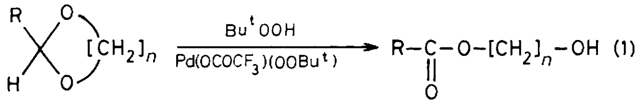
# Palladium(II)-catalysed Oxidative Ring Cleavage of Cyclic Acetals with t-Butyl Hydroperoxide: Preparation of Monoesters of Diols

**Takahiro Hosokawa,* Yasushi Imada, and Shun-Ichi Murahashi***

*Department of Chemistry, Faculty of Engineering Science, Osaka University, Machikaneyama, Toyonaka, Osaka, Japan 560*

Reaction of five- and six-membered cyclic acetals with $Bu^tOOH$ in the presence of palladium(II) catalyst gives monoesters of diols in good yields.

Cyclic acetals are important compounds for the protection of the carbonyl group,[1] and much effort has been devoted to the development of effective methods for cleaving the acetal ring. Lewis acid-induced ring opening of acetals with nucleophiles[2,3] or halogen-induced cleavage[4] is currently of interest. Herein we describe a novel cleavage of cyclic acetals with t-butyl hydroperoxide in the presence of palladium(II) catalyst, which affords glycol monoesters in good yields [equation (1)].† This is the first example of homogeneous metal-catalysed oxidation of acetals.



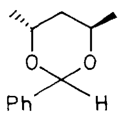
$$R\text{--}C(=O)\text{--}O\text{--}[CH_2]_n\text{--}OH \quad (1)$$

(1) (2)

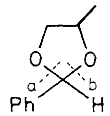
a; $n = 2$, R = Ph
b; $n = 2$, R = 3,4-$OCH_2OC_6H_3$–
c; $n = 2$, R = $o$-$MeC_6H_4CH_2$
d; $n = 2$, R = $C_7H_{15}$
e; $n = 2$, R = $Bu^tC(:O)CH_2$
f; $n = 3$, R = Ph
g; $n = 4$, R = Ph

---

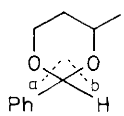
† A patent claims that ozonolysis of acetals gives the same type of products; see Can. Pat., 962 264; *Chem. Abs.*, 1975, **83**, 27622e.



(3)



(4)



(5)

**Table 1.** Reaction of cyclic acetals with Bu$^t$OOH in the presence of palladium(II) catalyst.

| Entry | Cyclic acetal | Reaction time/h | Product yield[a] (%) |
|---|---|---|---|
| 1 | **(1a)** | 12 | 68 (83)[b] |
| 2 | **(1b)** | 48 | 70 |
| 3 | **(1c)** | 48 | 76 |
| 4 | **(1d)** | 12 | 76[c] |
| 5 | **(1e)** | 46[d] | 26 |
| 6 | **(1f)** | 24 | 69[c] |
| 7 | **(1g)** | 24 | 38 |
| 8 | **(3)**[e] | 12 | 71 |
| 9 | **(4)**[f] | 12 | 78 (a : b = 67 : 33)[h] |
| 10 | **(5)**[g] | 24 | 60 (a : b = 33 : 67)[h] |

[a] Isolated yield by preparative t.l.c. unless otherwise noted. [b] G.l.c. yield. [c] Isolated yield by kugelrohr distillation. [d] 10 mol% of palladium catalyst was used. [e] Compound **(3)** was prepared from optically active (*R*,*R*)-pentane-2,4-diol and benzaldehyde. [f] A 52 : 48 mixture of *cis*- and *trans*-isomers. [g] >99% *cis*-isomer. [h] Ratio of products derived from cleavage a or b.

Glycol monoesters such as those of ethylene glycol have been used as cross-linking agents for polyesters or as fungicides. The major drawback for the preparation of these compounds from diols is the concurrent formation of the diester, necessitating a tedious separation procedure.[5] The present reaction provides a useful method for the selective mono-protection of some symmetrical diols.

The conversion of the acetal **(1a)** into **(2a)** is typical. A solution of **(1a)** (1 mmol) and anhydrous Bu$^t$OOH (benzene solution; 3.47 M; 2 mmol)[6] in dry benzene (4 ml) was stirred at 50 °C in the presence of Pd(OCOCF$_3$)(OOBu$^t$)[7] (0.05 mmol). The reaction was monitored by g.l.c. analysis, and after 12 h the product was taken up in ether, washed with 5% Na$_2$SO$_3$ and brine, and dried over Na$_2$SO$_4$. Evaporation followed by preparative t.l.c. (SiO$_2$, benzene–EtOAc, 4 : 1, as eluant) gave **(2a)** ($R_f$ 0.45) in 68% yield.

Other palladium(II) complexes also promote the reaction, but not as effectively as Pd(OCOCF$_3$)(OOBu$^t$); the g.l.c. yields of **(2a)** formed under the conditions described above are as follows: with Pd(OCOCF$_3$)(OOBu$^t$), 83% (12 h); Pd(OAc)$_2$, 64% (24 h); PdCl$_2$, 64% (24 h); PdCl$_2$(MeCN)$_2$, 62% (24 h). Even if only 1 equiv. of Bu$^t$OOH is used with Pd(OCOCF$_3$)(OOBu$^t$) (24 h), the yield of **(2a)** is 79%.

Table 1 summarizes representative results for the present reaction. Five-membered acetals **(1a—d)** bearing aromatic, benzylic, and alkyl substituents give the corresponding monoesters of ethylene glycol in good yields (entries 1—4). Likewise, six-membered cyclic acetals **(1f)** and **(3)** give good yields of the corresponding monoesters of propane-1,3-diols (entries 6 and 8). Thus, the reaction appears to be quite general for these types of acetals, although effective cleavage does not occur with the acetal **(1e)** bearing a ketone group and the seven-membered acetal **(1g)** (entries 5 and 7). It is noteworthy that the methylene dioxy-unit in **(1b)** is unaffected by this oxidation.

Five- and six-membered acetals **(4)** and **(5)** derived from unsymmetrical diols are again smoothly oxidized, but with less regioselectivity, to give the two corresponding products produced *via* cleavage of either of the two acetal C–O bonds (a or b).

A possible mechanism involves co-ordination of the acetal oxygen atom to palladium(II) followed by nucleophilic attack of Bu$^t$OOH on the acetal carbon atom. The Bu$^t$OO ligand of PdX(OOBu$^t$) (*e.g.*, X = OCOCF$_3$) may act as an alternative nucleophile. This process induces ring opening of the acetal with the formation of XPd–O–[CH$_2$]$_n$–CH(R)–OOBu$^t$. Decomposition of the peroxide species to the product and regeneration of PdX(OOBu$^t$) by the action of Bu$^t$OOH complete the catalytic cycle. The crucial step may be the co-ordination of the acetal oxygen atom to the metal, as invoked in Lewis acid-induced ring opening[3] and hydrogenolytic cleavage with heterogeneous transition metal catalysts.[8]

*Received, 1st August 1983; Com. 1023*

## References

1 T. W. Green, 'Protecting Groups in Organic Synthesis,' Wiley-Interscience, New York, 1981; F. A. J. Meskens, *Synthesis*, 1981, 501.
2 J. M. McNamara and Y. Kishi, *J. Am. Chem. Soc.*, 1982, **104**, 7371.
3 P. A. Bartlett, W. S. Johnson, and J. D. Elliott, *J. Am. Chem. Soc.*, 1983, **105**, 2088; W. S. Johnson, R. Elliott, and J. D. Elliott, *ibid.*, 1983, **105**, 2904.
4 A. Goosen and C. W. McCleland, *J. Chem. Soc., Chem. Commun.*, 1982, 1331.
5 J. H. Babler and M. J. Coghlan, *Tetrahedron Lett.*, 1979, 1971, and references therein.
6 K. B. Sharpless and T. R. Verhoeven, *Aldrichimica Acta*, 1979, **12**, 63.
7 H. Mimoun, R. Charpentier, A. Mitschler, J. Fischer, and R. Weiss, *J. Am. Chem. Soc.*, 1980, **102**, 1047.
8 M. Bartok and J. Czombos, *J. Chem. Soc., Chem. Commun.*, 1981, 106.