STRUCTURAL DETERMINATION OF THE OZONIDES DERIVED FROM MONO-SUBSTITUTED ALKENES

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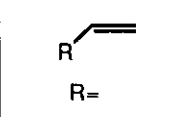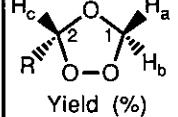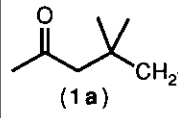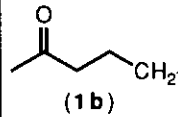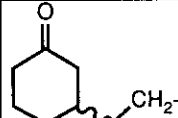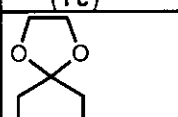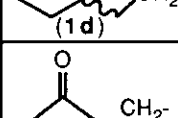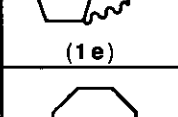Institute of Chemistry, Academia Sinica, Nankang, Taipei 11529, Taiwan, R. O. C.

Abstract — The structures of 1,2,4-trioxolanes (ozonides) (2a-2f) derived from mono-substituted alkenes (1a-1f), respectively, were determined by spectroscopic methods, such as [1]H-nmr, ^{13}C-nmr, ir, two-dimensional nmr, and mass spectra. The coupling constant of the geminal protons on the trioxolane ring is zero. This unusual coupling constant resulted from the electronegativity of two oxygen atoms near the geminal protons.
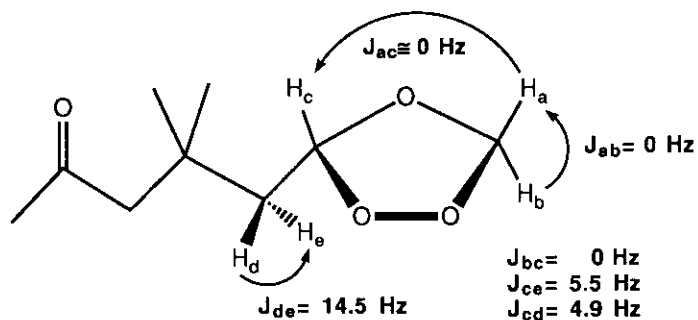
The ozonolysis is an important reaction to cleave the C=C double bond. The resulted ozonide was usually treated with reducing agents _in situ_ to give the corresponding alcohols or carbonyl compounds.[1,2] Occasionally, ozonides were isolated and characterized for mechanistic studies.[3-5] Recently, we found that ozonides could react directly with stabilized phosphorus ylides to form α,β-unsaturated esters or ketones in high yield.[6] During the course of this study, we make an effort in the isolation and the structural determination of these ozonides. These ozonides were isolable and stable in the refrigerator for several weeks. The structures of ozonides had been studied by low temperature infrared studies,[7,8] microwave spectra,[9] and nmr descriptions.[10-12] However, the detail descriptions of their spectroscopic data for a series of related compounds are still not available. In this communication, we would like to describe the detail of our work in this area.

The conjugate allylation of α,β-unsaturated ketones with allyltrimethylsilane in the presence of titanium tetrachloride afforded the corresponding δ,ϵ-unsaturated ketones (1a-1f) in high yield.[13,14] The typical procedure for the preparation of ozonides (2a-2f) was described as follows. In a 100 ml two-neck flask, equipped with a magnetic stirrer, a drying tube and a gas dispersion tube (with porous fritted tip), were placed 57 ml of dichloromethane and

Table 1 : Yields of The Ozonides Formation And Characteristic Chemical Shifts of The Ozonides

R=	Yield (%)	H^1-nmr δ (CDCl$_3$)			C^{13}-nmr δ (CDCl$_3$)	
		H_a	H_b	H_c	C^2	C^1
(1a)	93 (2a)	4.98(s)	5.18(s)	5.17(t) J=5.3 Hz	101.93	93.56
(1b)	93 (2b)	5.04(s)	5.14(s)	5.17(t) J=5.1 Hz	103.33	93.91
(1c)	95 (2c)	5.04(s)	5.18(s)	5.19(t) J=5.0 Hz	101.88	93.58
(1d)	94 (2d)	5.02(s)	5.18(s)	5.19(t) J=5.0 Hz	102.64	93.73
(1e)	90 (2e)	5.15(s)	5.18(s)	5.20(t) J=5.0 Hz	102.43	93.89
(1f)	90 (2f)	5.03(s)	5.19(s)	5.12(t) J=5.0 Hz	103.73	93.86

Figure 1 : The Characteristic Coupling Constants of Compound (2a)

$J_{ac} \cong 0$ Hz

$J_{ab} = 0$ Hz

$J_{bc} = 0$ Hz
$J_{ce} = 5.5$ Hz
$J_{cd} = 4.9$ Hz

$J_{de} = 14.5$ Hz
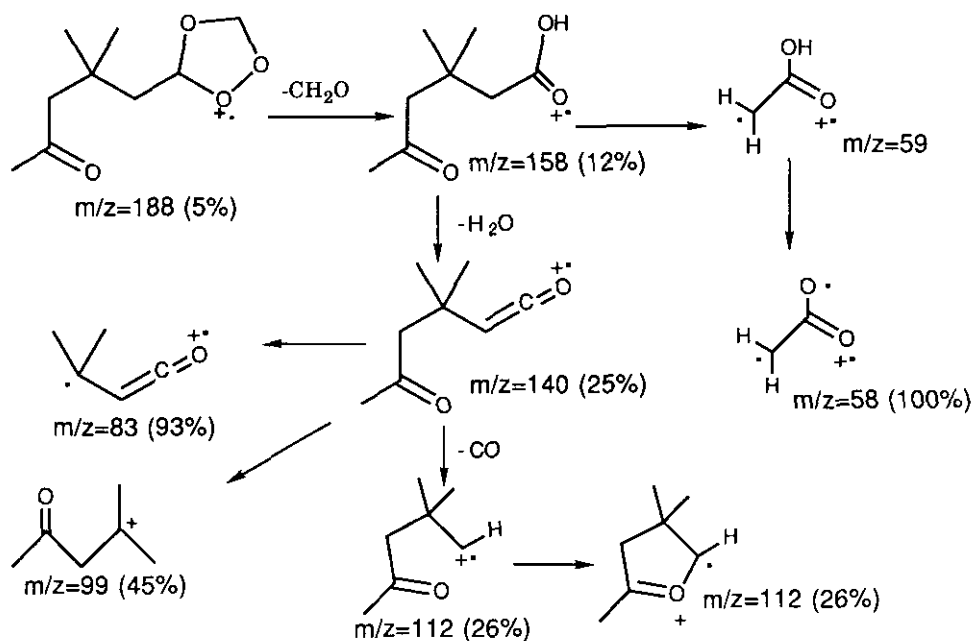
alkene (1a) (807 mg, 5.75 mmol). A stream of ozone was bubbled through the solution at -78°C. Ozone treatment was terminated when the solutions assumed a blue color. Excess ozone was removed by a stream of nitrogen. The reaction mixtures was then allowed to warm up to room temperature and concentrated to give the crude residues, which were chromatographed on silica gel to give 1.01 g of colorless oil (2a) in 93 % yield. All of compounds (2a-2f) are colorless oil and their odor is something like disinfectant or hypochlorite.(Table 1)

The methine proton (H_c) of 1,2,4-trioxolane ring of compound (2a) has the expected triplet splitting due to the adjacent methylene group.(δ 5.17 (1H, t, J=5.3 Hz)) The geminal methylene protons near the trioxolane ring (H_d and H_e) appeared as octet (δ 1.81 (1H, ABqd, J_{AB}= 14.5 and 5.5 Hz) and δ 1.94 (1H, ABqd, J_{AB}= 14.5 and 4.9 Hz)). Surprisingly, the ring geminal protons (H_a and H_b) appear as separate singlets (δ 5.01 (s, 1H) and 5.23 (s, 1H)), i.e. there is no spin-spin coupling between these two protons.(Figure 1) It is noteworthy to mention that the geminal coupling constant of the methylene group on the 1,2,4-trioxolane compound is much smaller than that of the carbocyclic compound (J=12-18 Hz). Several factors, such as H-C-H bond angle, ring size, and substituent electronegativity, could influence the magnitude of the geminal coupling constants.[15] Methylene groups adjacent to two oxygen atoms in five-membered rings have been reported to have geminal coupling constants in the range of 0 to 2 Hz.[16-19] Therefore, the zero coupling constant in our case was due to the ring size and the electronegativity of the di-oxygen moiety. This phenomenum turned out to be a general case for compound (2a-2f).[20](Table 1) Moreover, the signal corresponding to two carbons on the trioxolane ring appeared at δ 93.56 (2°) and 101.93 (3°) respectively in its ^{13}C-nmr spectrum. This assignment was also confirmed by its HETERCO 2D-nmr spectrum, where two protons (H_a and H_b) were connected to the same carbon whose signal appeared at δ 93.561.

The characteristic absorptions of 1,2,4-trioxolane are considered to be 1058 and 1109 cm^{-1} which probably arise from C—O—O strecting in the ir spectrum of compound (2a).[21] The molecular ion peak of the ozonide usually did not appear or very weak in mass spectrum even though the electron beam energy was lowered to 10 electron volt. The molecular ion peak of compound (2a) (m/z=188) was very weak and the signal corresponding to M+-CH_2O showed reasonable intensity. The fragmentation pattern of compound (2a) was proposed to follow the sequences described in Scheme 1. Similar observations of ir and mass spectra described here were also applied to compounds (2b-2f). In conclusion, the structures of ozonides were unambiguously determined by modern spectral techniques. The extremely small geminal coupling constant is an interesting observation. The synthetic application and the mechanistic studies of the reaction of the ozonides with phosphorus ylides have been extensively studied in our laboratory.

Scheme 1

ACKNOWLEDGEMENT

REFERENCES

1.   P. S. Bailey, *Ozonation in Organic Chemistry*, Academic Press, New York, Vol. 1, **1978**; Vol. 2, **1982**.

2.   R. L. Kuczkowski, *1,3-Dipolar Cycloaddition Chemistry*, ed. A. Padwa, John Wiley & Sons, New York,

     1984, Vol. 2, Chapter 11.

3.   B. J. Wojciechowski, C. Y. Chiang, and R. L. Kuczkowski, *J. Org. Chem.*, **1990**, *55*, 1120 and references cited

     therein.

4.   S. Fliszar and J. Carles, *Can J. Chem.*, **1969**, *47*, 3921.

5.   R. W. Murray and G. J. Williams, *J. Org. Chem.*, **1969**, 34, 1896.

6.   Y. S. Hon, L. Lu, and S. Y. Li, *J. Chem. Soc., Chem. Comm.*, **1990**, 1627.

7.   I. C. Hisatsune, L. H. Kolopajlo, and J. Heicklen, *J. Am. Chem. Soc.*, **1977**, *99*, 3704.

8.   I. C. Hisatsune, K. Shinoda, and J. Heicklen, *J. Am. Chem. Soc.*, **1979**, *101*, 2524.

9.   R. P. Lattimer, R. L. Kuczkowski, and C. W. Gillies, *J. Am. Chem. Soc.*, **1974**, *96*, 348.

10. N. L. Bauld, J. A. Thompson, C. E. Hudson, and P. S. Bailey, *J. Am Chem. Soc.*, **1968**, *90*, 1822.

11. R. W. Murray and A. Suzuki, *J. Am. Chem. Soc.*, **1973**, *95*, 3343.

12. R. W. Murray and G. J. Williams, *J. Org. Chem.*, **1969**, *34*, 1891.

13. A. Hosomi and H. Sakurai, *J. Am. Chem. Soc.*, **1977**, *99*, 1673.

14. H. Sakurai, A. Hosomi, and J. Hayashi, *Org. Synth.*, **1984**, *62*, 86.

15. L. M. Jackman and S. Sternhell, *Applications of Nuclear Magnetic Resonance Spectroscopy in Organic Chemistry*; Pergamon, New York, **1969**, 2nd. ed., Chapter 4.

16. T. Gilchrist, R. Hodges, and A. L. Porte, *J. Chem. Soc.*, **1962**, 1780.

17. N. S. Bhacca and R. Stevenson, *J. Org. Chem.*, **1963**, *28*, 1638.

18. P. Yates and R. S. Dewey, *Tetrahedron Lett.*, **1962**, 847.

19. F. Alderweirldt and M. Anteunis, *Bull. Soc. Chim. Belg.*, **1964**, *73*, 889 and 903.

20. Compound (**2a**): ^{1}H-Nmr (CDCl$_3$) δ 1.09 (s, 6H, geminal dimethyl), 1.81 (1H, ABqd, J_{AB}= 14.5 and 5.5 Hz, C-CH$_2$-CO$_2$), 1.94 (1H, ABqd, J_{AB}=14.5 and 4.9 Hz, C-CH$_2$-CO$_2$), 2.12 (s, 3H, O=C-CH$_3$), 2.45 (s, 2H, O=C-CH$_2$-), 4.98 (s, 1H, C$_5$-H of 1,2,4-trioxolane), 5.18 (s, 1H, C$_5$-H of 1,2,4-trioxolane), 5.17 (1H, t, J= 5.3 Hz, C$_3$-H of 1,2,4-trioxolane); ^{13}C-nmr (CDCl$_3$) δ 27.87 (CH$_3$)$_2$C), 31.52 (CH$_3$)$_2$C), 31.86 (CH$_3$C=O), 41.25 (CH$_2$-CHO$_2$), 53.20 (O=C-CH2-), 93.55 (C$_5$ of 1,2,4-trioxolane), 101.93 (C$_3$ of 1,2,4-trioxolane), 207.61 (C=O); ir (neat) v_{max} (cm^{-1}): 1711 (C=O), 1362, 1109 (C-O-O stretching), 1058 (C-O-O stretching); ms (m/z, %) (18 ev): 188 (M$^+$, 5), 158 (M$^+$-CH$_2$O, 12), 140 (25), 112 (26), 99 (45), 83 (93), 58 (100).

Compound (**2b**): ^{1}H-Nmr (CDCl$_3$) δ 1.74 (br, 4H), 2.14 (s, 3H, CH$_3$), 2.50 (br, 2H, O=C-CH$_2$-), 5.04 (s, 1H, C$_5$-H of 1,2,4-trioxolane), 5.14 (s, 1H, C$_5$-H of 1,2,4-trioxolane), 5.17 (1H, t, J= 5.0 Hz, C$_3$-H of 1,2,4-trioxolane); ^{13}C-nmr (CDCl$_3$) δ 17.74 (CH$_2$-CH$_2$-CH$_2$-), 29.77 (CH$_3$C=O), 30.33 (CH$_2$-CH$_2$-CHO$_2$), 42.76 (O=C-CH$_2$), 93.91 (C$_5$ of 1,2,4-trioxolane), 103.33 (C$_3$ of 1,2,4-trioxolane), 207.82 (C=O); ir (neat) v_{max} (cm^{-1}): 1712 (C=O), 1367, 1114, 1097 (C-O-O stretching), 1057 (C-O-O stretching).

Compound (**2c**): ^{1}H-Nmr (CDCl$_3$) δ 1.40 (m, 11H), 5.05 (s, 1H, C$_5$-H of 1,2,4-trioxolane), 5.19 (s, 1H, C$_5$-H of 1,2,4-trioxolane), 5.20 (1H, t, J= 5.0 Hz, C$_3$-H of 1,2,4-trioxolane); ^{13}C-nmr (CDCl$_3$) δ 24.58, <u>30.89, 31.03</u>, 34.53, 37.27, 40.75, <u>47.53, 47.62</u>, 93.58 (C$_5$ of 1,2,4-trioxolane), 101.88 (C$_3$ of 1,2,4-trioxolane), 209.98 (C=O); ir (neat) v_{max} (cm^{-1}): 1701 (C=O), 1101 (C-O-O, stretching), 1059 (C-O-O, stretching), 970; ms (m/z, %) (10 ev): 156 (M$^+$-CH$_2$O, 30), 140 (10), 139 (10), 112 (45), 97 (100), 95 (35), 84 (38). hrms (m/z): 156.0758 (M$^+$-CH$_2$O, C$_9$H$_{14}$O$_4$, calcd 156.0786). <u>The chemical shifts underlined together means that they are the isomeric carbon absorptions.</u> (The diastereomeric isomer ratio is about 1:1)

Compound (2d): ^{1}H-Nmr (CDCl$_3$) δ 0.9-2.0 (m, 11H), 3.94 (s, 4H, O-CH$_2$CH$_2$O-), 5.04 (s, 1H, C$_5$-H of 1,2,4-

trioxolane), 5.18 (s, 1H, C$_5$-H of 1,2,4-trioxolane), 5.19 (1H, t, J= 5.0 Hz, C$_3$-H of 1,2,4-trioxolane); ^{13}C-

nmr (CDCl$_3$) δ 22.81, 31.63, 31.76, 34.49, 37.73, 41.44, 41.62, 64.04 (O-CH$_2$-CH2-O), 64.15 (O-CH2-CH2-

O), 93.73 (C$_5$ of 1,2,4-trioxolane), 102.64 (C$_3$ of 1,2,4-trioxolane), 108.67 (C-CO$_2$-C); ir (neat) ν$_{max}$ (cm$^-$

^{1}): 1253, 1158 (ketal C-O stretching), 1103 (C-O-O stretching), 1071 (C-O-O stretching), 719, 692.

Compound (2e): ^{1}H-Nmr (CDCl$_3$) δ 1.53-2.53 (m, 9H), 5.02 (s, 1H, C$_5$-H of 1,2,4-trioxolane), 5.18 (s, 1H,

C$_5$-H of 1,2,4-trioxolane), 5.20 (1H, t, J= 5.0 Hz, C$_3$-H of 1,2,4-trioxolane); ^{13}C-nmr (CDCl$_3$) δ 29.68 (2°),

32.57, 36.69, 38.13, 44.92, 44.99, 93.89 (C$_5$ of 1,2,4-trioxolane), 102.43 (C$_3$ of 1,2,4-trioxolane), 218.12

(C=O); ir (neat) ν$_{max}$ (cm^{-1}): 1735 (C=O), 1402, 1245, 1103 (C-O-O stretching), 1049 (C-O-O stretching);

ms (m/z, %) (10 ev): 172 (M$^+$, 20), 142 (15), 125 (14), 98 (95), 83 (100), 69 (80), 55 (40); hrms (m/z):

172.0735 (M$^+$, C$_8$H$_{12}$O$_4$, calcd 172.0735).

Compound (2f): ^{1}H-Nmr (CDCl$_3$) δ 0.89 (3H, t, J= 6.7 Hz, CH$_3$), 1.29-1.60 (br., 8H), 1.7-1.9 (m, 2H), 5.03

(s, 1H, C$_5$-H of 1,2,4-trioxolane), 5.12 (1H, t, J= 5.0 Hz, C$_3$-H of 1,2,4-trioxolane), 5.19 (s, 1H, C$_5$-H of

1,2,4-trioxolane); ^{13}C-nmr (CDCl$_3$) δ 13.87, 22.26, 23.69, 28.92, 30.99, 31.48, 93.86 (C$_5$ of 1,2,4-

trioxolane), 103.73 (C$_3$ of 1,2,4-trioxolane); ir (neat) ν$_{max}$ (cm^{-1}): 1102 (C-O-O stretching).

21. E. Briner and E. Dallwigk, *Helv. Chim. Acta*, **1956**, *39*, 1446 and 1826.