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Trinuclear tin salicylaldoximate cluster-catalyzed selective acylation of alcohols

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The reactivity and catalytic potential of the tin salicylaldoximate cluster [$(Me_2Sn)_2(Me_2SnO)(OCH_3)$(HONZO)(ONZO)] (1), with HONZOH = *o*-HON=CH–C_6H_4OH, on the acylation reaction of various alcohols with ethyl acetate is reported. The catalyst is active toward primary and unhindered secondary alcohols, but inefficient toward tertiary and secondary bulky alcohols and phenols. A possible mechanism for the transesterification reaction catalyzed by 1, accounting for the influence of steric factors, is proposed. Copyright © 2005 John Wiley & Sons, Ltd.

KEYWORDS: organotin catalyst; acylation; transesterification

INTRODUCTION

Acylation of alcohols has enjoyed numerous applications, both in synthetic organic chemistry and industrial applications. Acetic anhydride is the most frequently employed reagent and a variety of acidic or basic catalysts have been reported for this purpose.[1–6] An alternative way to reach the same target compounds, the transesterification of ethyl acetate shown in Scheme 1, also needs to be catalyzed. Since basic or acidic conditions are often not suitable for industrial applications, the development of new catalysts that allow transesterification under milder conditions would increase the synthetic potential of this reaction considerably. The use of organotin compounds as catalysts allows the transesterification reaction to take place in the absence of strong acids and bases in an aqueous medium, thus minimizing any risk of corrosion of the reaction vessel.[1,7–10]

In this study, the reactivity and catalytic potential of the trinuclear tin cluster [$(Me_2Sn)_2(Me_2SnO)(OCH_3)$(HONZO)(ONZO)] (**1**), with HONZOH = *o*-HON=CH–C_6H_4OH = salicylaldoxime, on the acylation reaction of various alcohols with ethyl acetate is reported. The structure of **1**, resulting from condensation of dimethyltin(IV) oxide with salicylaldoxime and crystallization in methanol, was reported earlier.[11,12] This cluster can give rise to different compounds by reaction with other proton-donating nucleophiles, by a reversible nucleophilic substitution reaction (Scheme 2) at the cluster site Sn2–O40–Sn3.[13] In these compounds, the proton donor properties of the entering nucleophile, as well as the Sn2–O40–Sn3 bridging functionality, determine the reactivity of such clusters. Since nucleophiles possessing transferable protons, such as alcohols are amenable to such reactions we perceived that this cluster could be a suitable catalyst in transesterification reactions. It was a motivation for investigating the catalytic potential of compound **1** in the acylation reaction of various alcohols with ethyl acetate.

RESULTS AND DISCUSSION

The results of the acylation reaction of several alcohols, illustrating the catalytic activity and selectivity of **1**, are

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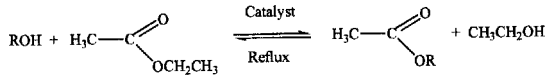
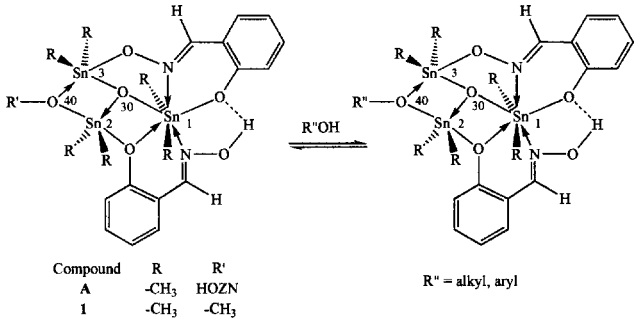


Scheme 1.



Scheme 2.

summarized in Table 1. From these results it can be concluded that the catalyst is very active toward primary alcohols and somewhat less so, but still active, toward some secondary alcohols. Cyclohexanol can be acetylated in 84% and 99% yield, after refluxing 8 h and 24 h respectively. A complete conversion was obtained after 48 h (Table 1, entries 1–3). 1-Phenyl ethanol reacted similarly. Conversions up to 90% and 96% were obtained after 24 h and 48 h respectively (Table 1, entries 10–12).

The acylation reaction is clearly influenced by steric factors, since primary alcohols are more reactive than secondary alcohols, whereas the catalyst is totally inefficient toward tertiary and secondary bulky alcohols (Table 1, entries 5 and 6). Also, no reaction was obtained with phenol (Table 1, entry 7).

Both trinuclear tin clusters **A** and **1** show similar activities (Table 1, entries 8 and 9) under the same reaction conditions under which, on the other hand, **1** is more reactive than the distannoxanne $\{[Me_2(CH_3COO)Sn]_2O\}_2$ (**2**). Cyclohexanol was acetylated in 84% and 58% yield after refluxing 8 h with compounds **1** and **2** respectively (Table 1, entries 1 and 4).

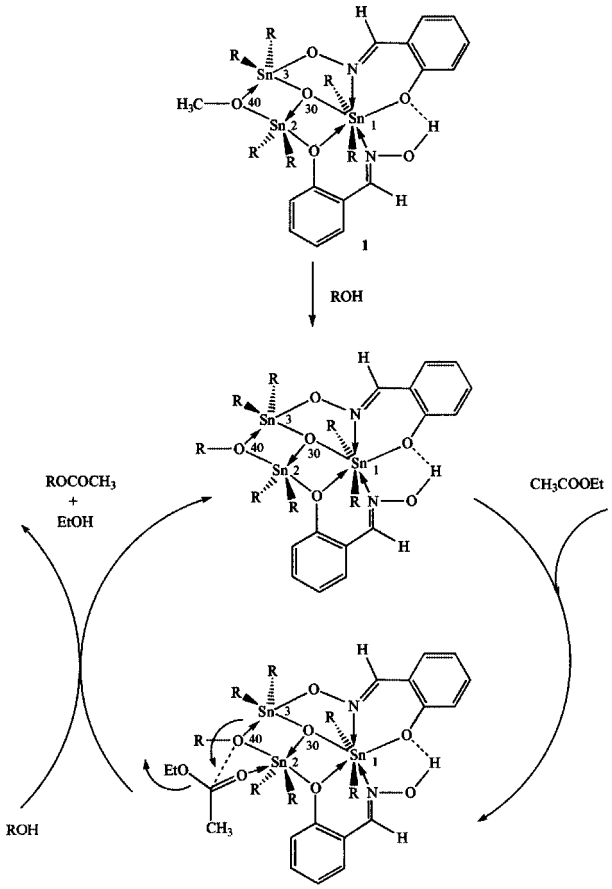
As a control, a reaction was performed in the absence of catalyst, in which case no reaction at all was observed (Table 1, entry 18).

A possible mechanism for the transesterification reaction catalyzed by **1** is depicted in Scheme 3. The initial step is the nucleophilic substitution of the methoxy group at the cluster site Sn2–O40–Sn3 by the reacting alcohol, the mechanism of which is well documented.[13] Subsequently, the carbonyl oxygen of the ester coordinates with Sn2. This coordination would activate the carbonyl group toward nucleophilic attack by the newly introduced alkoxy group, in the same way that the O–H bond is weakened when one alcohol substitutes another, when alcohol substitution occurs in the clusters at positions Sn2 and Sn3. According to this mechanism, the efficiency of the catalyst depends on two

Table 1. Acylation of various alcohols catalyzed by **1**,[a] and for comparison by **2** (*), **A** (**), and without catalyst (***)

Entry	Alcohol	Time (h)	Ester[b,c] (mol%)	Alcohol[b,c] (mol%)	Isolated material[c] (%)
1	Cyclohexanol	8	84	16	93
2	Cyclohexanol	24	99	1	85
3	Cyclohexanol	48	◊	—	89
4*	Cyclohexanol	8	58	42	95
5	$(i\text{-Pr})_2CHOH$	8	No	reaction	88
6	$(C_2H_5)_3COH$	24	No	reaction	95
7	C_6H_5-OH	8	No	reaction	87
8	$(CH_3)_2CH(CH_2)_2OH$	8	◊	—	93
9**	$(CH_3)_2CH(CH_2)_2OH$	8	◊	—	91
10	$PhCH(OH)CH_3$	8	61	39	93
11	$PhCH(OH)CH_3$	24	90	10	92
12	$PhCH(OH)CH_3$	48	96	4	94
13	$PhCH_2OH$	8	96	4	86
14	$PhCH_2OH$	24	99	1	95
15	$Ph(CH_2)_2OH$	8	92	8	92
16	$Ph(CH_2)_2OH$	24	◊	—	93
17	$CH_3(CH_2)_7OH$	8	◊	—	92
18***	$CH_3(CH_2)_7OH$	8	—	◊	93

[a] Amount of catalyst: 1 mol%, on the basis of alcohol concentration; *i.e.* 3 mol% of tin for **1** and **A** and 2 mol% of tin for **2** (calculated on basis of the monomeric formulation).
[b] Determined by ^1H NMR.
[c] Percentage of alcohol, ester or mixture of alcohol–ester isolated by distillation and calculated by integration of ^1H NMR spectra; ◊: only this product is observed; dashes indicate not observed.



Scheme 3.

stages in the reaction process. Regarding the first step, it was previously observed that the nucleophilic substitution of the methoxy group by another alkoxy group is dependent on the bulk of the entering alcohol, since no substitution could be achieved with tertiary alcohols or hindered phenols.[12,13] This fact explains the lack of reaction with tertiary alcohols or very bulky secondary alcohols (Table 1, entries 5 and 6), but not the negative result for phenol, since reaction with unhindered phenols does occur at this stage.[13] In the second step the approach of ethyl acetate to the reaction site should be hampered by steric hindrance of crowded alkoxy groups, explaining the diminished velocity at which secondary alcohols undergo transesterification. The absence of reaction with phenol also finds its origin in the second step, but for another reason. In this case, the tin–phenoxy bond is thermodynamically more stable than a tin–alkoxy bond, preventing the second step from taking place.

CONCLUSIONS

The trinuclear tin cluster **1**, soluble in organic solvents, is a reactive homogeneous acylation catalyst toward primary and unhindered secondary alcohols and is easy to separate by distillation from the reaction products.

EXPERIMENTAL

Starting materials

Dimethyltin dichloride, salicylaldoxime, ethyl acetate, di-*iso*-propyl alcohol, *iso*-amyl alcohol, phenethyl alcohol, *n*-octanol and benzyl alcohol were purchased from Aldrich. Cyclohexanol and phenol were purchased from UCB. The reagents were used without further purification.

Synthesis of catalysts

Compounds **1** and **A** were prepared as described in the literature,[14,15] as well as compound **2**.[13]

Procedure for transesterification

Ethyl acetate was used as starting ester and solvent in sevenfold excess with respect to the molar amount of the initial alcohol. 1 mol% of trinuclear tin cluster catalyst, i.e. 3 mol% of tin, with respect to the initial molar amount of the alcohol was used. The reaction mixture was refluxed for 8, 24 and 48 h. About 20% of ethyl acetate, together with the leaving alcohol, was distilled off during reflux. After reaction the excess of ethyl acetate was distilled off at atmospheric pressure. The residue, free of ethyl acetate, was subjected to a distillation at reduced pressure. The ester and residual non-reacted alcohol were distilled off and the tin cluster remained in the distillation flask. The ratio of ester to residual non-reacted alcohol was determined by ^{1}H NMR.

Measurements

The NMR spectra were acquired on a 250 MHz Bruker Avance instrument equipped with a Quattro probe tuned to 250.13 MHz and 62.93 MHz for ^{1}H and ^{13}C nuclei respectively. The chemical shifts were referenced to the standard Me_4Si scale from the residual solvent resonances of chloroform ($CHCl_3$, 7.23 ppm and 77.0 ppm for ^{1}H and ^{13}C nuclei respectively).

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REFERENCES

1. Otera J. *Chem. Rev.* 1993; **93**: 1449.
2. Orita A, Mitsutome A, Otera J. *J. Org. Chem.* 1998; **63**: 2420.
3. Vedejs E, Diver ST. *J. Am. Chem. Soc.* 1993; **115**: 3358.
4. Vedejs E, Bennet NS, Conn LM, Diver ST, Gingras M, Lin S, Oliver PA, Paterson MJ. *J. Org. Chem.* 1993; **58**: 7268.

5. Vedejs E, Daugulis O. *J. Org. Chem.* 1996; **61**: 5702.
6. D'Sa BA, Verkade JG. *J. Org. Chem.* 1996; **61**: 2963.
7. Mascaretti AO, Furlán RLE. *Aldrichim. Acta* 1997; **30**: 55.
8. Otera J, Yano T, Kawabata A, Nozaki H. *Tetrahedron Lett.* 1986; **27**: 2383.
9. Pereyre M, Collin G, Delvigne JP. *Bull. Soc. Chim. Fr.* 1969; 262.
10. Poller RC, Retout SP. *J. Organometal. Chem.* 1979; **173**: C7.
11. Willem R, Bouhdid A, Kayser F, Delmotte A, Gielen M, Martins JC, Biesemans M, Mahieu B, Tiekink ERT. *Organometallics* 1996; **15**: 1920.
12. Gielen M, Biesemans M, Willem R, Tiekink ERT. *Eur. J. Inorg. Chem.* 2004; 445.
13. Willem R, Bouhdid A, Meddour A, Camacho-Camacho C, Mercier F, Gielen M, Biesemans M, Ribot F, Sanchez C, Tiekink ERT. *Organometallics* 1997; **16**: 4377.
14. Kayser F, Biesemans M, Bouâlam M, Tiekink ERT, El Khloufi A, Meunier-Piret J, Bouhdid A, Jurkschat K, Gielen M, Willem R. *Organometallics* 1994; **13**: 1098.
15. Kayser F, Biesemans M, Bouâlam M, Tiekink ERT, El Khloufi A, Meunier-Piret J, Bouhdid A, Jurkschat K, Gielen M, Willem R. *Organometallics* 1994; **13**: 4126.

