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LANTHANIDE CATALYSIS OF CYCLOADDITIONS OF HETERODIENES WITH ENOL ETHERS

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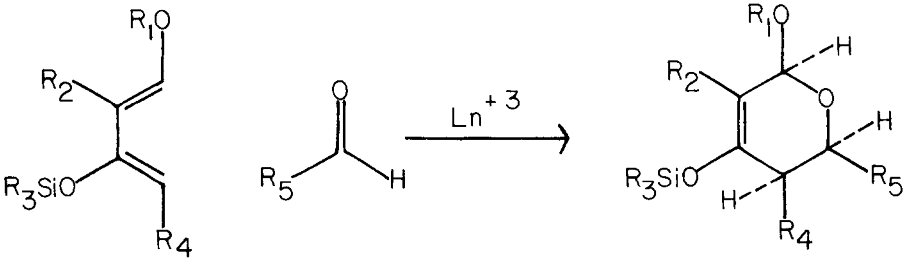
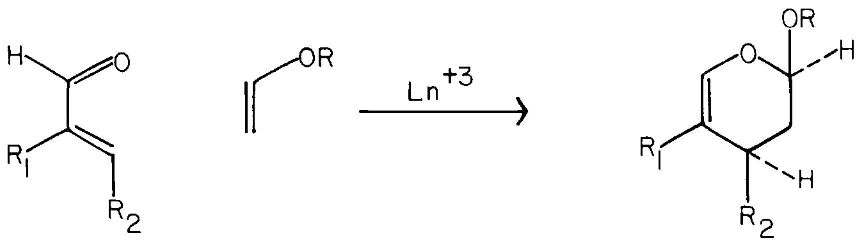
Abstract: The cycloadditions of enol ethers with α,β-unsaturated aldehydes is catalyzed by $Yb(fod)_3$.

Recently it was reported that certain soluble lanthanide complexes have the capacity to catalyze cycloadditions of the type shown in eq. 1.[1] These reactions exhibit the characteristics expected of bona fide cycloadditions. The remarkable feature of the lanthanide catalysis is its mildness which allows for survival of fragile but valuable functionality both in the diene and in the cycloadduct. Moreover, the turnover rate is such that a few mole percent of catalyst suffice for reasonable reaction rates at room temperature.

It was of interest to probe the applicability of lanthanide catalysis to other cycloadditions in which acid labile components are to be combined. In this connection we have examined a version of the inverse demand Diels-Alder reaction in which a heterodiene and a vinyl ether join to produce a dihydropyran (eq. 2).[2,3] Our results are reported herein.

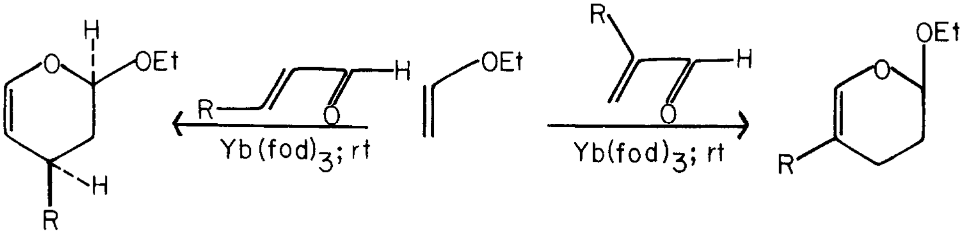


(1)



(2)

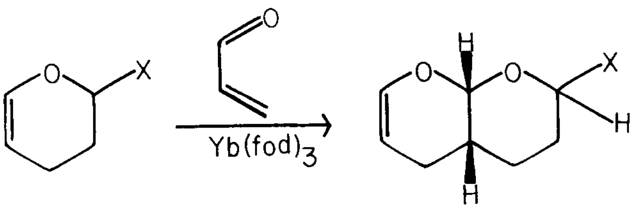
Reaction of acrolein with ethyl vinyl ether under catalysis by $Yb(fod)_3$[4] (5 mole %, neat, 24 h) occurs at room temperature.[5] Kugelrohr distillation affords **1** in 80% yield. Reactions of ethyl vinyl ether with methacrolein, crotonaldehyde and cinamaldehyde occur in a similar way to afford **2**, **3** and **4** in 60-80% yields.[6] In the latter two cases, the cycloadditions are apparently stereospecific, giving rise to the products of "endo" addition only.[7,8] The advantages of entry to compounds of the type **3** and **4** are implied in a recent paper of Snider and Phillips,[9] in which compounds of this type are shown to be useful for the synthesis of cyclobutanes.



3 $R=Me$
4 $R=\phi$

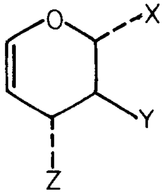
1 $R=H$
2 $R=Me$

Some possibilities for extending the reaction to more encumbered vinyl ethers were also probed. Reaction of dihydropyran **7** with acrolein (5 mole % of catalyst, 80 h, 50°) affords, after distillation, a 55% yield of **8**.[8] Reaction of **1** with acrolein (50 h, 50°) gave **9** as apparently a single stereoisomer, though only in 30% isolated yield.[10]



7 $X=H$
1 $X=OEt$

8 $X=H$
9 $X=OEt$



10 $X=\phi; Y=H; Z=OAc$
11 $X=CH_2OCH_2\phi; Y=Z=OCH_2\phi$
12 $X=CH_2OAc, Y=Z=OAc$

Unfortunately, glycals 10, 11 and 12 failed to react with acrolein under Yb(fod)$_3$ catalysis even up to 80°. This failure may well reflect a diminished nucleophilicity due to the inductive effect of the C_3-oxygen substituent (hexose numbering).

A typical experimental procedure is provided: to 0.24 g (3.4 m moles) of crotonaldehyde and 0.5 g (6.8 m moles) of ethyl vinyl ether is added 0.12 g (0.11 m moles) of Yb(fod)$_3$.[4] The reaction is maintained at room temperature and monitored by NMR spectroscopy for the disappearance of the aldehyde resonance. After 80 h, the excess volatiles are evaporated. Kugelrohr distillation of the crude residue affords 0.40 g (80% yield) of the previously reported compound 3.[7]

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References

[1] Bednarski, M.; Danishefsky, S. J. Am. Chem. Soc. 1983, 105, 3716.

[2] Desimoni, G.; Tacconi, G. Chem. Rev. 1975, 75, 651.

[3] For some recent applications of this reaction to specialized systems see: Tietze, Lutz-F.; Glusenkamp, K.H.; Holla, W. Angew. Chem. 1982, 94, 793; Berti, G.; Catelani, G.; Colonna, F.; Mont, L. Tetrahedron 1982, 38, 3067; Schmidt, R.R.; Maier, M. Tetrahedron Lett. 1982, 23, 1789.

[4] This is the trade name for tris(6,6,7,7,8,8,8-heptafluoro-2,2-dimethyl-3,5-octanedionato)ytterbium.

[5] Zeinhom, M.I.; Hoffmann, H.M.R. Angew. Chem. Int. Ed. Engl. 1982, 21, 860.

[6] In the strictly thermal mode, reactions of enol ethers with typical α,β-unsaturated aldehydes are carried out from 160 to 220° C. Langley, R.I., Jr.; Emerson, W.S. J. Am. Chem. Soc. 1950, 72, 3079.

[7] Dauben, W.G.; Krabbenhoft, H.O. J. Org. Chem. 1977, 42, 282 and references therein.

[8] The structure of compounds 8 and 9 are assigned on the basis of the following spectral properties:

8 IR ($CHCl_3$) $\bar{\nu}$ 2900 and 1650 (br) cm^{-1}; ^1H NMR (90 MHz, $CDCl_3$) δ 6.30 (1 H, br d, J = 6 Hz), 5.25 (1 H, br s), 4.75-4.45 (1 H, m), 4.20-3.55 (2 H, m), 2.70-1.30 (7 H, m); m/e 140 (M^+).

9 IR ($CHCl_3$) $\bar{\nu}$ 2900 and 1650 (br) cm^{-1}; ^1H NMR (90 MHz, $CDCl_3$) δ 6.21 (1 H, br d, J = 6 Hz), 5.24 (1 H, br s), 5.10-4.85 (1 H, m), 4.80-4.45 (1 H, m), 4.80-3.35 (2 H, m), 2.20-1.40 (7 H, m), 1.32-1.00 (3 H, t, J = 6 Hz); m/e 184 (M^+).

Compounds 1, 2, 3 and 4 were previously reported by Langley and Emerson,[6] and also by Dauben.[7]

[9] Snider, B.B.; Phillips, G.B. J. Org. Chem. 1983, 48, 2789.

[10] The stereochemistry at the anomeric center of 9 is unassigned.

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