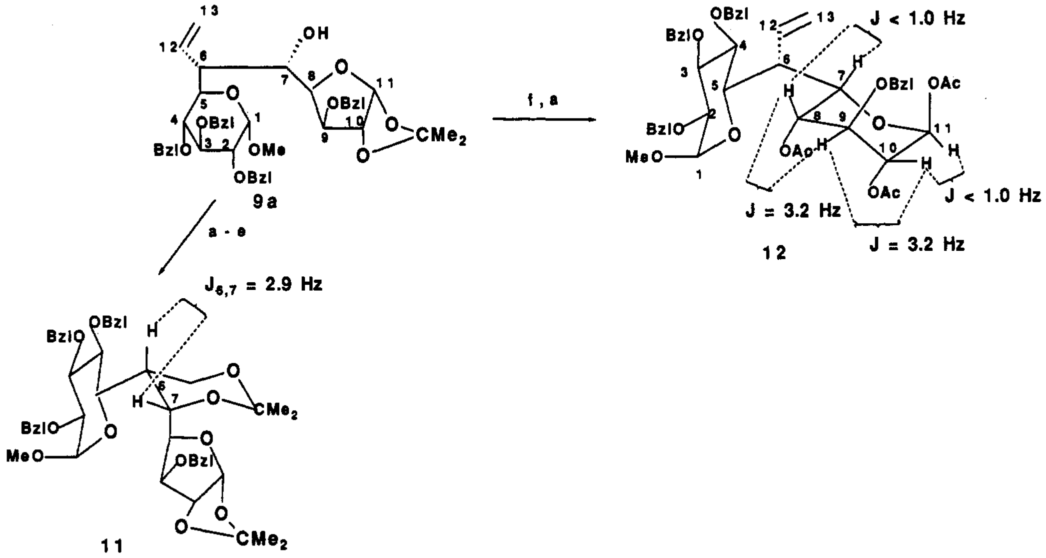
Scheme III[a]



[a] (a) Ac_2O/Py/DMAP; (b) O_3, CH_2Cl_2, -78 °C; (c) Me_2S, then $Zn(BH_4)_2$; (d) MeONa/MeOH; (e) acetone, CSA, room temperature; (f) CF_3COOH/H_2O/dioxane, room temperature.

the appropriate coupling constants, $J_{8,9} = J_{9,10} = 3.2$ Hz.

In conclusion, the method presented here allows the direct connection of "the ends" of two simple monosaccharide subunits. It should be also pointed out that either the coupling products **9a** and **9b** or dieno aldehyde **10** (which will be used in the synthesis of carbocycles) *can be obtained from the same precursor*, allyltin derivative **7**, using appropriate reaction conditions.

Distannoxane as Reverse Micelle-Type Catalyst: Novel Solvent Effect on Reaction Rate of Transesterification

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Summary: Distannoxane-catalyzed transesterification has an unusual solvent effect: the reaction proceeds more than 100 times faster in hydrocarbon and halocarbon solvents than in polar solvents. The effect is attributed to the unique reverse micelle-type structure of the distannoxane.

Table I. Distannoxane-Catalyzed Reaction of Butyrate Esters 2 with Benzyl Alcohol in Various Solvents at 80 °C[a,b]

2	solvent	yield of 4,[c] %	10^5k, L mol^{-1} min^{-1}
methyl butyrate	heptane	92	810 ± 50
	toluene	62	350 ± 40
	1,2-dichloroethane	71	300 ± 50
	acetonitrile	7	19 ± 2
	1,4-dioxane	8	36 ± 5
	diglyme	1	5 ± 2
ethyl butyrate	heptane	68	450 ± 40
	acetonitrile	2	9 ± 2
	1,4-dioxane	2	5 ± 3
	diglyme	1	1 ± 0.5
butyl butyrate	heptane	50	270 ± 50
	acetonitrile	3	8 ± 1
	1,4-dioxane	1	4 ± 1
	diglyme	1	3 ± 2

[a] Reaction conditions: butyrate ester-benzyl alcohol-1 = 1:2:0.005. The reaction was followed by means of GLC. [b] No reaction occurred in heptane or acetonitrile in the absence of the catalyst under the similar conditions. [c] Determined on the basis of GLC analysis after 20 h.

Sir: The interactions between reactants and solvents have considerable influence on organic reactions. It is often found that polar solvents accelerate reactions, especially when the reaction goes through a polar transition state.[1] In addition, Breslow et al. found that the Diels-Alder reaction, when conducted in aqueous solution, was accelerated due to the hydrophobic interactions between the reactants.[2] Grieco et al. reported analogous reactions which were attributed to micelle formation.[3] More recently, Liotta et al. uncovered a rate increase by the use of ethylene glycol as a reaction medium.[4] Despite different methodologies, the reactions of these three groups have the something in common, namely the aggregation of reactants induced by highly self-associating solvents incompatible with hydrophobic solutes. In this paper, we

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[1] For recent relevant discussion on the Claisen rearrangements, see: Brandes, E.; Grieco, P. A.; Gajewski, J. J. *J. Org. Chem.* **1989**, *54*, 515 and references cited therein.

[2] Rideout, D. C.; Breslow, R. *J. Am. Chem. Soc.* **1980**, *102*, 7817. Breslow, R.; Maita, U.; Rideout, D. *Tetrahedron Lett.* **1983**, *24*, 1901. Breslow, R., Maitra, U. *Tetrahedron Lett.* **1984**, *25*, 1239.

[3] Grieco, P. A.; Carner, P.; He, Z.-M. *Tetrahedron Lett.* **1983**, *24*, 1897. Grieco, P. A.; Calatsis, P.; Spohn, R. F. *Tetrahedron* **1986**, *42*, 2847 and references cited therein.

[4] Dunams, T.; Hoekstra, W.; Pentaleri, M.; Liotta, D. *Tetrahedron Lett.* **1988**, *29*, 3745.

0022-3263/89/1954-4013$01.50/0

describe the opposite solvent-dependence discovered in distannoxane-catalyzed transesterification, i.e. the reaction in nonpolar solvents proceeds much faster than in polar ones even in the absence of the relatively strong interactions of the type described above.

We previously disclosed that 1,3-disubstituted tetraorganodistannoxanes were effective for catalyzing transesterification under neutral conditions.[5,6] Further study has led us to find that polar solvents suppress greatly the reaction rate in contrast to smooth reactions in hydrocarbon and halocarbon solvents. The reactions of butyrate esters **2** (2 mmol) and benzyl alcohol (**3**) (4 mmol) in various solvents (10 mL) at 80 °C (eq 1) were monitored by means of GLC analysis. 1,3-Diisothiocyanatotetrabutyldistannoxane (**1**) (0.5 mol % of **2**) was employed as a catalyst.

$$\underset{\mathbf{2}}{\mathrm{PrCOOR}} + \underset{\mathbf{3}}{\mathrm{PhCH_2OH}} \xrightarrow{\mathbf{1}} \underset{\mathbf{4}}{\mathrm{PrCOOCH_2Ph}} + \mathrm{ROH} \quad (1)$$

Table I shows that the reaction occurs sluggishly in polar solvents such as acetonitrile, 1,4-dioxane, and ethylene glycol dimethyl ether (diglyme) while the yield of **4** is dramatically increased in hydrocarbon and halocarbon solvents. Estimation of this solvent effect is also provided by the rate constants (k) obtained as a pseudo-second-order reaction with respect to each reactant neglecting the influence of the catalyst.[7] Since transesterification is an equilibrium reaction, the constants are calculated at an early reaction stage: up to 50% conversion for the faster reactions and between the reaction time 1–10 h for the slower reactions. Apparently, the reaction rates in less polar solvents are more than 100 times greater than those in polar solvents. Note that the data in Table I do not result after an equilibrium has been reached since the reverse reaction between benzyl butyrate and 1-butanol (1:2 molar ratio) shows a similar tendency as shown below. Obviously, the rate of the reaction 1 (where R = Bu) is slower than that of the reverse reaction 2. If the equilibrium has been reached in heptane after 20 h, the equilibrium constants obtained from both forward and reverse reactions should coincide with one another. However, calculation of these values based on the present data gives 0.33 for reaction 1 and 1.0 for reaction 2. The yield of the transesterification product after 8 h in this solvent is 35% in the former reaction while 64% in the latter. Accordingly, we assume that reaction 2 has almost reached an equilibrium state after 10 h while reaction 1 is still moving forward even after 20 h.

$$\mathrm{PrCOOCH_2Ph} + \text{1-BuOH} \xrightarrow{\mathbf{1}} \mathrm{PrCOOBu} + \mathrm{PhCH_2OH} \quad (2)$$

solvent	yield after 20 h, %	10^5k, L min^{-1} mol^{-1}
heptane	66	810 ± 15
acetonitrile	8	20 ± 5

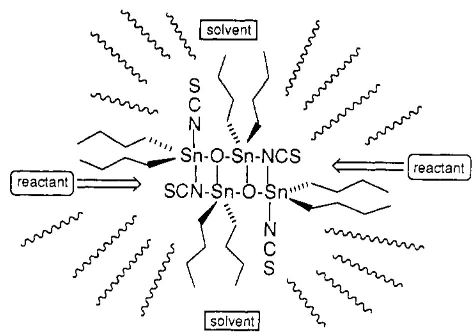

Figure 1. Distannoxane in solution.

The distannoxanes are quite unique in that they are soluble in any of organic solvents including aliphatic hydrocarbons in spite of involving a metalloxane moiety as the major portion of the molecular skeleton. This unusual solubility is ascribed to the dimeric structure surrounded by eight alkyl groups.[8] The surface alkyl chains wrap the inorganic moiety in the central pocket allowing the molecules to readily dissolve in organic solvents (Figure 1). Thus the solution of **1** in organic solvents consists of highly polar stannoxane islands dispersed in a less polar ocean, having structures like reverse micelles,[9] particularly in hydrocarbon and halocarbon solvents. When transesterification is run in these solvents, polar alcohols and esters are expelled from the medium to the polar stannoxane sites. By contrast, the polar reactants prefer to stay in the solvent phase in the cases where the solvents are polar.[10] As a consequence, the reaction is accelerated in the former cases whereas retarded in the latter.

Obviously, the solute–solute or solute–solvent interactions involved in the present system are much weaker than the hydrophobic interactions which originate from the strong tendency of water toward self-attraction excluding the hydrophobic solutes.[11] On this basis, it may be rather surprising that the rate enhancement amounts to more than 100 times which is comparable to the 100–1000-fold acceleration by changing the solvent from isooctane to water in Breslow's case.[2]

In conclusion, we have discovered that molecular interactions which are much weaker than hydrophobic interactions can also be influential on certain reactions. Design of an appropriate reaction field allows us to conduct the polar reactions more efficiently in nonpolar solvents, the employment of which would be of great synthetic value. Since the reverse micelle-type structure seems to be easily accessible for a wide variety of organometallic compounds, the work described herein probably will find further applications.

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(5) Otera, J.; Yano, T.; Kawabata, A.; Nozaki, H. *Tetrahedron Lett.* **1986**, *27*, 2383.

(6) Further synthetic applications: Schreiber, S. L.; Meyers, H. V. *J. Am. Chem. Soc.* **1988**, *110*, 5198. Schreiber, S. L.; Desmaele, D.; Porco, J. A., Jr. *Tetrahedron Lett.* **1988**, *29*, 6689.

(7) The catalyst may affect the reaction course because the reaction deviates from the theoretical second order rate equation to some degree especially in the latter stage. However, the rate constants listed in Table I, we believe, clearly demonstrate the features of the solvent dependence in a qualitative sense at least.

(8) Okawara, R.; Wada, M. *Adv. Organomet. Chem.* **1967**, *5*, 137. Yano, T.; Nakashima, K.; Otera, J.; Okawara, R. *Organometallics* **1985**, *4*, 1501 and references cited therein.

(9) Luisi, P. L. *Angew. Chem., Int. Ed. Engl.* **1985**, *24*, 439.

(10) Enzyme reactions in organic solvents seem to proceed with similar solution structures, but the role of the solvents which serve to prevent water on the enzyme surface from being stripped off is completely different from the present case: Klibanov, A. M. *Chemtech* **1986**, 354.

(11) Tanford, C. *The Hydrophobic Effect*, 2nd ed.; Wiley: New York, 1980.