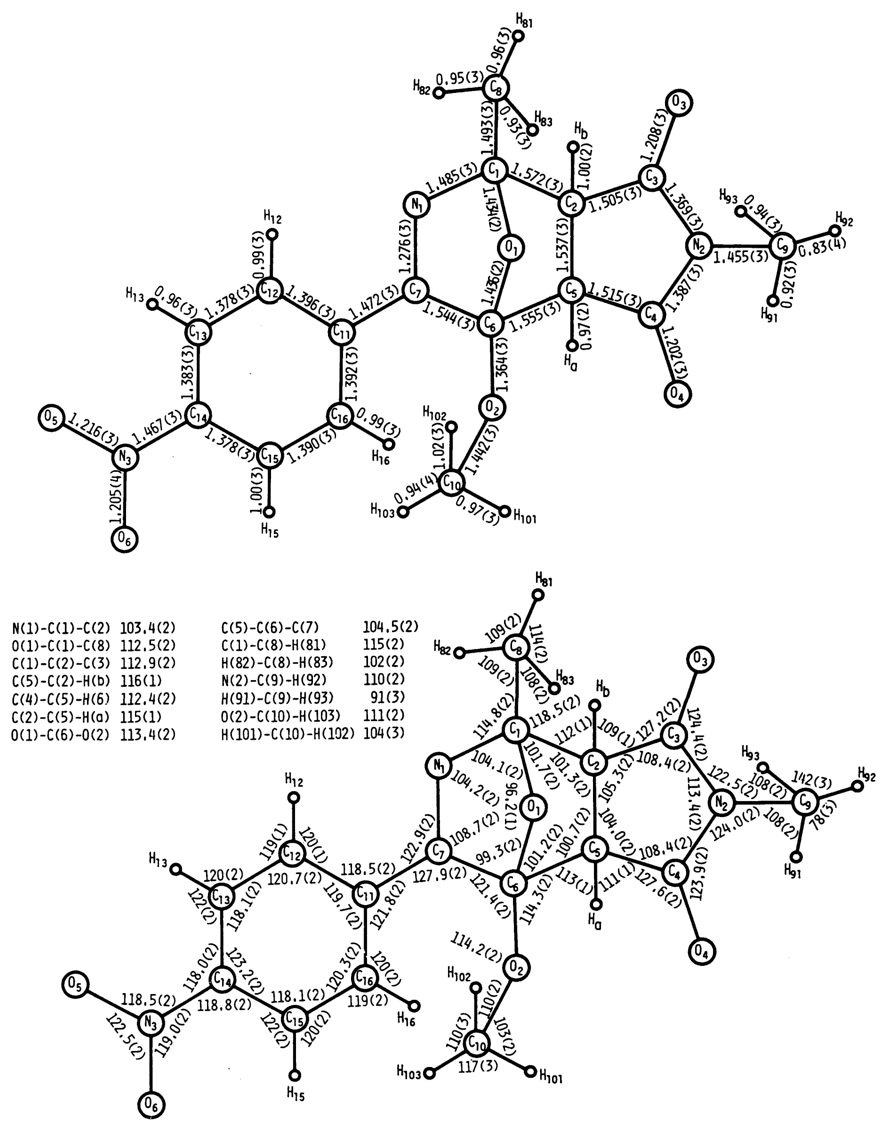


Fig. 1. Perspective view of the exo-adduct (**3**).

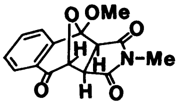


N(1)-C(1)-C(2)	103.4(2)	C(5)-C(6)-C(7)	104.5(2)
O(1)-C(1)-C(8)	112.5(2)	C(1)-C(8)-H(81)	115(2)
C(1)-C(2)-C(3)	112.9(2)	H(82)-C(8)-H(83)	102(2)
C(5)-C(2)-H(b)	116(1)	N(2)-C(9)-H(92)	110(2)
C(4)-C(5)-H(6)	112.4(2)	H(91)-C(9)-H(93)	91(3)
C(2)-C(5)-H(a)	115(1)	O(2)-C(10)-H(103)	111(2)
O(1)-C(6)-O(2)	113.4(2)	H(101)-C(10)-H(102)	104(3)

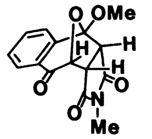
Fig. 2. Bond lengths (l/Å) and angles (ϕ/°).

been deduced on the basis of the NMR data. Bond distances and angles are given in Fig. 2.

The bond lengths and bond angles of *N*-methyltetrahydrofuran-3,4-dicarboximide ring system of the adduct (**3**) agree fairly well with those of the corresponding parts of the exo-(**5**) and endo-adduct (**6**) between *N*-methylmaleimide and 1-methoxy-2-benzopyrylium-4-olate[8] except for the following points. The bond lengthes, O(1)–C(1) and O(1)–C(6) of **3** are equal within the limits of experimental errors, while the differences between the corresponding bonds in the exo- and endo-adducts (**5** and **6**) are regarded as significant. The observation that the C(1)–O(1)–C(6) bond angle (96.2°) of **3** is smaller than those of **5** (104.1°) and **6** (105.0°) may be ascribed to the difference of the ring system which consists of a five-membered ring in **3** in contrast to a six-membered rings in **5** and **6**.



5



6

There is no appreciable interaction between the hydrogen atoms of the methoxyl group and the bridged oxygen atom, while the corresponding intramolecular distances in the exo-2:1-adduct between 1-methoxy-2-benzopyrylium-4-olate and acenaphthylene are shorter than the van der Waals distance.[10] The intramolecular distance (2.49 Å) between imide-carbonyl oxygen O(4) and one of the *N*-methyl hydrogen H(91) is shorter than the van der Waals distance. The torsion angle C(13)–C(14)–N(3)–O(5) is 6°, which is comparable to some of the corresponding torsion angles of the nitrobenzene derivatives.[11]

Coupling Constant and Ring-Current Effect. The coupling constant between the vicinal protons of the exo-adduct (**3**) $J_{5,6}$=6.3 Hz is consistent with the calculated value (8.19 Hz) according to the Karplus's Equation.[9] The distance (4.40 Å) between imide-methyl group and bridged oxygen in **3** is far enough to cause the anisotropic deshielding effect of bridged oxygen on chemical shift of *N*-methyl group. In fact, chemical shift of *N*-methyl of **3**, δ 3.04, is quite similar to the value of *N*-methylsuccinimide (δ 2.98). Therefore, the value of chemical shift (δ 2.55) of the endo-adduct (**4**) may be attributed to the anisotropic shielding effect of a *p*-nitrophenyl group located near the *N*-methyl group; that is distance between the *N*-methyl carbon and the center of phenyl group is approximated to 4.5 Å by the CPK model inspection of **4**.

References

1) J. Sauer, *Angew. Chem. Internat. Edit.*, **5**, 211 (1966); J. Sauer, *ibid*, **6**, 16 (1967); D. L. Boger, *Tetrahedron*, **39**, 2869 (1983).

2) T. Naito, K. Ueno, M. Sano, Y. Omura, I. Itoh, and F. Ishikawa, *Tetrahedron Lett.*, **1968**, 5767.

3) T. Ibata, S. Nakano, H. Nakawa, J. Toyoda, and Y. Isogami, *Bull. Chem. Soc. Jpn.*, **59**, 433 (1986).

4) P. Main, S. J. Fiske, S. E. Hull, L. Lessinger, G. Germain, J-P. Declercq, and M. M. Woolfson, "MULTAN 80. A System of Computer Programs for the Automatic Solution of Crystal Structures from X-Ray Diffraction Data," Univ. of York, England and Louvain, Belgium (1980).

5) "International Tables for X-Ray Crystallography," Kynoch Press, Birmingham (1974), Vol IV, p. 71.

6) T. Ashida, "HBLS V, p. 53 and DAPH, p. 61, The Universal Crystallographic Computing System-Osaka", The Computation Center, Osaka University (1979).

7) The F_o and F_c tables, anisotropic temperature factors, and hydrogen positional and isotropic thermal parameters are kept as Document No. 8650 at the Chemical Society of Japan.

8) H. Tamura, T. Ibata, and K. Ogawa, *Bull. Chem. Soc. Jpn.*, **57**, 926 (1984).

9) M. Karplus, *J. Chem. Phys.*, **30**, 15 (1959).

10) J. Toyoda, T. Ibata, H. Tamura, K. Ogawa, T. Nishino, and M. Takebayashi, *Bull. Chem. Soc. Jpn.*, **58**, 2212 (1985).

11) T. C. W. Mark and J. Trotter, *Acta Crystallogr.*, **18**, 68 (1965); P. Coppens, G. M. J. Schmidt, *Acta Crystallogr.*, **18**, 654 (1965); A. T. McPhail, G. A. Sim, *J. Chem. Soc.*, **1965**, 227; E. G. Boonstra, *Acta Crystallogr.*, **16**, 816 (1963).