

## Carbonyl Cluster Derived Polystyrene Supported Platinum for Asymmetric Hydrogenation of $\alpha$ -Ketoesters

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Ion-pairing of anionic carbonyl clusters with cinchona alkaloid groups on cross-linked polystyrene is a viable method for the synthesis of asymmetric catalysts for the hydrogenation of methyl pyruvate.

While notable progress has been made in asymmetric homogeneous catalysis, examples of the effective use of heterogeneous catalysts in chiral syntheses are very few.<sup>1,2</sup> The best example of such a transformation in a heterogeneous system is the catalytic hydrogenation of pyruvate esters. Using platinum catalysts modified with cinchona alkaloids lactate esters with high enantioselectivities are obtained. This reaction was first reported by Orito and has subsequently been studied in considerable detail by others.<sup>3,4</sup> Here we report a general method for synthesising heterogeneous catalysts with

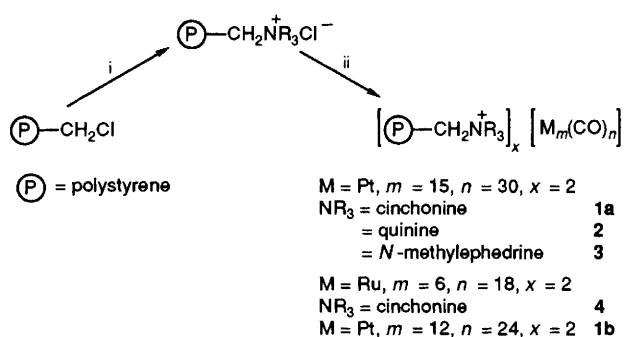
potential applications in asymmetric hydrogenation reactions. In this method fully characterised anionic carbonyl clusters are ion-paired with chiral quaternary nitrogen containing groups on a polystyrene-support. Many anionic clusters of different metals and chiral quaternary nitrogen containing groups can be synthesised. The scope of bringing clusters of different metal atoms of well defined shapes and sizes in close proximity to different chiral environments by this method is therefore wide. The viability of this reasoning has been established by carrying out the Orito reaction with a catalyst derived from

anionic platinum carbonyl clusters, and cross-linked polystyrene with pendant quaternary cinchona alkaloid functionalities.

The reactions employed for anchoring carbonyl clusters on the polymer support with chiral groups are shown in Scheme 1. The syntheses, characterisations and uses of polymer-supported cinchona and ephedra alkaloid salts in asymmetric reactions have been reported.<sup>5</sup> Anionic carbonyl clusters are also known to undergo exchange with halide ions of anion exchange resins.<sup>6</sup> The supported carbonyls **1** to **4** are synthesised by treating a methanolic solution of the sodium salt of the anionic carbonyl<sup>7</sup> with the functionalised polymer at ambient temperatures. The supported and the parent clusters have identical infrared spectra in the inorganic carbonyl region. This indicates that on anchoring the structure and composition of the clusters are not effected. The nitrogen contents of the functionalised polymers are determined by microanalyses. The amount of platinum present in species **1**–**3** is measured by atomic absorption spectrometry. These values taken together indicate the presence of quaternary nitrogen and cluster molecules, approximately per 75 and 150 monomeric units, respectively.

Species **1**–**4**, when activated by heating (80 °C) under vacuum (10<sup>-3</sup> mmHg), are effective hydrogenation catalysts for a variety of ketoesters (Table 1). In the hydrogenation of methyl pyruvate, high conversions and enantioselectivities (>75%) are obtained with catalysts containing platinum and cinchona alkaloids. Although, in terms of conversions, the platinum clusters lead to more effective catalysts than the ruthenium cluster, high enantiomeric excess is also obtained with the latter. The lower activity of the ruthenium cluster is probably due to incomplete decarbonylation of species **4** under the conditions employed for activation (see later).

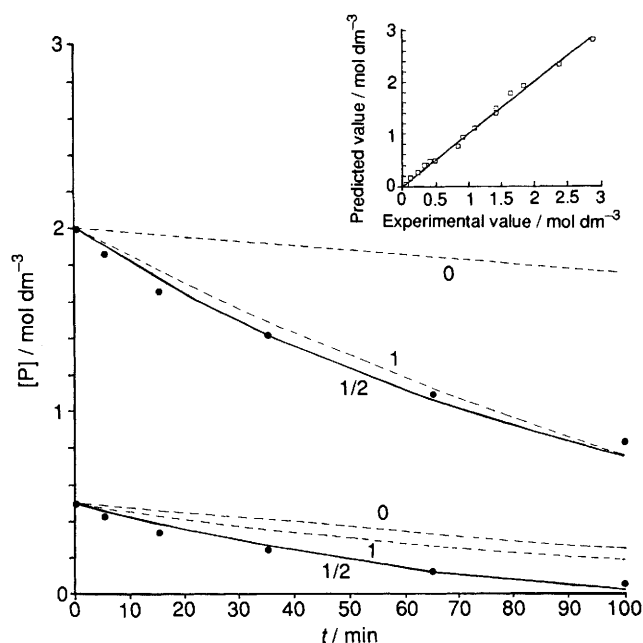
Species **1a** and **1b** have similar catalytic activities both in terms of conversion and enantioselectivity. However, unlike



**Scheme 1** Reagents and conditions: i, toluene-ethanol (1:1), 20% divinylbenzene (DVB) cross-linked chloromethylated polystyrene (Strem Chemicals) to NR<sub>3</sub> in 1:1 mass ratio, 110 °C, 24 h; ii, 25 °C, MeOH, Na<sub>2</sub>[M<sub>*m*</sub>(CO)<sub>*n*</sub>]

species **1**–**3**, the material derived from ion exchange of the functionalised polymer with PtCl<sub>6</sub><sup>2-</sup> is catalytically inactive (data not shown in Table 1). Among the substrates high enantiomeric excess is obtained only for methyl pyruvate with all the catalysts. Similar observations with conventional cinchona modified platinum catalysts have been reported.<sup>3,4a</sup> The cinchona alkaloids are more effective in bringing about enantioselectivity than *N*-methylephedrine. Interestingly, using **4**, a low but definite enantiomeric excess is obtained in the hydrogenation of methyl acetoacetate.

The conditions under which species **1**–**4** are activated (see above) result in the total decarbonylation of **1**–**3** and only partial decarbonylation of **4**. Species **1**–**3** could be regenerated by exposing the used catalysts to CO (500 psi, 25 °C, 24 h). The IR and the UV-VIS spectra<sup>6</sup> of the freshly anchored cluster and the recarbonylated materials are almost identical. Separate experiments establish that creation of coordinative unsaturation by decarbonylation is essential for catalytic activity. Thus, no catalysis is observed either by the intact



**Fig. 1** Change in concentration of methyl pyruvate, P, with time during catalytic runs. Experimental points (●) with two different initial concentrations of P are shown. Temperature and pressure as described in Table 1. (---) Assumed that *n* = 0, 1; (—) assumed that *n* = ½ labelled by respective *n* where rate = *k*[P]<sup>*n*</sup> (*k* = constant). Inset: Parity plot *i.e.* plot of predicted values for the concentration of methyl pyruvate assuming half-order rate dependence vs. experimental values.

**Table 1**<sup>a,b</sup> Conversion (% of two enantiomers or net enantiomeric excess) in the hydrogenations of keto esters with different catalysts

Catalyst	Substrate			
<b>1a</b>	100 (90 <i>S</i> , 10 <i>R</i> )	100 (65 <i>R</i> , 35 <i>S</i> )	100 (≤5)	20 (≤5)
<b>1b</b>	100 (89 <i>S</i> , 11 <i>R</i> )	100 (63 <i>R</i> , 37 <i>S</i> )	100 (≤5)	20 (≤5)
<b>2</b>	100 (88 <i>R</i> , 12 <i>S</i> )	100 (64 <i>S</i> , 36 <i>R</i> )	100 (≤5)	15 (≤5)
<b>3</b>	100 (75 <i>S</i> , 25 <i>R</i> )	100 (≤10)	100 (≤5)	15 (≤5)
<b>4</b>	30 (85 <i>R</i> , 15 <i>S</i> )	35 (≤10)	25 (≤5)	30 (60 <i>S</i> , 40 <i>R</i> )

<sup>a</sup> All reactions carried out in methanol (10 ml) at 25 °C under hydrogen (500 psi) with polymer-supported catalyst (100 mg, *ca.* 13 mg platinum) and substrate (20 mmol) in a glass vessel with magnetic stirring over a period of 4 h. <sup>b</sup> Conversion (%) and enantiomeric excess measured by gas chromatography and polarimetry (average of two experiments), respectively.

parent clusters in solution, or by species 1-4 without activation.

In so far as the order of the rate with respect to the concentration of methyl pyruvate is concerned the kinetic behaviour of 1a is different from that of the cinchona modified conventional platinum catalysts. An approximate zero-order rate dependence has been reported with conventional catalysts.<sup>4</sup> In contrast, as can be seen from Fig. 1, a good fit between the experimental data points and simulated time-dependent concentrations can only be obtained if the rate is assumed to be half-order with respect to the concentration of methyl pyruvate. The goodness of fit, when half-order rate dependence is assumed, is also apparent from the parity-plot (Fig. 1, inset) where experimental concentration values under a set of conditions are compared with the predicted ones. Most of the points fall very close to the 45° line where prediction coincides with the experimental data. The coefficient of variation is as low as 5.3%.

The half-order dependence is best explained in terms of an equilibrium between the free methyl pyruvate (P) and surface-adsorbed methyl pyruvate in approximately equal *s-cis* (P<sub>c</sub>) and *s-trans* (P<sub>t</sub>) configurations. If the mole fraction of adsorbed pyruvate is much smaller than 1 then  $[P_c] = [P_t] = K[P]^{\frac{1}{2}}$  where K is a constant. It is probable that the enantioselective hydrogenation step is associated with only one of these two configurations of the surface adsorbed species.

In conclusion the synthesis of asymmetric catalysts by ion-pairing of anionic clusters with chiral quaternary nitrogen containing groups on a polymer-support, has been shown to be a viable method. Further work involving variation of the chiral group, and the carbonyl clusters is underway.

The authors wish to thank ICI India Limited for financial support.

Received, 22nd June 1992; Com. 2/03264C

## References

- 1 R. Noyori, *Science*, 1990, **248**, 1149; R. Noyori and H. Takaya, *Acc. Chem. Res.*, 1990, **23**, 345; I. Ohima, N. Clos and C. Bosters, *Tetrahedron*, 1989, **45**, 6901; S. L. Blystone, *Chem. Rev.*, 1989, **89**, 1663.
- 2 Y. Izumi, *Advances in Catalysis*, ed. D. D. Eley, H. Pines and P. B. Weisz, Academic Press, San Diego, 1983, vol. 32, p. 215.
- 3 Y. Orito, S. Imai, S. Niwa and G. H. Nguyen, *J. Synth. Org. Chem. Jpn.*, 1979, **37**, 173; Y. Orito, S. Imai and S. Niwa, *Nippon Kagaku Kaishi*, 1979, **8**, 1118.
- 4 (a) I. M. Sutherland, A. Ibbotson, R. B. Moyes and P. B. Wells, *J. Catal.*, 1990, **125**, 77; (b) P. A. Maheux, A. Ibbotson and P. B. Wells, *J. Catal.*, 1991, **128**, 387; (c) J. T. Wehrli, A. Baiker, D. M. Monti, H. U. Blaser and H. P. Jalett, *J. Mol. Catal.*, 1989, **57**, 245; (d) J. T. Wehrli, A. Baiker, D. M. Monti and H. U. Blaser, *J. Mol. Catal.*, 1990, **61**, 207; (e) M. Garland and H. U. Blaser, *J. Am. Chem. Soc.*, 1990, **112**, 7048; (f) J. T. Wehrli, A. Baiker, D. M. Monti and H. U. Blaser, *J. Mol. Catal.*, 1989, **49**, 195.
- 5 M. Ingaki, J. Hiratake, Y. Yamamoto and J. Oda, *Bull. Chem. Soc. Jpn.*, 1987, **60**, 4121; P. Hodge, E. Khoshdel, J. Waterhouse and M. J. Frechet, *J. Chem. Soc., Perkin Trans. 1*, 1985, 2327; P. Hodge, E. Khoshdel and J. Waterhouse, *J. Chem. Soc., Perkin Trans. 1*, 1983, 2205.
- 6 S. Bhaduri and K. R. Sharma, *J. Chem. Soc., Dalton Trans.*, 1984, 2309.
- 7 G. Longoni and P. Chini, *J. Am. Chem. Soc.*, 1976, **98**, 7225; C. R. Eady, P. F. Jackson, B. F. G. Johnson, J. Lewis, M. C. Malatesta, M. McPartlin and W. J. H. Nelson, *J. Chem. Soc., Dalton Trans.*, 1980, 383.