Supporting Information

Synthesis, Characterization and Catalytic Application of Chiral Recyclable Dimeric Copper(II)-Salen Complexes for Asymmetric Nitroaldol(Henry) Reaction

Anjan Das,[a, b] Rukhsana I. Kureshy,*[a, b] P. S. Subramanian,[a, b] Noor-ul H. Khan,[a, b] Sayed H. R. Abdi,[a, b] and Hari C. Bajaj[a, b]
* Corresponding author

[a]*Discipline of Inorganic Materials and Catalysis,Central Salt and Marine Chemicals Research Institute (CSIR-CSMCRI), Bhavnagar- 364 002, Gujarat, India. Fax: +91-0278-2566970; E-mail:*rukhsana93@yahoo.co.in
[b] *Academy of Scientific and Innovative Research (AcSIR), CSIR-CSMCRI, Bhavnagar, Gujarat-364021*

General:

Different starting materials and reagents were used as received from supplier. All the solvents used in the present study were dried by known purification technique. Chemical reactions (which have been mentioned) were conducted under anhydrous conditions using nitrogen atmosphere and oven-dried glassware's unless otherwise stated. Enantiomeric excess (ee) and optical purity of the products and intermediates were determined by using programmable high performance liquid chromatography (HPLC) and automatic polarimeter. ^{1}H and ^{13}C-NMR spectra were recorded on 200 MHz or 500 MHz spectrometer. Chemical shifts were reported in ppm from tetramethylsilane with the solvent resonance as the internal standard ($CDCl_3$, = 7.26). Spectra are reported as follows: chemical shift (ppm), multiplicity (s = singlet, d = doublet, t =triplet, q = quartet, m = multiplet), coupling constants (Hz), integration, and assignment.

Characterization of the products:

1. (*R*)-2-Nitro-1-Phenylethanol: Yellow oil, Yield: 78%, Ee: 88%, HPLC (Chiralcel OD, hexane/*i*PrOH, 90:10 *v*/*v*, 0.6 mL/min, 25 ^{o}C, UV 215 nm): t_r (minor)=12.12 min, t_r (major)=13.17, $[\alpha]_D^{20}$ =+25.0 (C 1, $CHCl_3$) , ^{1}H NMR (200 MHz, $CDCl_3$) 7.21-7.28 (m, 5H), 5.41-5.39, 5.32-5.30 (2H, dd, *J*= 4Hz), 4.58-4.42 (m, 1H), 2.91 (br s, 1H).
2. (*R*)-2-Nitro-1-(2-flouroPhenyl)ethanol: Yellow oil, Yield: 67%, Ee: 78%, HPLC (Chiralcel AD, hexane/*i*PrOH, 90:10 *v*/*v*, 0.6 mL/min, 25 ^{o}C, UV 215 nm): t_r (major)= 43.96, t_r (minor)= 50.17, $[\alpha]_D^{20}$ = +25.25 (c 0.60, $CHCl_3$), ^{1}H NMR (200 MHz, $CDCl_3$) 7.42-7.35 (m, 2H), 7.13-7.04 (m, 2H), 5.48-5.47, 5.44-5.42 (dd, 2H, *J*= 3.4 Hz), 4.64-4.50 (m, 1H), 3.1(brs, 1H).
3. (*R*)-2-Nitro-1-(4-fluoroPhenyl)ethanol: Yellow oil, Yield: 70%, Ee: 85%, HPLC (Chiralcel OD, hexane/*i*PrOH, 90:10 *v*/*v*, 0.6 mL/min, 25 ^{o}C, UV 230 nm): t_r (major)= 24.39, t_r (minor)= 19.99, $[\alpha]_D^{20}$ = +15.99 (C 1, $CHCl_3$), ^{1}H NMR (200 MHz, $CDCl_3$) 7.42-7.35 (m, 2H), 7.13-7.04 (m, 2H), 5.48-5.47, 5.44-5.42 (dd, 2H, *J*= 3.4 Hz), 4.64-4.50 (m ,1H) 3.13 (br s, 1H).
4. (*R*)-2-Nitro-1-(2-chloroPhenyl)ethanol: Yellow oil, Yield: 70%, Ee: 90%, HPLC (Chiralcel OD, hexane/*i*PrOH, 90:10 *v*/*v*, 0.6 mL/min, 25 ^{o}C, UV 230 nm): t_r (major)= 15.88, t_r (minor)= 16.88, $[\alpha]_D^{20}$ = +28.85 (C 1, $CHCl_3$), ^{1}H

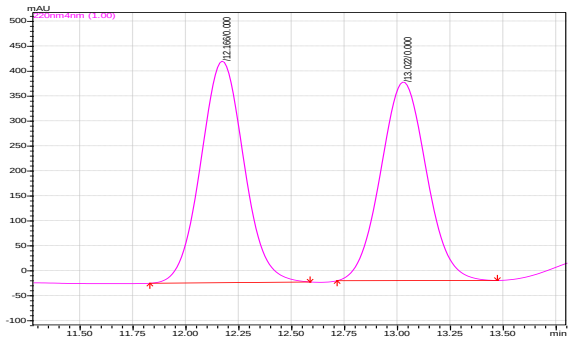
NMR (200 MHz, $CDCl_3$) 7.41-7.50 (s, 1H), 7.35-7.20 (m, 2H), 5.36-5.33, 5.40-5.38 (dd, 2H, *J*= 3.8Hz), 3.09 (br s, 1H).

5. (*R*)-2-Nitro-1-(2-MethoxyPhenyl)ethanol: Yellow oil, Yield: 68%, Ee: 93%, HPLC (Chiralcel OD-H, hexane/*i*PrOH, 90:10 *v*/*v*, 0.6 mL/min, 25 ^{o}C, UV 230 nm): t_r (major)= 55.09, t_r (minor)= 64.34, $[\alpha]_D^{20}$ = +45.23 (C 1, $CHCl_3$), 7.46-7.29 (m, 1H), 7.05-6.89 (m, 2H), 4.70-4.68, 4.63-4.61(dd, 2H, *J*=3.8Hz), 5.68-5.59 (m, 1H), 3.88 (s, 3H), 3.19 (br s, 1H).
6. (*R*)-2-Nitro-1-(3-methoxyphenyl)ethanol: Yellow oil, Yield: 72%, Ee: 90%, HPLC (Chiralcel OD-H, hexane/*i*PrOH, 90:10 *v*/*v*, 0.6 mL/min, 25 ^{o}C, UV 230 nm): t_r (major)= 12.69, t_r (minor)= 11.69 , $[\alpha]_D^{20}$ = +16.56 (C 1, $CHCl_3$), ^{1}H NMR (200 MHz, $CDCl_3$) 7.29-6.89 (m, 4H), 5.42-5.36 (m, 2H), 4.56-4.49 (m, 2H), 3.80 (s, 3H), 3.22(br s, 1H).
7. (*R*)-2-Nitro-1-(4-methoxyphenyl)ethanol: Yellow oil, Yield: 75%, Ee: 89%, HPLC (Chiralcel OD-H, hexane/*i*PrOH, 90:10 *v*/*v*, 0.6 mL/min, 25 ^{o}C, UV 230 nm): t_r (major)= 15.27, t_r (minor)= 14.45 , $[\alpha]_D^{20}$ = +14.52 (C 1, $CHCl_3$), ^{1}H NMR (200 MHz, $CDCl_3$) 7.12-6.18 (m, 4H), 5.40-5.34 (m, 2H), 4.32-4.23 (m, 2H), 3.20 (s, 3H), 3.10 (br s, 1H).
8. *(R)*-2-Nitro-1-(3-nitrophenyl)ethanol: Yellow oil, Yield: 80%, Ee: 75%, HPLC (Chiralcel OD, hexane/*i*PrOH, 90:10 *v*/*v*, 0.6 mL/min, 25^{o}C, UV 230 nm): t_r (major)= 40.60, t_r (minor)= 36.76, $[\alpha]_D^{20}$ = +11.99 (C 2, $CHCl_3$), ^{1}H NMR (200 MHz, $CDCl_3$) 7.36-7.34 (m, 1H), 7.13-7.11(m, 3H), 5.54-5.49 (m, 2H), 4.38-4.30 (m, 1H), 3.03 (s, 1H).
9. *(R)*-2-Nitro-1-(4-nitrophenyl)ethanol: Yellow oil, Yield: 82%, Ee: 78%, HPLC (Chiralcel OD, hexane/*i*PrOH, 90:10 *v*/*v*, 0.6 mL/min, 25^{o}C, UV 230 nm): t_r (major)=31.46, t_r (minor)=34.56, $[\alpha]_D^{20}$ = +14.20 (C 1.5, $CHCl_3$), ^{1}H NMR (200 MHz, $CDCl_3$) 8.30-7.60 (m, 4H), 5.64-5.61, 5.60-5.58 (dd, 2H, *J*= 5 Hz), 4.51-4.57 (m, 1H), 2.30 (br s, 1H).
10. (*R*)-2-Nitro-1-(2-bromophenyl)ethanol: Yellow oil, Yield: 64% ,Ee: 88%, HPLC (Chiralcel OD, hexane/*i*PrOH, 90:10 *v*/*v*, 0.6 mL/min, 25 ^{o}C, UV 230 nm): t_r (major)= 24.13, t_r (minor)= 19.82, $[\alpha]_D^{20}$ = +30.16 (C 1, $CHCl_3$), ^{1}H NMR (200 MHz, $CDCl_3$) 7.59-7.15 (m, 4H), 5.74-5.69 (m, 2H), 4.58-4.38 (m ,1H), 3.11 (br s, 1H).
11. (*R*)-2-Nitro-1-(4-bromophenyl)ethanol: Yellow oil, Yield: 65%, Ee: 89%, HPLC (Chiralcel OD, hexane/*i*PrOH, 85:15 *v*/*v*, 0.8 mL/min, 25 ^{o}C, UV 230 nm): t_r (major)= 24.75, t_r (minor)= 33.90, $[\alpha]_D^{20}$ = +23.12 (C 1, $CHCl_3$), ^{1}H NMR (200 MHz, $CDCl_3$) 7.52-7.47 (m, 2H), 7.26-7.21 (m, 2H), 5.41-5.33 (m, 2H), 3.48(br s, 1H).
12. (*R*)-2-Nitro-1-(n-hexylphenyl)ethanol: Yellow oil, Yield: 67%, Ee: 90%, HPLC (Chiralcel AD-H, hexane/*i*PrOH, 92:08 *v*/*v*, 0.6 mL/min, 25 ^{o}C, UV 230 nm): t_r (major)=24.13, t_r (minor)=19.83, $[\alpha]_D^{20}$ = -12.55 (C 1, $CHCl_3$), ^{1}H NMR (200 MHz, $CDCl_3$) 4.47-4.36 (m, 2H), 2.55 (br s, 1H), 1.61-1.31 (m, 9H), 0.89 (s, 2H).
13. *(R)*-2-Nitro-1-(cyclohexylphenyl)ethanol: Yellow oil, Yield: 68%, Ee: 91%, HPLC (Chiralcel AD-H, hexane/*i*PrOH, 90:10 *v*/*v*, 0.8 mL/min, 25^{o}C, UV 220 nm): t_r (major)=33.07, t_r (minor)= 26.66, $[\alpha]_D^{20}$ = +25.16 (C 0.5, $CHCl_3$), ^{1}H NMR (200 MHz, $CDCl_3$) 4.46-4.41 (m, 2H), 4.12-4.05 (m, 1H), 2.59 (br s, 1H), 1.19-1.16(m, 11H).
14. (*R*)-2-Nitro-1-(4-hydroxylphenyl)ethanol: Yellow oil, Yield: 62%, Ee: 82%, HPLC (Chiralcel OD, hexane/*i*PrOH, 80:20 *v*/*v*, 0.6 mL/min, 25 ^{o}C, UV 230 nm): t_r (major)=29.25, t_r (minor)=23.95, $[\alpha]_D^{20}$ = +22.15 (C 1, $CHCl_3$), ^{1}H NMR (200 MHz, $CDCl_3$) 9.24 (s, 1H), 7.56-7.28 (m, 4H), 5.36-5.32 (m, 2H), 4.32-.30 (m, 1H), 3.02 (br s, 1H).

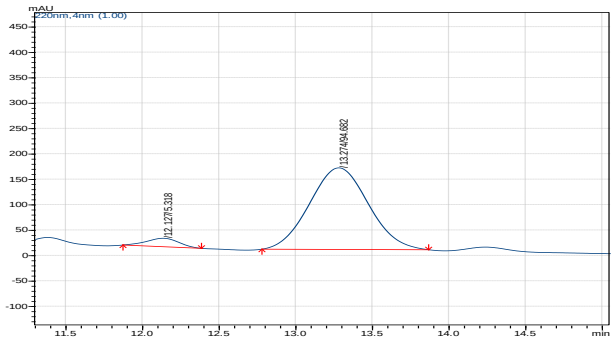
15. (*R*)-2-Nitro-1-(4-acetamidophenyl)ethanol: Yellow oil, Yield: 70%, Ee: 86%, HPLC (Chiralcel IC, hexane/*i*PrOH, 80:20 *v*/*v*, 0.6 mL/min, 25 ^{o}C, UV 230 nm): t_r (major)= 26.30, t_r (minor)=19.14, $[\alpha]_D^{20}$ = +24.12 (C 1, $CHCl_3$), ^{1}H NMR (200 MHz, $CDCl_3$) 9.57 (s, 1H), 7.60-7.29 (m, 4H), 5.84-5.31 (m, 2H), 4.54-4.50 (m, 1H), 3.28 (br s, 1H), 2.11 (s, 3H).

HPLC profiles:

1. (*R*)-2-Nitro-1-Phenylethanol

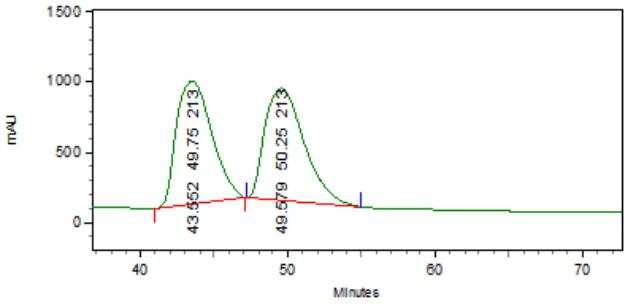


Racemic

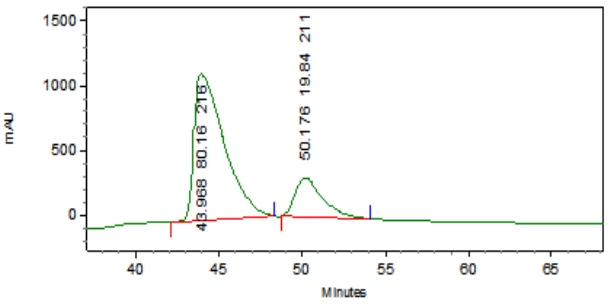


Enantioriched

2. (*R*)-2-Nitro-1-(2-flouroPhenyl)ethanol

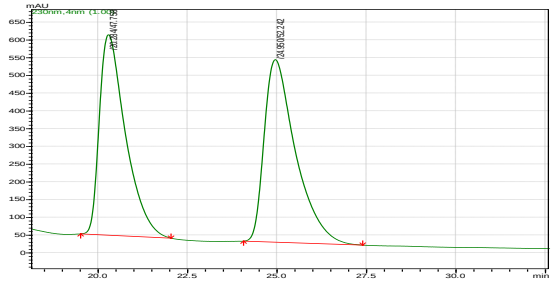


Racemic

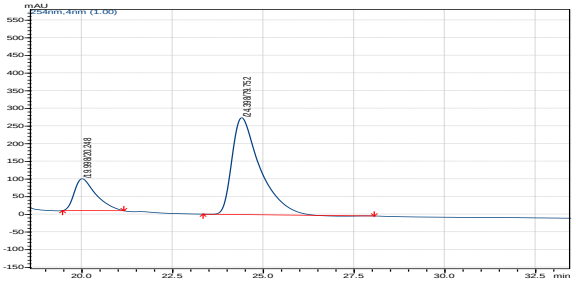


Enantioriched

3. (*R*)-2-Nitro-1-(4-flouroPhenyl)ethanol

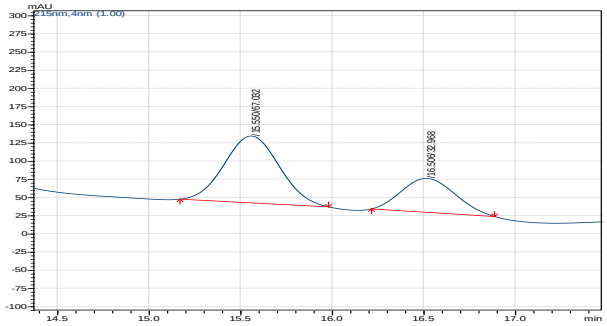


Racemic

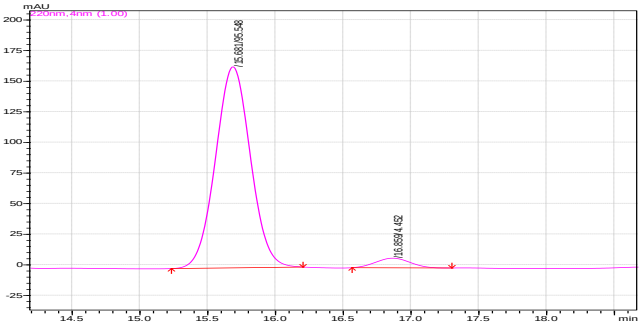


Enantioriched

4. (*R*)-2-Nitro-1-(2-ChloroPhenyl)ethanol

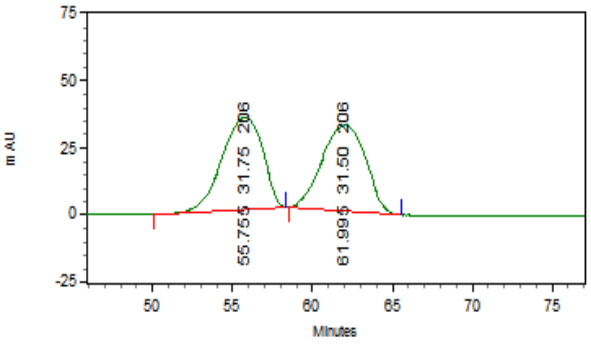


Racemic

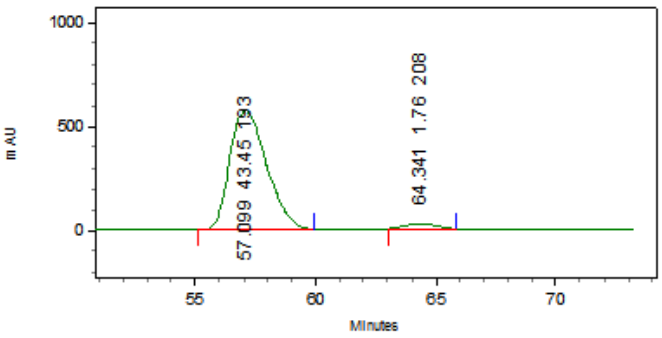


Enantioriched

5. (*R*)-2-Nitro-1-(2-MethoxyPhenyl)ethanol

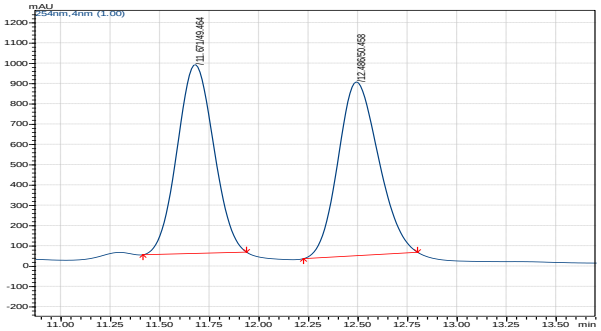


Racemic

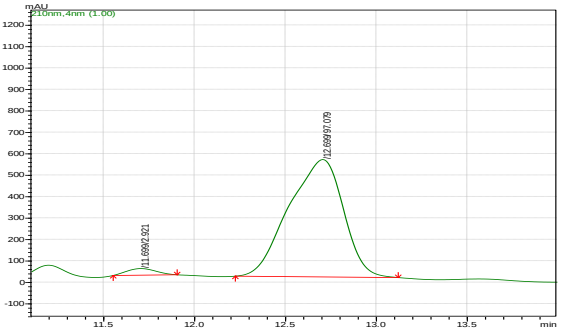


Enantioriched

6. (*R*)-2-Nitro-1-(3-methoxyphenyl)ethanol

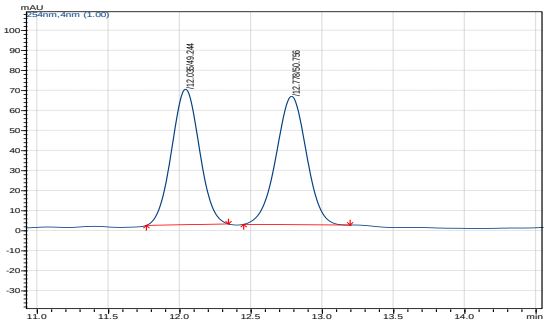


Racemic

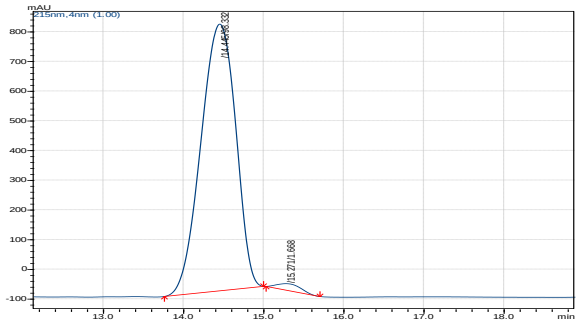


Enantioriched

7. (*R*)-2-Nitro-1-(4-methoxyphenyl)ethanol

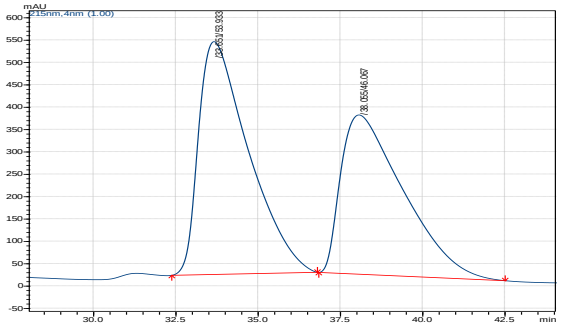


Racemic

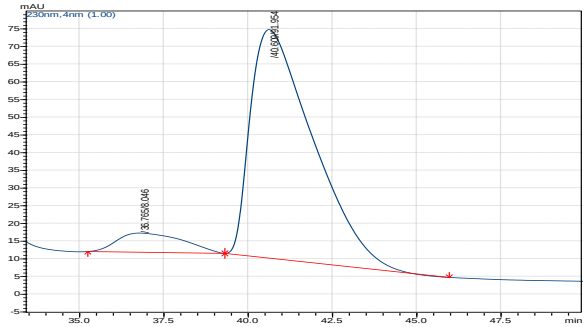


Enantioriched

8. (*R*)-2-Nitro-1-(3-nitrophenyl)ethanol
9.

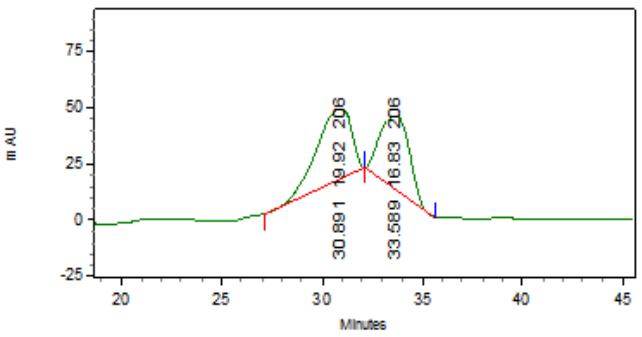


Racemic

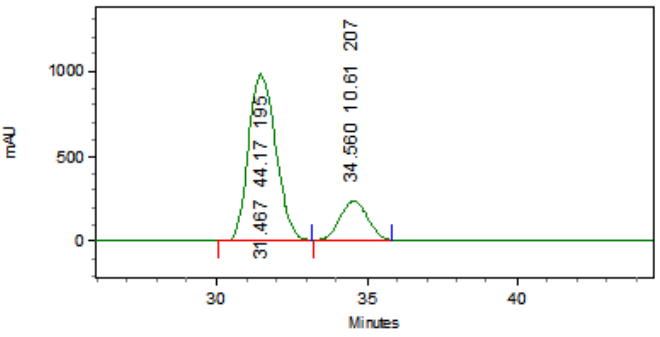


Enantioriched

10. (*R*)-2-Nitro-1-(4-nitrophenyl)ethanol

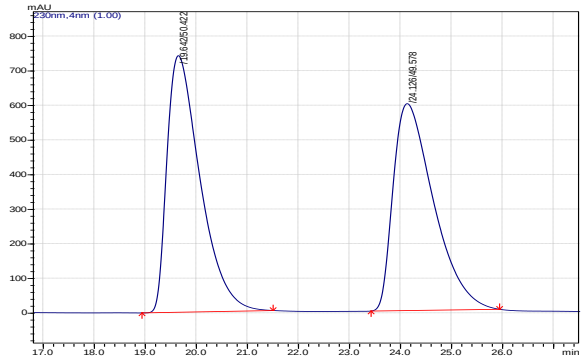


Racemic

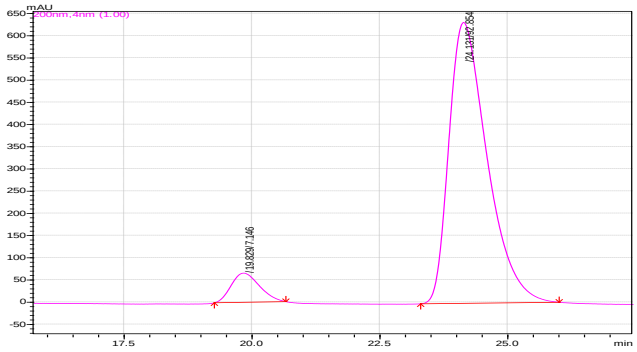


Enantioriched

11. (*R*)-2-Nitro-1-(2-bromophenyl)ethanol

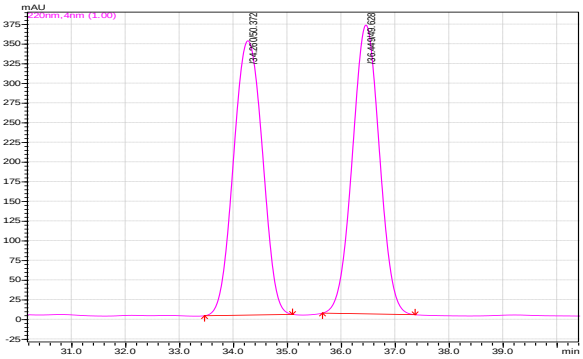


Racemic

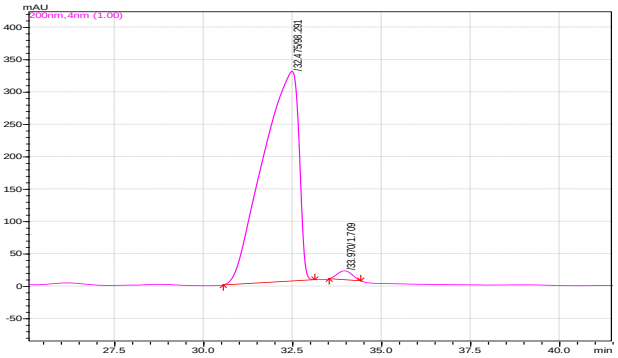


Enantioriched

12. (*R*)-2-Nitro-1-(n-hexylphenyl)ethanol

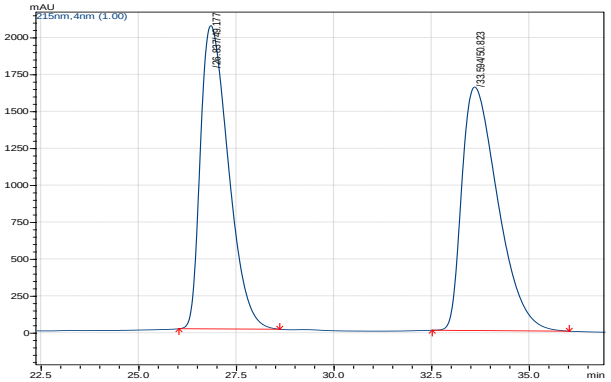


Racemic

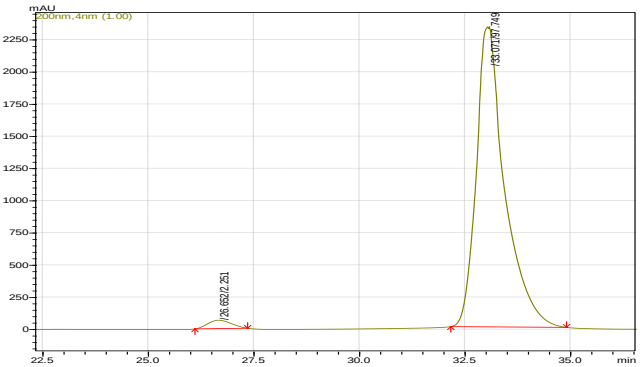


Enantioriched

13. (*R*)-2-Nitro-1-(cyclohexylphenyl)ethanol

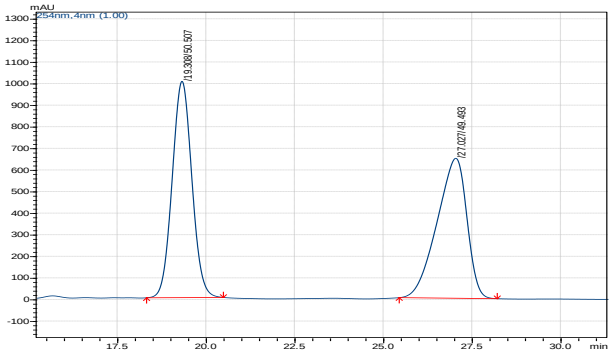


Racemic

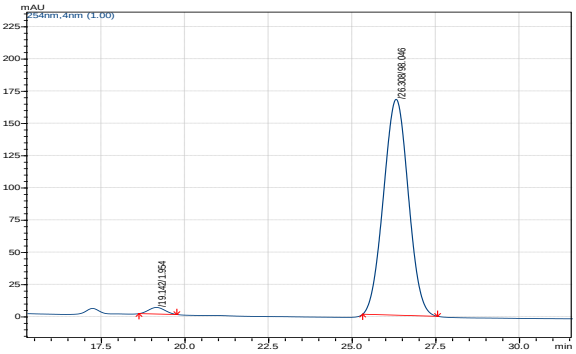


Enantioriched

14. (*R*)-2-Nitro-1-(4-hydroxyphenyl)ethanol

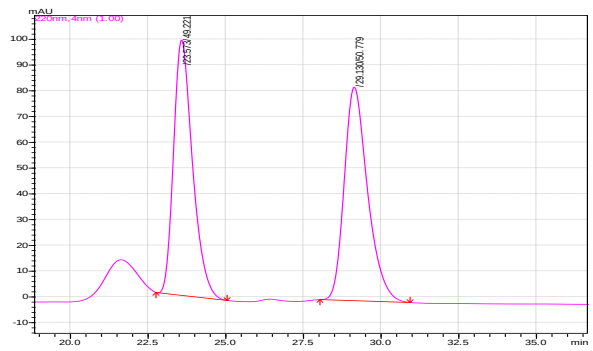


Racemic

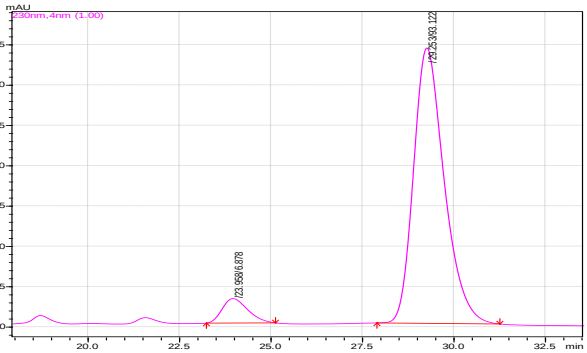


Enantioriched

15. (*R*)-2-Nitro-1-(4-Acetamidophenyl)ethanol



Racemic



Enantioriched

Magnetic Moment for C^1-C^5 at T =296K using THF as solvent.

Complex	μ BM
C^1	1.76
C^2	1.78
C^3	1.73
C^4	1.72
C^5	1.72

General experimental procedure for Nitroaldol reaction. Chiral dimeric salen **L^1-L^6** (0.05 mmol) and $Cu(OAc)_2.H_2O$ (0.10 mmol) were added to a screw-capped vial containing a stirring magnetic bar. Anhydrous THF (0.5 ml) was then added, and a clear green solution formed was stirred for 45 min at RT. To the resulting solution nitromethane (5.0 mmol, 10 equiv) and desired aldehyde (0.5 mmol, 1 equiv) were added. After running the reaction for the specified time, the volatile components were removed under reduced pressure, and the crude product was purified by flash column chromatography.