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Clay Montmorillonite-Catalyzed Aldol Reactions of Silyl Enol Ethers with Aldehydes and Acetals

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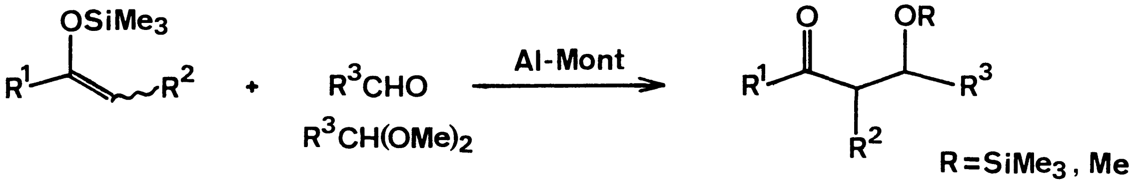
By the use of clay montmorillonite as a catalyst, cross aldol adducts are obtained from silyl enol ethers and aldehydes or acetals. The diastereoselectivity in the reaction is significantly sensitive to the solvent used.

Concerning the aldol reactions using silyl enol ethers, several efficient promoters for the reactions have been offered. In the reactions of silyl enol ethers with aldehydes, besides the stoichiometric use of a Lewis acid like $TiCl_4$,$^{1)}$ the catalytic use of $^{n}Bu_4NF$,$^{2)}$ $(Et_2N)_3S^+Me_3SiF_2^-$,$^{3)}$ Ph_3CClO_4,$^{4)}$ or $Me_2AlCl$$^{5)}$ is effective. In the case of acetal as an electrophile, $Me_3SiOTf$$^{6)}$ is also a good catalyst. These promoters are employed exclusively in homogeneous systems.$^{7)}$

In the previous paper we reported that clay montmorillonites were efficient, heterogeneous catalysts in allylation reactions of acetals and carbonyl compounds with allylic silanes.$^{8)}$ Here we wish to describe the cross aldol reactions of silyl enol ethers with aldehydes and acetals catalyzed by aluminum cation-exchanged montmorillonite (Al-Mont).$^{9)}$ Incidentally, an acidic montmorillonite K-10 was reported to catalyze the condensation of acetals with alkyl vinyl ethers.$^{10)}$



In the first place, the reaction of 1-(trimethylsiloxy)cyclohexene with benzaldehyde was examined. The reaction proceeded smoothly in a heterogeneous system at a low temperature by the use of Al-Mont to afford the corresponding aldol adducts in good yields (Table 1, Entries 1-4).[11)] The diastereoselectivity of the reaction was independent of catalyst amount, but considerably varied with the nature of solvent.[12)] Namely, the threo isomer was preferentially formed in toluene (Entry 1), while the erythro isomer was dominant in 1,2-dimethoxyethane (DME)(Entry 4). The solvent effect on the diastereoselectivity was also observed with other substrates in Table 1. Generally, when benzaldehyde or its acetal was used as an electrophile, the ratio of threo to erythro isomer increased in the following order in the solvents used: DME $<$ CH_2Cl_2 $<$ $PhCH_3$ (Entries 1-13). In the case of aliphatic aldehydes and acetal (Entries 14-25), however, different solvent effects were observed depending on the substrates.

Because the proton exchanged montmorillonite (H-Mont) showed almost similar activity and diastereoselectivity to those by the Al-Mont, we assume that the Brönsted acid sites on the Al-Mont actually play an important role in activating the present aldol reaction.[13)]

As work-up, only the filtration of the reaction mixture was required in order to separate the catalyst from the organic products. Thus the aldol adducts of aldehydes can be obtained in the form of trimethylsilyl ether owing to the procedure free from the use of water.

A typical experimental procedure is described for the reaction of 1-(trimethylsiloxy)cyclohexene and benzaldehyde: Al-Mont (0.2 g, dried before use)[9)] was suspended in toluene (2 ml) under nitrogen atmosphere. Then a mixture of benzaldehyde (1 mmol) and 1-(trimethylsiloxy)cyclohexene (1 mmol) in toluene (2 ml) was added at -78 °C. After being stirred at that temperature for 0.5 h and then at -50 °C for an additional hour, ether (5 ml) was added, and Al-Mont was filtered off through a Celite pad and washed with ether. The organic layer was evaporated and distilled on Kugelrohr to yield 2-(trimethylsiloxyphenylmethyl)cyclohexanone (82% yield, threo:erythro=71:29).

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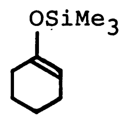
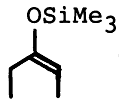
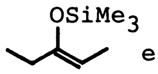
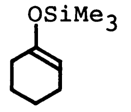
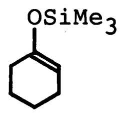
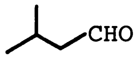
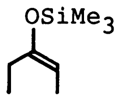
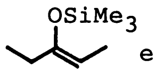
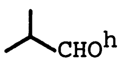
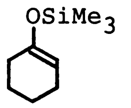
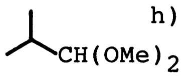
Table 1. The reactions of silyl enol ethers with aldehydes or acetals catalyzed by Al-Mont[a]

Entry	Silyl enol ether	Aldehyde or acetal	Solvent	Conditions Temp/°C (Time/h)	Yield/%[b]	Threo:Erythro[c]
1		PhCHO	$PhCH_3$	-78(0.5), -50(1)	82	71:29
2			CH_2Cl_2	-95(2.5)	91	63:37
3			Et_2O	-50(0.1), -30(1)	82	44:56
4			DME	-60(6.5)	81	21:79
5	 [d]	PhCHO	$PhCH_3$	-60(0.5)	97	76:24
6			CH_2Cl_2	-78(0.5)	93	59:41
7			DME	-50(1), -30(1)	76	56:44
8	 [e]	PhCHO	$PhCH_3$	-70(1), -60(2)	85	63:37
9			CH_2Cl_2	-78(1)	89	53:47
10			DME	-50(1), -30(1)	73	50:50
11		$PhCH(OMe)_2$	$PhCH_3$	-50(3), -30(2)	94	49:51
12			CH_2Cl_2	-30(3), -15(1)	82	43:57
13			DME	-65(0.5), -50(1.5)	93	13:87
14			$PhCH_3$	-40(1), -30(4)	22[f]	43:57
15			CH_2Cl_2	-78(0.5), -50(1)	86	62:38
16			DME	-30(0.5), -20(1)	29[g]	43:57
17	 [d]	 [h]	$PhCH_3$	-30(2), -20(2)	57	72:28
18			CH_2Cl_2	-65(1), -50(1.5)	69	46:54
19			DME	-40(0.5), -20(2)	22[f]	74:26
20	 [e]	 [h]	$PhCH_3$	-30(0.5), -20(2)	68	41:59
21			CH_2Cl_2	-50(1), -30(1)	64	37:63
22			DME	-30(0.5), -20(2)	14[f]	42:58
23		 [h]	$PhCH_3$	-50(0.5), -30(2)	77	30:70
24			CH_2Cl_2	-50(1), -30(1)	75	30:70
25			DME	-55(0.2), -30(1)	55[f]	25:75

a) Silyl enol ether (1 mmol), aldehyde (1 mmol), and Al-Mont (0.2 g) were used.
b) Isolated yield. c) Diastereomeric ratios were determined by capillary-GC or ^1H NMR. The diastereomers were assigned by ^1H and/or ^{13}C NMR[14] before or after hydrolysis of trimethylsilyl ethers. d) E/Z=83/17. e) E/Z=10/90. f) Unidentified by-products were obtained. g) The major by-product was cyclohexanone.
h) 1.3 mmol of aldehyde or acetal was used.

References

1) T. Mukaiyama, K. Banno, and K. Narasaka, J. Am. Chem. Soc., 96, 7503 (1974).

2) E. Nakamura, M. Shimizu, I. Kuwajima, J. Sakata, K. Yokoyama, and R. Noyori, J. Org. Chem., 48, 932 (1983).

3) R. Noyori, I. Nishida, and J. Sakata, J. Am. Chem. Soc., 105, 1598 (1983).

4) T. Mukaiyama, S. Kobayashi, and M. Murakami, Chem. Lett., 1985, 447.
S. Kobayashi, M. Murakami, and T. Mukaiyama, Chem. Lett., 1985, 1535.

5) Y. Naruse, J. Ukai, N. Ikeda, and H. Yamamoto, Chem. Lett., 1985, 1451.

6) S. Murata, M. Suzuki, and R. Noyori, J. Am. Chem. Soc., 102, 3248 (1980).

7) Trityl perchlorate was also used as a heterogeneous catalyst in a polymer-supported form: T. Mukaiyama and H. Iwakiri, Chem. Lett., 1985, 1363.

8) M. Kawai, M. Onaka, and Y. Izumi, Chem. Lett., 1986, 381.

9) Al-Mont was prepared from "Kunipia F" (sodium cation exchanged montmorillonite, cation exchange capacity=1.19 mequiv./g, Kunimine Industries Co.) and aluminum nitrate: J. A. Ballantine, J. H. Purnell, M. Rayanakorn, and K. J. Williams, J. Mol. Catal., 30, 373 (1985). Al-Mont was pre-dried at 25 °C/0.5 Torr for 16 h and stored in a desiccator, and then dried at 120 °C/0.5 Torr for 3 h in a reaction vessel.

10) D. Fishman, J. T. Klug, and A. Shani, Synthesis, 1981, 137.

11) Titanium(III) ion- and proton-exchanged montmorillonite also catalyzed the aldol reaction requiring slightly longer reaction time and almost the same diastereoselection was observed as that in the case of Al-Mont.

12) The dependence of diastereoselectivity on solvent has not yet been known in the aldol reaction using silyl enol ether.

13) Nafion 117 (acidic ion exchange resin, 10 mol% as H^+) of Brönsted acid also catalyzed the aldol reaction of 1-(trimethylsiloxy)cyclohexene with benzaldehyde dimethyl acetal in CH_2Cl_2 at 0 °C for 1 h (69%, threo:erythro=23:77). This result supports that Brönsted acid sites are effective in the reaction.

14) 2-(1-Hydroxy-3-methylbutyl)cyclohexanone : ^1H NMR ($CDCl_3$) of a carbinol proton, a threo isomer: δ=3.79 ppm (ddd, J=9.0, 7.0, 4.5 Hz), an erythro isomer: δ=4.21 ppm (ddd, J=9.0, 3.6, 2.7 Hz). The stereochemistry of the other products was assigned on the basis of the spectral data reported in the literatures.[1,15]

15) C. H. Heathcock, C. T. Buse, W. A. Kleschick, M. C. Pirrung, J. E. Sohn, and J. Lampe, J. Org. Chem. 45, 1066 (1980); C. H. Heathcock, M. C. Pirrung, and J. E. Sohn, J. Org. Chem., 44, 4294 (1979).

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