Res Chem Intermed (2010) 36:227–236
DOI 10.1007/s11164-010-0132-7

# Synthesis of chiral α-ethylphenylamine salts of tartaric acid and novel application to cyanosilylation of prochiral ketones

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Received: 14 May 2009 / Accepted: 25 December 2009 / Published online: 11 March 2010


**Abstract** Chiral α-ethylphenylamine tartaric acid salts were synthesized from α-ethylphenylamine by direct reaction with chiral tartaric acid. The crystal structure of *S*-(−)-α-ethylphenylamine-(2*R*,3*R*)-(−)-dihydroxybutanedioic acid was determined. The crystal is monoclinic, of space group $P2_{1/n}$, with $a = 6.331(5)$ Å, $b = 14{,}209(11)$ Å, $c = 7.495(6)$ Å, $\alpha = 90.00^\circ$, $\beta = 107.000(13)^\circ$, $\gamma = 90.00^\circ$, $\lambda = 0.7103$ Å, $V = 644.7(9)$, $Z = 2$, $D_c = 1.397$ g/cm$^3$, $M_r = 271.27$ and $F(000) = 288$, $R = 0.0477$, and $\omega R = 0.0838$ for 1388 observed reflections with $I > 2\sigma(I)$. We then used the chiral α-ethylphenylamine tartaric acid salts as catalysts in the cyanosilylation of prochiral ketones, and moderate conversions were obtained.

**Keywords** Chiral α-ethylphenylamine tartaric acid salts 1a–1d · Crystal structure · Cyanosilylation of prochiral ketones · Cyanohydrin trimethylsily ethers

## Introduction

Cyanosilylation reactions involving enantioselective addition of cyanotrimethylsilane (TMSCN) to aldehydes have been studied by many groups, for example Shibasaki [1–3], Deng, Jacobsen [4–6], Corey [7, 8], and Feng [9]. As novel catalysts, they have high reaction activities and selectivities. Using this as a basis for our work, we first employed the easily obtainable chiral α-ethylphenylamine tartaric acid salts 1a–1d as catalysts in the cyanosilylation of prochiral ketones [10].

**Electronic supplementary material** The online version of this article (doi: 10.1007/s11164-010-0132-7) contains supplementary material, which is available to authorized users.

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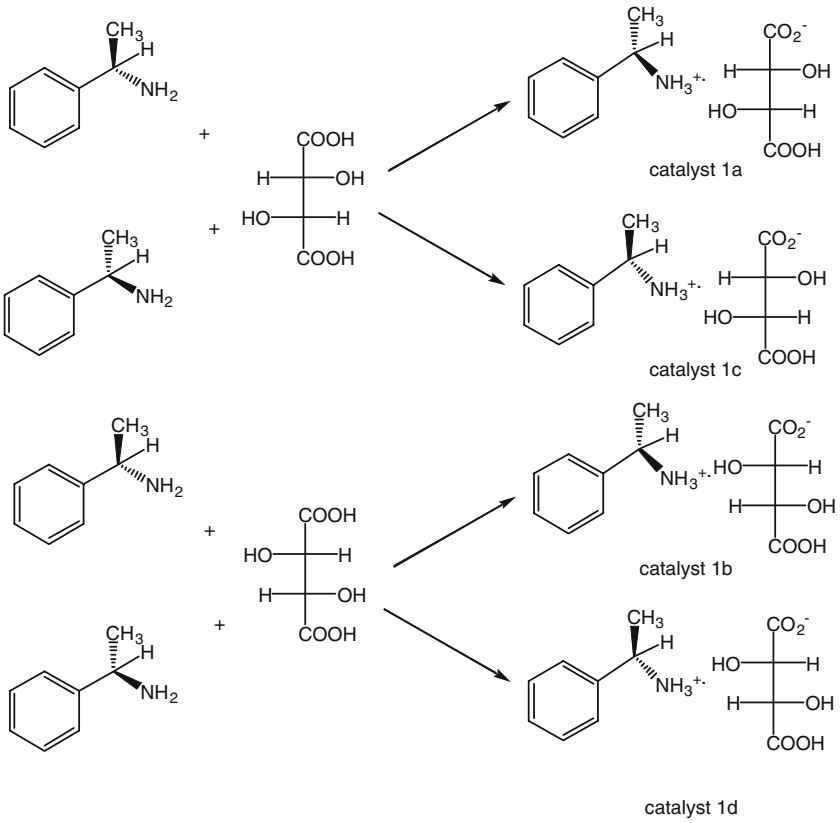
As Bronsted acids, they were synthesized from *R*-(+)/*S*-(−)-α-ethylphenylamine by reaction with (2*S*,3*S*)-(+)/(2*R*,3*R*)-(−)-dihydrobutanedioic acid in methanol (Scheme 1). The salts were collected by filtration and recrystallized twice from methanol to give single white crystals. The crystal structure of *S*-(−)-α-ethylphenylamine-(2*R*,3*R*)-(−)-dihydroxybutanedioic acid was obtained from these crystals.

## Experimental

### General procedures

The course of all cyanosilylation reactions was monitored by thin-layer chromatography using 0.25-mm E. Merck silica gel-coated glass plates ($60F_{254}$), and




Catalyst 1a: R-(+)- α-Methylbenzylamine-(2R,3R)-(-)-2,3-dihydroxybutanedioic acid salt
Catalyst 1b: R-(+)- α-Methylbenzylamine-(2S,3S)-(+)-2,3-dihydroxybutanedioic acid salt
Catalyst 1c: S-(-)- α-Methylbenzylamine-(2R,3R)-(-)-2,3-dihydroxybutanedioic acid salt
Catalyst 1d: S-(-)- α-Methylbenzylamine-(2S,3S)-(+)-2,3-dihydroxybutanedioic acid salt

**Scheme 1** Synthetic routes to catalysts 1a–1d

UV light for visualization. Flash column chromatography was performed using E. Merck silica gel 60 (particle size 0.02–0.03 mm). Chemical conversion were determined by $^{1}$H NMR and $^{13}$C NMR spectroscopy. $^{1}$H and $^{13}$C NMR spectra were obtained using Bruker AM-300 and Bruker AM-400 spectrometers. The following abbreviations were used to designate chemical shift multiplicities: s = singlet, d = doublet, t = triplet, m = multiplet. Infrared spectra were recorded on a Mattson Galaxy Series FTIR 3000 Spectrometer. High-resolution mass spectra were obtained on Micro GCT-MS, Optical rotation was measured on WZZ-1 automatic polarimeter. Enantiomeric excess (ee) was determined by HPLC analysis. HPLC was performed on a Beijing Chuangxin tonghang system comprising a pump, UV detector, and Daicel Chiralcel OD-H column with hexane as mobile phase. *R*-(+)/*S*-(−)-α-ethylphenylamine and (2*R*,3*R*)-(−)/(2*S*,3*S*)-(+)-2,3-dihydroxybutanedioic acid were bought from the Changzhou KeRuiDa Corporation, China. ee for *R*-(+)/*S*-(−) ethylphenylamine and (2*R*,3*R*)-(−)/(2*S*,3*S*)-(+)-2,3-dihydroxybutanedioic acid were >99%.

## Synthesis of catalysts 1a–1d

1a: preparation of *R*-(+)-α-ethylphenylamine-(2*R*,3*R*)-(−)-2,3-dihydroxybutanedioic acid salt

(−)-Tartaric acid (6.3 g) was dissolved in 90 mL methanol and 5 g *R*-α-phenylethylamine was slowly added in a dry 250 mL cone bottle. The mixture was left motionless for more than 24 h and the salts were collected by filtration and recrystallized twice from methanol to give white single crystals (3.5 g). Melting point: 66–68 °C, $[\alpha]_D^{25} = -13.9^\circ$ ($c$ = 1.72, $CH_3OH$); $^{1}$H NMR (300 MHz, $CD_3OD$, 27 °C), $\delta$ (ppm) = 7.38–7.48 (m, 5H), 4.89 (s, 5H), 4.43–4.48 (m, 1H), 4.40 (s, 2H), 1.62–1.64 (d, $J$ = 5.16, 3H), $^{13}$C NMR: 20.80 (×2), 52.27, 74.20, 127.69, 130.04, 130.24, 139.89, 177.07, I R: 3274, 3193, 2950, 2867, 2838, 1710, 1597, 1436, 1354, 1309, 1165, 1089, 996, 920, 898, 813, 754, 706, 669, 548, 577, 532; HRMS (EI): *m*/*z* (%): calcd for $C_{14}H_{26}N_2O$: 271.1056; found: 271.1053.

1b: preparation of *R*-(+)-α-ethylphenylamine-(2*S*,3*S*)-(+)-2,3-dihydroxybutanedioic acid salt

The procedure described for 1a was followed $[\alpha]_D^{25} = +13.6^\circ$ ($c$ = 1.54, $CH_3OH$).

1c: Preparation of *S*-(−)-α-ethylphenylamine-(2*R*,3*R*)-(−)-2,3-dihydroxybutanedioic acid salt

The procedure described for 1a was followed. $[\alpha]_D^{25} = -13.5^\circ$ ($c$ = 1.62, $CH_3OH$).

1d: Preparation of *S*-(−)-α-ethylphenylamine-(2*S*,3*S*)-(+)-2,3-dihydroxybutanedioic acid salt

The procedure described for 1a was followed. $[\alpha]_D^{25} = +13.1^\circ$ ($c$ = 1.42, $CH_3OH$).

## Structure determination

A colorless block monoclinic crystal of the catalyst 1c with approximate size 0.51 mm × 0.46 mm × 0.35 mm was selected for data collection on a Bruker Smart diffractometer with graphite monochromatic Mo$K\alpha$ radiation ($\lambda$ = 0.7103 Å). A total of 3767 reflections were collected in the range $2.87 < \theta < 27.00°$ by using the "phi and omega" scan techniques at 293(2) K; of these, 1459 independent reflections were used in

the succeeding refinements for 1388 observed reflections with $I > 2\sigma(I)$. $R_{int} = 0.0331$ and *Lp* corrections were applied to the data.

The structure was solved by direct methods and different Fourier map techniques by using the Bruker Smart software, and refinement on $F^2$ was performed by full-matrix least-squares methods with anisotropic displacement parameters for all non-hydrogen atoms. All hydrogen atoms were found by difference Fourier map techniques by using SHELXS-97 software and refined isotropically in the riding mode with fixed thermal factors. The molecular graphics were drawn with the Bruker SHELTXL software package [11–13].

## Preparation of the cyanosilylation products

### *2-(Trimethylsilyloxy)-2-phenylpropanenitrile*

1a 0.070 g (0.258 mmol) was dissolved in 1 mL $CH_2Cl_2$, acetophenone 0.1 mL (0.857 mmol) and TMSCN (0.2 mL, 1.50 mmol) were successively added at room temperature. After 0.5 h, the reaction was quenched. Further purification was performed by silica gel column chromatography (petroleum–dichloromethane 4:1). The title compound was obtained as a colorless oil, conversion = 45%, $^1$H NMR (300 MHz, $CDCl_3$): 7.44–7.47 (m, 3H), 7.24–7.32 (m, 2H), 1.76 (s, 3H), 0.079 (s, 9H). $^{13}$C NMR (75 MHz, $CDCl_3$): 0.98 (×3), 22.56, 33.51, 71.53, 121.54, 124.53 (×2), 128.57 (×2), 141.92. ee 5%; HPLC (Chiralcel OD-H), mobile phase hexane; flow = 0.5 mL/min, $t_r$(minor) = 16.579, $t_r$(major) = 18.027.

### *2-(Trimethylsilyloxy)-2-(2′-bromophenyl)propanenitrile*

The title compound was obtained as a colorless oil, conversion = 29%, $^1$H NMR (300 MHz, $CDCl_3$): 7.73–7.76 (m, 2H), 7.22–7.24 (m, 2H), 1.27 (s, 3H), 0.24 (s,9H). $^{13}$C NMR (75 MHz, $CDCl_3$): 1.16 (×3), 29.8, 71.36, 120.08, 120.36, 127.24, 127.59, 130.08 135.17, 139.15; ee 1%, HPLC (Chiralcel OD-H), mobile phase hexane; flow = 0.35 mL/min, $t_r$(minor) = 49.469, $t_r$(major) = 61.434.

### *2-(Trimethylsilyloxy)-2-(2′-methylphenyl)propanenitrile*

The title compound was obtained as a colorless oil, conversion = 60%, $^1$H NMR (300 MHz, $CDCl_3$): 7.53–7.58 (m, 1H), 7.18–7.27 (m, 3H), 2.55 (s, 3H), 1.94 (s, 3H), 0.077 (s, 9H). $^{13}$C NMR (75 MHz, $CDCl_3$): 1.09 (×3), 20.68, 30.51, 71.68, 121.62, 125.29, 125.97, 128.66, 132.64, 135.50, 138.41; ee 2%, HPLC (Chiralcel OD-H), mobile phase hexane; flow = 0.35 mL/min, $t_r$(minor) = 25.989, $t_r$(major) = 28.390.

### *2-(Trimethylsilyloxy)-2-(4′-methylphenyl)propanenitrile*

The title compound was obtained as a colorless oil, conversion = 55%; $^1$H NMR (300 MHz, $CDCl_3$): 7.33–7.37 (m, 2H), $\delta$ 7.09–7.17 (m, 2H), 2.28 (s, 3H), 1.18 (s, 3H), 0.068 (s, 9H). $^{13}$C NMR (75 MHz, $CDCL_3$): 1.00 (×3), 20.98, 33.45, 71.44, 121.67,

124.51 (×), 129.19 (×2), 138.43, 139.03. ee 2%; HPLC (Chiralcel OD-H), mobile phase hexane; flow = 0.35 mL/min, $t_r$(minor) = 22.778, $t_r$(major) = 24.012.

*2-(Trimethylsilyloxy)-2-(4′-bromophenyl)propanenitrile*

The title compound was obtained as a yellow solid, conversion = 91%; $^1$H NMR (300 MHz, $CDCl_3$): $\delta$ 7.42–7.46 (d, $J$ = 13.5 Hz, 2H), 7.31–7.35 (d, $J$ = 12.6 Hz, 2H), 1.74 (s, 3H), −0.002(s, 9H). $^{13}$C NMR (75 MHz, $CDCl_3$): 1.00 (×), 33.42, 71.02, 115.87, 121.07,122.66, 126.30 (×2), 131.73 (×2), 141.19; ee 3%; HPLC (Chiralcel OD-H), mobile phase hexane; flow = 0.35 mL/min, $t_r$(minor) = 25.358, $t_r$(major) = 27.717.

*2-(Trimethylsilyloxy)-2-(4′-chlorophenyl)propanenitrile*

The title compound was obtained as a colorless oil, conversion = 89%; the physical and spectral data were identical to those previously reported for this compound. $^1$H NMR (300 MHz, $CDCl_3$): $\delta$ 8.13–8.16 (m, 2H), 7.61–7.64 (m, 2H), 7.33–7.36 (m, 2H), 1.75 (s, 3H), 0.12 (s, 9H). $^{13}$C NMR (75 MHz, $CDCl_3$): 0.96 (×3), 33.42, 70.96, 121.12, 126.00, 128.75 (×2), 134.5 (×2), 140.64. ee 2%; HPLC (Chiralcel OD-H), mobile phase hexane; flow = 0.35 mL/min, $t_r$(minor) = 29.850, $t_r$(major) = 32.291.

## Results and discussion

The Bronsted acids were synthesized from *R*-(+)/*S*-(−)-α-ethylphenylamine by reaction with (2*S*,3*S*)-(+)/(2*R*,3*R*)-(−)-dihydrobutanedioic acid in methanol (Scheme 1). The salts were collected by filtration and recrystallized twice from methanol to give single white crystals. The crystal structure of *S*-(−)-α-ethylphenylamine-(2*R*,3*R*)-(−)-dihydrobutanedioic acid was obtained from these crystals.

The final atomic coordinates and equivalent isotropic displacement parameters are listed in Table 1. Hydrogen bond lengths and angles are listed in Table 2. The selected bond lengths and angles are shown in Tables 3 and 4 respectively. It can be seen from Fig. 1 that a molecule of catalyst 1c was composed of *S*-(−)-α-ethylphenylamine and (2*R*,3*R*)-(−)-2,3-dihydroxybutanedioic acid which together formed an ammonium salt complex. The C(6), C(7), C(8), C(9), C(10), and C(11) atoms were coplanar and the plane equation was found to be $-2.8203(0.0059)x + 12.7206(0.0117)y + 1.0243(0.0080)z = 7.0314(0.0071)$ with a maximum deviation of 0.0454 Å for C(8). The C–C distances ranged from 1.372(4) to 1.393(3) with an average of 1.381 Å. The C–C bond angles ranged from 118.6(2)° to 120.8(2)°. The aromatic ring in the molecule is in agreement with the literature without any unusual features. The structure of the ammonium salt was pyramidal and the bond angles of N–C and N–H were all nearly 109°. For example, the angle between C(5)–N(1)–H(1A) was 109.7(16)°, between C(5)–N(1)–H(2A) it was 109.7(19)°, between H(1A)–N(1)–H(2A) it was 106(2)°, between C(5)–N(1)–H(3A) it was 111.7(19)°, and between H(1A)–N(1)–H(3A) it was 104(2)°. (2*R*,3*R*)-(−)-2,3-dihydroxybutanedioic acid was

**Table 1** Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement parameters ($Å^2 \times 10^3$)

| | *x* | *y* | *z* | *U* (eq) |
|---|---|---|---|---|
| O(1) | 7079(2) | 3493(1) | 5162(2) | 38(1) |
| O(2) | 10710(2) | 3491(1) | 6531(2) | 40(1) |
| O(3) | 10388(2) | 3917(1) | 9830(2) | 42(1) |
| O(4) | 7843(3) | 2190(1) | 9044(2) | 45(1) |
| O(5) | 7892(2) | 3018(1) | 12232(2) | 38(1) |
| O(6) | 5033(2) | 3934(1) | 10809(2) | 43(1) |
| N(1) | 2550(3) | 4182(1) | 3752(2) | 32(1) |
| C(1) | 8775(3) | 3578(1) | 6548(2) | 28(1) |
| C(2) | 8366(3) | 3835(2) | 8401(2) | 28(1) |
| C(3) | 6899(3) | 3099(1) | 8937(2) | 30(1) |
| C(4) | 6500(3) | 3391(1) | 10774(2) | 29(1) |
| C(5) | 2411(3) | 5239(2) | 3607(3) | 36(1) |
| C(6) | 3966(3) | 5690(1) | 5329(3) | 36(1) |
| C(7) | 3705(4) | 5571(2) | 7081(3) | 44(1) |
| C(8) | 5122(4) | 6004(2) | 8626(4) | 53(1) |
| C(9) | 6819(4) | 6558(2) | 8433(4) | 60(1) |
| C(10) | 7097(4) | 6680(2) | 6696(5) | 62(1) |
| C(11) | 5693(4) | 6252(2) | 5148(4) | 48(1) |
| C(12) | 25(3) | 5536(2) | 3278(4) | 48(1) |

**Table 2** Hydrogen bond lengths and angles for catalyst 1c

| D–H···A | d(D–H) | d(H···A) | d(D···A) | <(DHA) |
|---|---|---|---|---|
| 0.827(18) | 2.03(2) | 2.610(3) | 127(2) | O3–H1···O2 |
| 0.827(18) | 2.30(2) | 2.815(3) | 120(2) | O3–H1···O6 |
| 0.825(19) | 2.05(3) | 2.655(3) | 130(4) | O4–H4···O5 |
| 0.870(19) | 1.63(2) | 2.491(3) | 169(3) | O5–H5···O1 |
| 0.91(2) | 1.94(3) | 2.842(3) | 175(2) | N1–H1A···O2 |
| 0.84(3) | 2.09(3) | 2.882(3) | 155(3) | N1–H2A···O3 |
| 0.89(3) | 2.03(3) | 2.920(3) | 177(3) | N1–H3A···O1 |

deprotonated. The C–O bond lengths of the carboxyl group were 1.263(2) [O(1)–C(1)], 1.235(2)[O(2)–C(1)] Å. The amino group of *S*-(−)-α-ethylphenylamine was protonated and the three bond lengths of N–H were nearly the same.

Catalyst 1c is further linked together to form a three-dimensional network packing structure (Fig. 2). The hydrogen bond distances ranged from 0.827(18) to 0.870(19) Å between the O atoms of tartaric acid and the hydrogen atoms, from 0.84(3) Å to 0.91(2) Å between the N atom and the hydrogen atoms.

First, we compared the activities of catalysts 1a–1d under the same conditions. It was found that 1a had relatively good activity and enantioselectivity. The solvent effects were also optimized. The results are listed in Table 5. The conclusions about

**Table 3** Bond lengths [Å] for catalyst 1c

| Length (Å) | Length (Å) |
|---|---|
| O(1)–C(1) 1.263(2) | C(3)–H(3) 0.98(2) |
| O(2)–C(1) 1.235(2) | C(5)–C(6) 1.517(3) |
| O(3)–C(2) 1.413(2) | C(5)–C(12) 1.518(3) |
| O(3)–H(1) 0.827(18) | C(5)–H(6) 1.00(2) |
| O(4)–C(3) 1.416(3) | C(6)–C(7) 1.381(3) |
| O(4)–H(4) 0.825(19) | C(6)–C(11) 1.393(3) |
| O(5)–C(4) 1.299(2) | C(7)–C(8) 1.384(3) |
| O(5)–H(5) 0.870(19) | C(7)–H(7) 0.9300 |
| O(6)–C(4) 1.213(3) | C(8)–C(9) 1.372(4) |
| N(1)–C(5) 1.505(3) | C(8)–H(8) 0.9300 |
| N(1)–H(1A) 0.91(2) | C(9)–C(10) 1.375(5) |
| N(1)–H(2A) 0.84(3) | C(9)–H(9) 0.9300 |
| N(1)–H(3A) 0.89(3) | C(10)–C(11) 1.379(4) |
| C(1)–C(2) 1.530(2) | C(10)–H(10) 0.9300 |
| C(2)–C(3) 1.528(3) | C(11)–H(11) 0.9300 |
| C(2)–H(2) 0.94(2) | C(12)–H(12A) 0.9600 |
| C(3)–C(4) 1.528(3) | C(12)–H(12B) 0.9600 |

**Table 4** Bond angles [°] for catalyst 1c

| Angle (°) | Angle (°) |
|---|---|
| C(2)–O(3)–H(1) 102.8(19) | N(1)–C(5)–H(6) 107.6(14) |
| C(3)–O(4)–H(4) 96(3) | C(6)–C(5)–H(6) 111.3(13) |
| C(4)–O(5)–H(5) 107(2) | C(12)–C(5)–H(6) 105.4(13) |
| C(5)–N(1)–H(1A) 109.7(16) | C(7)–C(6)–C(11) 118.6(2) |
| C(5)–N(1)–H(2A) 109.7(19) | C(7)–C(6)–C(5) 121.94(19) |
| H(1A)–N(1)–H(2A) 106(2) | C(11)–C(6)–C(5) 119.5(2) |
| C(5)–N(1)–H(3A) 111.7(19) | C(6)–C(7)–C(8) 120.8(2) |
| H(1A)–N(1)–H(3A) 104(2) | C(6)–C(7)–H(7) 119.6 |
| H(2A)–N(1)–H(3A) 115(3) | C(8)–C(7)–H(7) 119.6 |
| O(2)–C(1)–O(1) 126.11(17) | C(9)–C(8)–C(7) 120.2(3) |
| O(2)–C(1)–C(2) 117.70(15) | C(9)–C(8)–H(8) 119.9 |
| O(1)–C(1)–C(2) 116.17(15) | C(7)–C(8)–H(8) 119.9 |
| O(3)–C(2)–C(3) 110.04(15) | C(8)–C(9)–C(10) 119.5(2) |
| O(3)–C(2)–C(1) 110.55(14) | C(8)–C(9)–H(9) 120.2 |
| C(3)–C(2)–C(1) 110.61(15) | C(10)–C(9)–H(9) 120.2 |
| O(3)–C(2)–H(2) 110.2(13) | C(9)–C(10)–C(11) 120.8(2) |
| C(3)–C(2)–H(2) 108.5(13) | C(9)–C(10)–H(10) 119.6 |
| C(1)–C(2)–H(2) 107.0(15) | C(11)–C(10)–H(10) 119.6 |
| O(4)–C(3)–C(2) 111.12(15) | C(10)–C(11)–C(6) 120.1(3) |
| C(2)–C(3)–H(3) 106.9(14) | C(10)–C(11)–H(11) 119.9 |
| C(4)–C(3)–H(3) 106.7(13) | C(6)–C(11)–H(11) 119.9 |

**Table 4** continued

| Angle (°) | Angle (°) |
|---|---|
| O(6)–C(4)–O(5) 125.22(17) | C(5)–C(12)–H(12A) 109.5 |
| O(6)–C(4)–C(3) 121.43(16) | C(5)–C(12)–H(12B) 109.5 |
| O(5)–C(4)–C(3) 113.33(16) | H(12A)–C(12)–H(12B) 109.5 |
| N(1)–C(5)–C(6) 110.51(17) | C(5)–C(12)–H(12C) 109.5 |
| N(1)–C(5)–C(12) 108.90(18) | H(12A)–C(12)–H(12C) 109.5 |
| C(6)–C(5)–C(12) 112.80(19) | H(12B)–C(12)–H(12C) 109.5 |

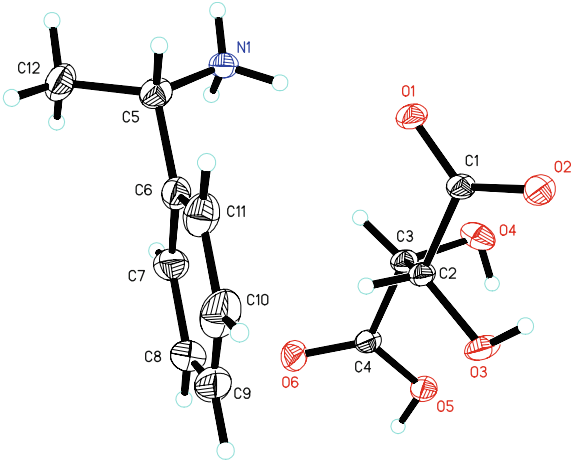



**Fig. 1** Crystal structure of catalyst 1c

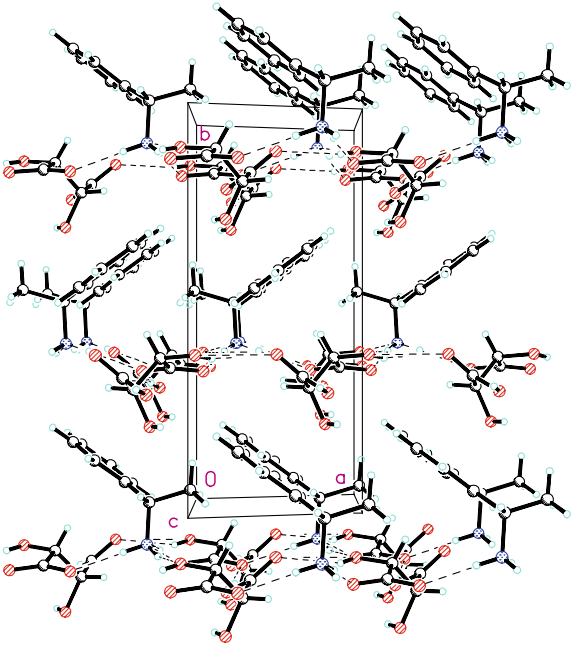
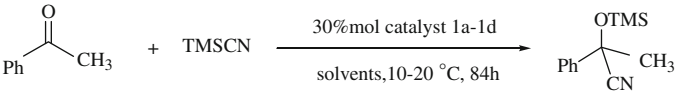



**Fig. 2** Packing structure of catalyst 1c

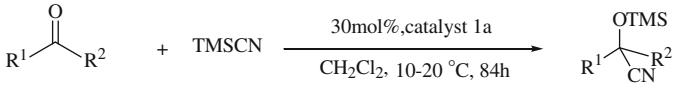
**Table 5** Effects of catalysts and solvents on the cyanosilylation of acetophenone[a]




| Catalyst | Solvent | Conv. (%) |
|---|---|---|
| 1a | $CH_2Cl_2$ | 45 |
| 1b | $CH_2Cl_2$ | 14 |
| 1c | $CH_2Cl_2$ | 25 |
| 1d | $CH_2Cl_2$ | 44 |
| 1a | THF | 48 |
| 1a | Hexane | 65 |
| 1a | Ether | 60 |
| 1a | Isopropanol | 16 |
| 1a | Toluene | 45 |
| 1a | $CH_2Cl_2$ | 19 |
| No catalyst | $CH_2Cl_2$ | 0 |

[a] Conversion (%) was determined by use of $^1$H NMR ($CDCl_3$)

**Table 6** The cyanosilylation of acetophenone catalyzed by 1a




| Entry | $R^1$ | $R^2$ | Conv. (%)[a] |
|---|---|---|---|
| 1 | $C_6H_5$ | $CH_3$ | 45 |
| 2 | 2-$BrC_6H_4$ | $CH_3$ | 29 |
| 3 | 2-$CH_3C_6H_4$ | $CH_3$ | 60 |
| 4 | 4-$CH_3C_6H_4$ | $CH_3$ | 55 |
| 5 | 4-$BrC_6H_4$ | $CH_3$ | 91 |
| 6 | 4-$ClC_6H_4$ | $CH_3$ | 89 |

[a] Conversion (%) was determined by use of $^1$H NMR ($CDCl_3$)

the catalysts were as follows. The catalysts all had moderate activities in hexane, ether, isopropanol, toluene, and dichloromethane. Hexane gave better reaction activity than the other solvents, but lower enantioselectivity than ether. The temperature also affected the reactivities. The lower the temperature, the better the enantioselectivites.

Ranges of ketone activity were determined with 30 mol% catalyst 1a in hexane at room temperature. The results are summarized in Table 6.

Table 6 shows that the 2-position substitution substrates gave slightly higher conversion than the 4-position substitution substrates.

A probable reaction mechanism that can be proposed is that the proton acid can greatly activate the C=O bond, increasing the electrophilic reactivity of the carbon atom, which can then accept nucleophilic attack of $CN^-$.

## Conclusions

In conclusion, novel chiral catalysts were synthesized and applied for the first time in the cyanosilylation of ketones, with moderate yields. One X-ray structure characterization is also reported. Study of other applications of the catalysts in aldol reactions, Henry reactions, and Baylis–Hillman reactions are all in progress. A complete crystallographic information file for 1c has been deposited with the Cambridge Crystallographic Data Center as supplementary publication CCDC 639907.

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