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A New Crosslinked Polymer for the Heterogeneous Catalytic Asymmetric Dihydroxylation of Alkenes

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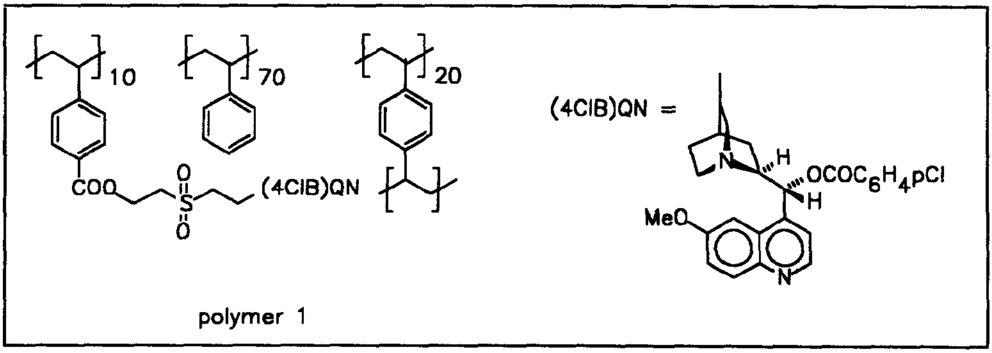
Abstract : Heterogeneous catalytic asymmetric dihydroxylation of alkenes has been reported using a new crosslinked polymer containing a cinchona alkaloid derivative.

The catalytic asymmetric dihydroxylation of alkenes has been the subject of intensive research in recent years[1]. Thanks to the development of more effective chiral cinchona alkaloid derived ligands reported[2] by the Sharpless group, today a large class of olefinic substrates can be transformed to enantiomerically pure or enriched diols, which are useful intermediates in organic synthesis. To explore the possibility of recycling both the expensive osmium tetroxide and the chiral ligand and of easily recovering the reaction products, polymer bound cinchona alkaloid derivatives have been employed[3,4,5,6].

In a continuing effort to improve the results obtained in our first paper[3,5] on heterogeneous catalytic dihydroxylation, we investigated the possibility of using new polymeric supports for this important reaction; we now wish to report the preliminary results obtained by the use of a crosslinked polymer containing a cinchona alkaloid derivative, which furnished diols from alkenes in high chemical yields and good enantioselectivity.



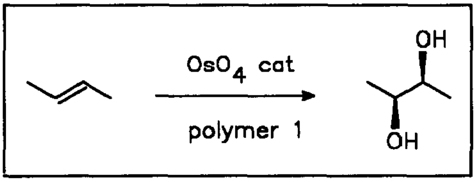
polymer 1

The polymer 1 was prepared by copolymerization of a chiral monomer containing the p-chlorobenzoate ester of quinine: this is in fact one of the most used and effective ligand employed in the homogeneous dihydroxylation of alkenes[7]. A spacer group was also introduced between the quinine derivative and the styryl group, to let the quinuclidinic moiety of the ligand, responsible of the complexation with osmium tetroxide, unaffected by the steric hindrance of the polymeric chain.

In order to obtain a highly insoluble and easily filtrable material, we have copolymerized the chiral monomer with 70% by mol of styrene and 20% by mol of divinylbenzene, obtaining copolymer **1**, with an alkaloid content of 10% by mol, as confirmed by nitrogen analysis[8]. Higher levels of alkaloid incorporation should be avoided because in these conditions, as we have previously[5] pointed out, asymmetric dihydroxylation of alkenes is completely inhibited or very slow.

This new polymer was tested with *trans*-stilbene and other olefins in different experimental conditions (see Table 1).

Table 1: Heterogeneous Catalytic Asymmetric Dihydroxylation of Olefins with Polymer 1[9].



Entry	Olefin	Secondary oxidant	Reaction time	Temperature (°C)	% Yield	%e.e.[a]	config.
1	*trans*-stilbene	NMO	6	25	81	69	(*S*,*S*)
2	"	NMO	6	25	77	65[b]	"
3	"	$K_3Fe(CN)_6$	24	25	-	-	-
4	"	NMO	7	0	85	87	(*S*,*S*)
5	styrene	"	4	25	70	40	(*S*)
6	"	"	5	0	72	54	"
7	E-β-methylstyrene	"	6	0	69	60	(*S*,*S*)

a) Determined by comparison of $[\alpha]_D^{10}$ with literature values. b) Polymer from entry 1 was recycled.

As shown in entries 1 and 2, asymmetric dihydroxylation of *trans*-stilbene using copolymer **1** and with NMO as secondary oxidant is fast (even at 0°C) and occurs with high extent of enantioselectivity; on the contrary with $K_3Fe(CN)_6$ the formation of the diol was not observed.

This result can be attributable to the different behaviour of the copolymer in the two solvent systems used. In fact in the protic polar solvent mixture (^{t}BuOH:water 1:1) used with potassium ferricyanide as secondary oxidant, the polymer is likely to collapse, thus preventing substrate penetration; on the contrary, the reaction proceeds in the aprotic polar solvent mixture acetone:water 10:1, used with NMO as secondary oxidant.

In entry 2 are reported the chemical yield and e.e. obtained recycling the polymer from entry 1, without adding additional OsO_4: it was observed only a small decrease in the catalytic activity probably due to loss of OsO_4, during the isolation of the product.

The enantioselectivity obtained with styrene and E-methylstyrene are higher than those reported[11] previously for the heterogeneous reaction and nearly the same as obtained with the free alkaloid under similar reaction conditions. It is particularly noteworthy that these results are obtained in a short reaction time and without the reported [6] slow addition of the olefin. As previously noted, a lowering of the temperature (see for example entry 4) from 25°C to 0°C led to an improvement of the e.e of the diols.

Further studies are in progress to improve the enantioselectivity with other classes of alkenes and to widen the applicability of the polymeric system .

REFERENCES AND NOTES

1. For a review see: Lohray, B.B. *Tetrahedron Asymmetry* **1992**, *3*, 1317-1349.
2. a) Sharpless, K. B.; Amberg, W.; Bennani, Y. L.; Crispino, G. A.; Hartung, J.; Jeong, K.; Kwong, H.; Morikawa, K.; Wang, Z.; Xu, D.; Zhang, X. *J.Org. Chem.* **1992**, *57*, 2768-2771. b) Sharpless, K.B.; Amberg, W.; Beller, M.; Chen, H.; Hartung, J.; Kawanami, Y.; Lubben, D.; Manoury, E.; Ogino, Y.; Shibata, T., Ukita, T. *J. Org. Chem.* **1991**, *56*, 4585-4588.
3. Pini, D.; Rosini, C.; Nardi, A.; Salvadori, P. *Fifth IUPAC Symposium On Organometallic Chemistry Directed Towards Organic Synthesis*, Abstract PS1-67, Florence (ITALY).
4. Kim, B.M.; Sharpless, K. B. *Tetrahedron Lett.* **1990**, *31*, 3003-3006.
5. Pini, D.; Petri, A.; Nardi, A.; Rosini, C.; Salvadori, P. *Tetrahedron Lett.* **1991**, *32*, 5175-5178.
6. Lohray, B.B.; Thomas, A.; Chittari, P.; Ahuja, J. R.; Dhal, P.K. *Tetrahedron Lett.* **1992**, *33*, 5453-5456.
7. Lohray, B.B.; Kalantar, T.H.; Kim, B.M.; Park, C. Y.; Shibata, T.; Wai, J.S.M.; Sharpless, K.B.*Tetrahedron Lett.* **1989**, *30*, 2041-2044.
8. Polymer **1** was obtained by reaction of 2 mmol of the chiral monomer with 4 mmol of DVB and 14

mmol of styrene, in benzene, using AIBN (0.4 mmol) as radical initiator at 75°C for 30 hours. The precipitated polymer was filtered and continously extracted with acetone in order to avoid the presence of non reacted monomer. As copolymer 1 is insoluble in the most common organic solvents, the alkaloid content was determined elemental analysis.

9. ***A typical general procedure is as follow:*** to a solution of 1.6 eq. of NMO in 5.5 mL acetone:water(10:1) is added OsO_4(0.005 eq., solution in acetonitrile) and polymer 1 (0.11 eq. based on alkaloid incorporated). After stirring for 30 minutes the olefin was added all at once; then the heterogeneous mixture was stirred for the given time and monitored by T.L.C.. When the reaction was complete, water (3 mL) was added and the mixture was centrifugated. The centrifugate was stirred for one hour with an excess of sodium metabisulfite and sodium sulfate. After filtration of the solids, the filtrate was concentrated to give the crude diols, which were purified by chromatography on a silica gel column (hexane: ethyl acetate as eluent).

10. (a) *trans*-stilbene: $[\alpha]_D^{21}$+91.0 (c 1.10, EtOH), Berti,G.; Bottari, F. *J. Org. Chem.* **1960**, *25*, 1286. (b) E-methylstyrene: $[\alpha]_D^{20}$ + 32.1 (c 1.79, EtOH), Tomioka, K.; Nakajima, M.; Koga, K. *J.Am.Chem. Soc.* **1987**, *109*, 6213. (c) styrene: $[\alpha]_D^{25.5}$ -63.7 (c 5.5, $CDCl_3$), Dale, J. A.; Mosher, H.S. *J. Org. Chem.* **1970**, *35*, 4002.

11. Jacobsen, E.N.; Markò, I.; Mungall, W.S.; Schroder, G.; Sharpless, K.B. *J. Am.Chem. Soc.* **1988**,*110*, 1968.