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Chiral Recyclable Dimeric and Polymeric Cr(III) Salen Complexes Catalyzed Aminolytic Kinetic Resolution of *trans*-Aromatic Epoxides Under Microwave Irradiation

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ABSTRACT Aminolytic kinetic resolution (AKR) of *trans*-stilbene oxide and *trans*-β-methyl styrene oxide proceeded smoothly under microwave irradiation using chiral dimeric and polymeric Cr(III) salen complexes as efficient catalysts, giving regio-, diastereo-, and enantioselective *anti*-β-amino alcohols in high yields (49%) and chiral purity (ee up to 94%) in case of 4-methylaniline within 2 min. The kinetic resolution system is approximately five times faster than traditional oil bath heating at 70°C and 420 times faster than the reaction conducted at room temperature with concomitant recovery of respective chirally enriched epoxides (ee, 92%) in excellent yields (up to 48%). The catalyst **1** worked well in terms of enantioselectivity than the catalyst **2**, but both the catalysts were easily recovered and reused five times with the retention of its efficiency. *Chirality 19:809–815, 2007.*

KEY WORDS: aminolytic kinetic resolution; *trans* epoxides; chiral; Cr(III) dimeric and polymeric salen; recyclable

INTRODUCTION

Optically pure β-amino alcohols are important structural units for many biologically active, natural synthetic products and are valuable chiral auxiliaries/ligands in the area of asymmetric synthesis.[1–4] Several strategically different approaches exist toward the direct synthesis of β-amino alcohols such as (a) via sharpless osmium catalyzed aminohydroxylation[5,6] of alkenes (b) direct addition of α-hydroxy ketones[7–9] to imines, and (c) ring opening of *meso*-epoxides with amines.[10,11] Though these methods gave products with high enantioselectivity for *syn*-β-amino alcohols, very few methods favored the formation of optically pure *anti*-β-amino alcohols.[12–19] In this direction, aminolytic kinetic resolution (AKR) of racemic 1,2-disubstituted epoxides with amines as nucleophiles is an attractive method for the synthesis of optically pure *anti*-β-amino alcohols with high diastereoselectivity.[20–22] Bartoli et al. for the first time has reported the ring opening of *trans*- and *meso*-epoxides with anilines for the synthesis of *anti*/*syn*-β-amino alcohols using chiral monomeric Cr(III) salen as a catalyst, but separation and recycling of the catalyst is not feasible under homogeneous catalytic system.[23] As chiral catalysts are expensive, their separation and recycling is an important aspect. In order to make the catalytic process recyclable, attempts were made in the past for the anchoring of chiral homogeneous catalyst,[24] either on solid supports[25] or by making use of ionic liquids.[26] Though these approaches are interesting but usually demand additional modifications in the structure of the catalyst for making the catalyst compatible with the desired support, such approaches frequently lead to partial loss of activity and/or enantioselectivity.

The use of microwave (MW) irradiations to speed up the sluggish chemical reactions is of current interest.[27–31] The use of MW irradiations has been reported for the ring opening of vinyl and terminal epoxides by NH_4OH,[32,33] thiols[34] pyrazole, imidazole,[35] and amines.[36–38] Yet, its use in the area of transition metal catalyzed asymmetric reactions[39] has not been successful, probably because of the small difference in the activation energy of the two enantiomers involved in the asymmetric reaction that is insignificant in comparison to the energy supplied by the MWs.[29] Consequently, the enantioselectivity of the reactions could be adversely affected by the use of MWs as a source of energy. Nevertheless, Dioos and Jacobs have recently reported the asymmetric ring opening of epoxides using $TMSN_3$ as nucleophile under MW irradiation.[40] In continuation of our ongoing research toward developing the recyclable chiral dimeric and polymeric catalysts with different metal ions for various organic transformations, namely asymmetric epoxidation,[41–43] cyanation,[44,45] hydrolytic kinetic resolution,[46] oxidative kinetic resolution,[47,48]

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and asymmetric ring opening of *meso* and *trans* epoxides with anilines,[49,50] in the present study we are reporting the use of recyclable dimeric and polymeric chiral Cr(III)X salen complexes **1** and **2** as catalysts for the production of enantioselective *trans* 1,2 aminoalcohols through AKR of racemic *trans*-stilbene oxide and *trans*-β-methyl styrene oxide, with anilines under MW irradiation as an alternate source of energy to step up the reaction rate. Significantly, the rate of reactions was greatly enhanced and there was no loss in enantioselectivity under MW irradiation in comparison to the same reaction when conducted at room temperature. On the contrary, in some cases there was an improvement in the ee of the products. Chiral dimeric Cr(III) salen complex **1** gave better results in term of enantioselectivity than Jacobsen monomeric Cr(III) salen complex and polymeric Cr(III) salen complex **2**. The catalysts used in the present study were conveniently recovered and reused for five successive catalytic runs.

EXPERIMENTAL

Materials and Methods

Reagents and solvents were of laboratory grade and were used without further purification. *trans*-Stilbene oxide, *trans*-β-methyl styrene, aniline, 2-methoxyaniline, 4-methoxyaniline, 4-methylaniline, 4-chloroaniline, and 4-nitroaniline were purchased from Aldrich and were used as received. Racemic *trans*-β-methyl styrene oxide was prepared by the oxidation of respective alkene with *m*-CPBA (Spectrochem).[51] (*R,R*) Polymeric [Cr(Salen)Cl] **2** was prepared and characterized by the reported procedure.[50] ^{1}H and ^{13}C NMR spectra were recorded at 200 MHz and 50 MHz, respectively on a Bruker F113V. The chemical shifts (δ) for ^{1}H and ^{13}C are given in ppm relative to the signal of TMS. FTIR spectra were recorded on a Perkin Elmer Spectrum GX spectrophotometer in KBr/nujol mull. Microanalysis of the complex was done on CHNS analyzer, Perkin Elmer model 2400. MW reactor with temperature controller used in the present study was from ETHOS 1600 Advanced Microwave Lab station. Purification of reaction products was carried out by flash column chromatography on silica gel (60–200 mesh). Melting points reported in the present study are uncorrected. Diastereomeric purity and enantiomeric excesses (ee) were determined by NMR analysis of the crude mixture and by HPLC (Shimadzu SCL-10AVP) analysis using Daicel Chiralpak OD and OJ chiral columns at wavelength 243 nm, with 2-propanol/hexane as mobile phase. Optical rotations were measured on a Digipol 781 automatic Polarimeter, Rudolph Instruments and are reported as: α_D^{27} (c = in g per 100 ml, solvent). HPLC traces of aminoalcohols were compared with authentic racemic samples prepared by the ring opening of respective epoxides with required amine using racemic Jacobsen Cr(III) salen as a catalyst. High-resolution mass spectra were obtained with a LC-MS (Q-TOFF) LC (Waters), MS (Micromass) instruments.

All *anti*-β-amino alcohol (**6a–f** and **7a–c**) and *trans*-epoxides (**3** and **4**) were characterized by ^{1}H and ^{13}C NMR, LCMS, and IR. These spectroscopic data are comparable with literature values.[23] The enantiomeric excess (ee) of *anti*-β-amino alcohol (**6a–f** and **7a–c**) and *trans*-stilbene oxide (**3**) were determined by HPLC using Chiralpak OD column except for **6b**, **7b**, where Chiralpak OJ column was used. The enantiomeric excess of *trans*-β-methyl styrene oxide was determined on GC using GTA-type column.

Synthesis of 5,5-Methylene Di-[(R,R*)-{ N-(3-*tert*-butyl salicylidine)-N′-(3′,5′-di-*tert*-butyl salicylidene)]-cyclohexane-1,2-diaminato (2-) Cr(III) Chloride 1*

Chiral dimeric ligand namely 5,5-methylene di-[(*R,R*)-{*N*-(3-*tert*-butyl salicylidine)-*N*′-(3′,5′-di-*tert*-butyl salicylidene)}-1,2-cyclohexanediamine][41,42] (0.4 mmol) was dissolved in dry degassed THF (20 ml). The resulting yellow solution was interacted with anhydrous Cr(II) chloride (0.8 mmol) in a glove box under nitrogen atmosphere to give a brown solution. The brown solution turned dark green during 4 h of stirring under a blanket of nitrogen after which it was exposed to air with stirring for further 3 h. The resulting dark green solution was treated with *tert*-butyl methyl ether to precipitate out the dimeric Cr(III) complex **1**. The precipitate was filtered and washed with water to remove the unreacted chromium chloride and dried overnight under vacuum (yield 65%). The filtrate was sequentially washed with saturated solution of NH_4Cl and brine. The resulting solution was dried over anhydrous Na_2SO_4, filtered, and the solvent was removed to give another crop (∼22%) of complex **1** as brown solid. The overall yield was found to be 87%. mp >250°C; Anal. Calcd for $C_{65}H_{88}Cl_2Cr_2N_4O_4$ (Calcd) C, 67.05; H, 7.62; N, 4.81 Found: C, 67.01; H,7.60; N, 4.78%; IR in KBr (cm^{-1}): 2946, 2363, 2342, 1617 (C=N), 1536, 1435, 1350, 1316, 1161, 831, 738, 658, 563; $[\alpha_D^{rt}] = -324$ (c = 0.024 g in 100 ml of CH_2Cl_2); Λ_M (MeOH) 116 mho cm^{-1} mol^{-1}; UV–vis: (CH_2Cl_2) λ_{max} (ϵ) 232 (52030), 263 (32125), 296 (19513), 345 (7689), 435 (3354) nm.

General Procedure for AKR of trans*-aromatic epoxides*

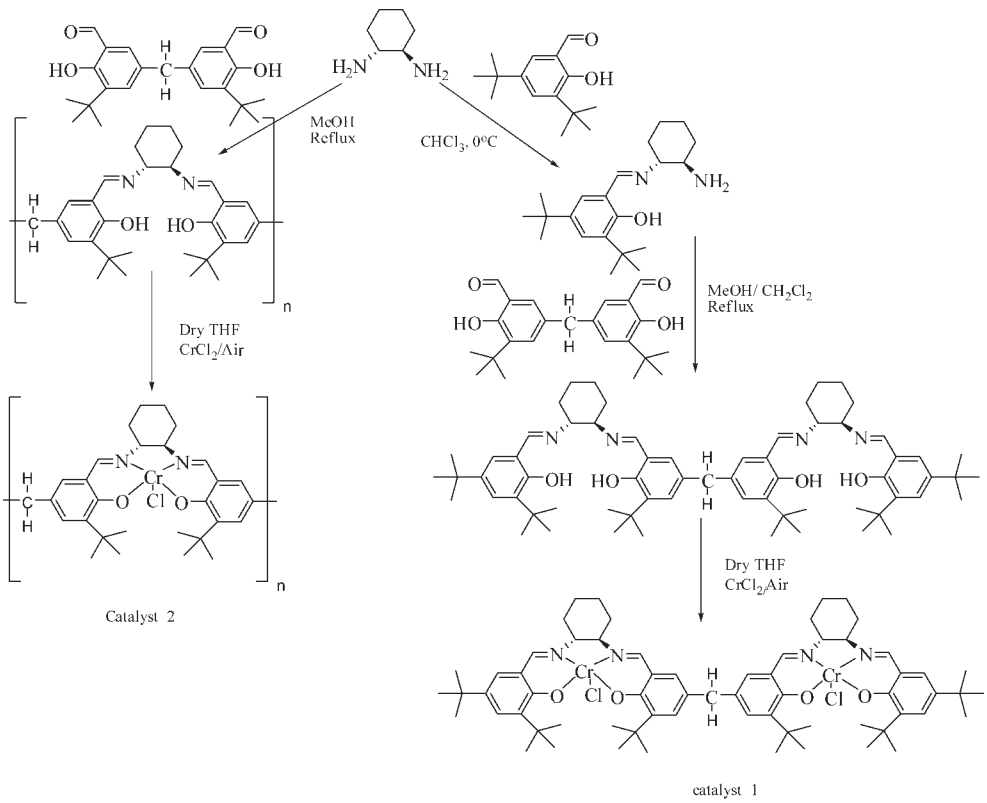
The AKR reactions were carried out in a corning glass test tube placed in a sealed reactor-ETHOS 1600 (Advanced Microwave Lab station) having temperature and MW power output control. In a typical AKR reaction catalysts **1/2** (0.01 mmol, based on monomeric salen unit), appropriate epoxide (0.20 mmol) and aniline (0.10 mmol) were taken in a mixed solvent CH_2Cl_2:MeOH (9:1, 200 μl), and the mixture was irradiated with MW (900 W) at 70°C for 2 min. The conversion of the product was determined on a HPLC equipped with Chiralpak OD column, using calibration of peak area % of the amino alcohol and *trans*-stilbene oxide at 243. The catalyst was precipitated out from the reaction mixture by the addition of 5 ml of hexane:diethyl ether (1:1), filtered, vacuum-dried, and kept in a desiccator for further use. The filtrate was concentrated and the desired product was purified by column chromatography using silica gel 60–200 mesh as a stationary phase and hexane:ethyl acetate (8:2) as a mobile phase. All the products were characterized by ^{1}H and ^{13}C NMR spectroscopy.

Recycling Experiment

After one catalytic cycle (checked on HPLC), the catalysts were precipitated out with hexane:diethyl ether (1:1) followed by thorough washing with hexane (10 ml). They were dried under reduced pressure and used as recovered catalyst for successive catalytic runs, using *trans*-stilbene oxide as a representative substrate for AKR reaction.

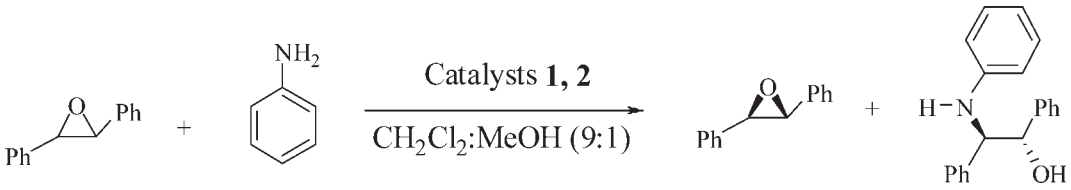
RESULTS AND DISCUSSION

Synthesis of chiral dimeric Cr(III) salen complex, namely, 5,5-methylene di-[(*R,R*)-{*N*-(3-*tert*-butyl salicylidine)-*N*′-(3′,5′-di-*tert*-butyl salicylidene)}-1,2-cyclohexanediaminato (2-) chromium (III) chloride] **1** (Scheme 1), which carries two active catalytic metal centers was obtained by the interaction of 5,5-methylene di-[(*R,R*)-{*N*-(3-*tert*-butyl salicylidine)-*N*′-(3′,5′-di-*tert*-butyl salicylidene)}-1,2-cyclohexanediamine with anhydrous Cr(II) chloride in dry THF under nitrogen atmosphere followed by its auto oxidation in air. The characterization data for complex **1** is given in Experimental section. Whereas polymeric Cr(III) salen complex **2** namely poly [(*R,R*)-*N,N*′-bis{3-(1,1-dimethylethyl)-5-methylene salicylidine} cyclohexene-1,2-diaminato-chromium(III) chloride with 12 repetitive units was synthesized by the reported method[50,52,53] (Scheme 1). Chiral dimeric and polymeric Cr(III) salen complexes **1** and **2** were used as catalysts for the AKR of *trans*-stilbene oxide, with aniline as nucleophile in a model reaction for optimizing reaction conditions such as temperature and MW output. To begin with we first carried out AKR of *trans*-stilbene oxide with aniline, using complexes **1** and **2** as catalysts over a temperature range of (40–80°C) exposed to 900 W MW irradiation (Table 1, entries 1–10) in CH_2Cl_2:MeOH (9:1) as solvent. From the data in Table 1 it is evident that 70°C is the optimum temperature to achieve the highest yield (49%) with high enantioselection (92%) in the product (entry 7). Next, we studied the effect of MW output (800–1000 W) on the efficacy of AKR keeping the reaction temperature 70°C as constant. However, a MW output of 800 W caused reduction in both yield (32–35%) and enantioselectivity (37–42%) (Table 1, entries 11 and 12). On the other hand, 1000 W MW output resulted in an increase in the yield (72–74) of the product amino alcohol but with lower enantioselectivity (Table 1, entries 13 and 14). Consequently, 900 W MW output and 70°C (Table 1, entries 7 and 8) reaction temperature were found to be ideal for AKR of *trans*-stilbene oxide with aniline. Further, in an ideal situation, 0.5 equiv of amine with respect to 1 equiv of racemic epoxide should react with only one enantiomer of epoxide to give the product *anti*-β-aminoalcohol in 100% ee with a maximum theoretical yield of 50%. However, practically this situation is seldom achievable. It is known in the literature that the equivalence of the nucleophile with respect to racemic epoxide greatly influences the product distribution in a kinetic resolution reaction.[50] Therefore, we varied the equivalence of nucleophile (aniline, 0.4–0.75 equiv) with respect



Scheme 1. Synthesis of the catalysts **1** and **2**.

TABLE 1. Aminolytic kinetic resolution (AKR) of *trans*-stilbene epoxides using recyclable catalysts, with aniline under different reaction conditions[a]



Entry	Temp. (°C)	Time (min)	MW (W)	*trans*-Epoxide ee[c] (%)	*trans*-Epoxide Yield[d] (%)	*anti*-β-Amino alcohol ee[c] (%)	*anti*-β-Amino alcohol Yield[d] (%)	*s*[b]
1 (2)	40	2	900	78 (73)	78 (83)	94 (81)	22 (16)	36 (10)
3 (4)	50	2	900	81 (74)	62 (65)	94 (80)	35 (30)	39 (10)
5 (6)	60	2	900	84 (72)	63 (62)	92 (78)	42 (37)	30 (9)
7 (8)	70	2	900	90 (72)	48 (48)	92 (78)	49 (49)	31 (10)
9 (10)	80	2	900	81 (69)	35 (37)	92 (67)	65 (62)	32 (7)
11 (12)	70	2	800	35 (25)	65 (67)	42 (37)	35 (32)	3 (2)
13 (14)	70	2	1000	40 (31)	37 (26)	55 (55)	72 (74)	10 (5)
15 (16)	70	2	900	75 (68)	65 (67)	96 (80)[e]	36 (32)	59 (10)
17 (18)	70	2	900	92 (79)	45 (46)	68 (70)[f]	60 (57)	7 (7)
19 (20)	70	2	900	96 (83)	39 (41)	61 (62)[g]	69 (68)	5 (6)
21	70	2	900	30	72	75[h]	27	8
22 (23)	70	5	–	42 (40)	65 (68)	75 (73)[i]	35 (32)	8 (7)
24 (25)	70	10	–	79 (73)	51 (50)	61 (67)[i]	48 (49)	5 (6)
26 (27)	27	840	–	85 (80)	47 (48)	93 (87)[j]	49 (49)	36 (18)

[a]The 0.01 mmol catalyst was taken in 200 μl CH_2Cl_2:MeOH (9:1), 0.2 mmol epoxides and 0.1 mmol aniline were added and the reaction mixture was irradiated for 2 min in a microwave oven at 70°C. Data given in parentheses are for catalyst **2**.
[b]s = selectivity factor = $\ln[1 - c(1 + \text{ee})]/\ln[1 - c(1 - \text{ee})]$, where ee is enantiomeric excess of the aminoalcohol product and c is the conversion (set to the isolated yield).[23]
[c]The diastereoselectivity of product was found to be >99% determined by ^{1}H NMR and HPLC. The ee of amino alcohols and epoxides are determined on Chiralpak OD column and the absolute configuration was assigned by comparing the optical rotation with literature.[23]
[d]The conversion of the product **7a** was determined on Chiralpak OD column, using a calibration curve of epoxide and aminoalcohols and rest given as isolated yield.
[e]Reaction was performed with 0.4 equiv aniline.
[f]Reaction was performed with 0.6 equiv aniline.
[g]Reaction was performed with 0.75 equiv aniline.
[h]Reaction with Jacobsen catalyst under microwave irradiation at 70°C
[i]Reaction carried out at 70°C on oil-bath heating in absence of MW and aliquot was taken at 5 and 10 min, respectively.
[j]Reaction carried out at 27°C in absence of MW.

to the substrate racemic *trans*-stilbene oxide (1.0 equiv), keeping the other reaction parameters same as mentioned in entry 7 of the Table 1. As the amount of nucleophile was reduced to 0.4 equiv, there was a slight improvement in the ee of the product but with significantly lower yield (Table 1, entries 15 and 16). On increasing the amount of nucleophile (0.6–0.75 equiv) there was a steady decrease in the ee of product *anti*-β-aminoalcohol with concomitant increase in the ee of *trans*-stilbene oxide (83–96%; Table 1, entries 17–20). Hence, the kinetic resolution reaction can be optimized depending upon which product (epoxide or aminoalcohol) is required in higher chiral purity by simply adjusting the amount of nucleophile (aniline) used. For the sake of comparison, we conducted the AKR of racemic *trans*-stilbene oxide with aniline, using monomeric Jacobsen Cr(III)Cl as catalyst (Table 1, entry 21) that gave far less yield (27%) of the product *anti*-β-aminoalcohol (**6a**); however, the ee was nearly the same as it was obtained with polymeric complex **2** but inferior than dimeric Cr(III) salen complex **1** under identical conditions (Fig. 1). Further, when the aforementioned reaction was conducted in the absence of MW irradiation at 70°C on an oil-bath, there was a drop in yield (32–35%) for similar enantioselection in 5 min (Table 1, entries 22 and 23) as compared to the similar reaction under MW irradiation (Table 1, entries 7 and 8). In an attempt to increase the yield by way of increasing the time (10 min) of the reaction, there was a drop in ee (61–67%) of the product (Table 1, entries 24 and 25). On the other hand when the same reaction was conducted at room temperature, it took 840 min to give 49% *anti*-β-aminoalcohol with 87–93% ee (Table 1, entries 26 and 27), which is 420 times slower as compared to the reaction conducted under MW irradiation with comparable enantioselectivity. The rapid homogeneous energy transfer offered by MW irradiation as compared to traditional heating could be responsible for this remarkable reduction

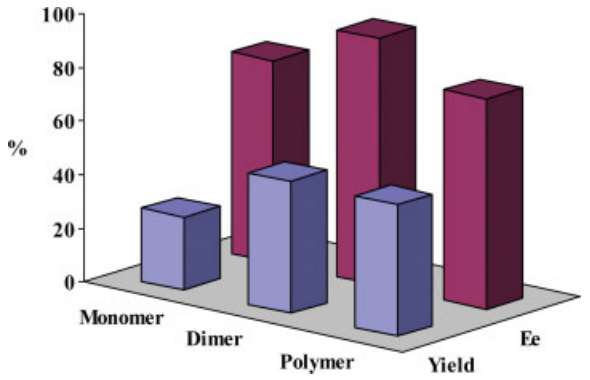
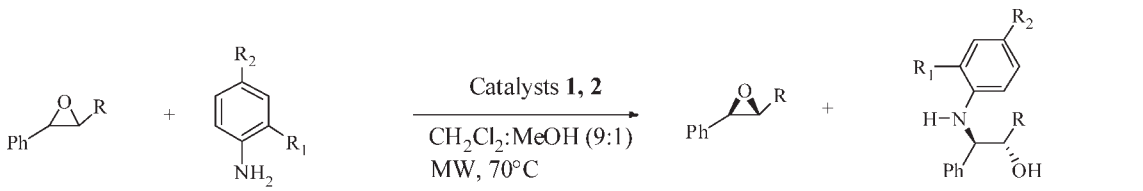


Fig. 1. 3D view representation of % yield and % ee of anti-β-amino alcohol of *trans*-stilbene oxide using monomer, dimer, and polymer Cr(III) salen complexes. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

of reaction time without significant reduction in enantioselectivity.

In a metal complex catalyzed ring opening of epoxides, electronic and steric features of nucleophiles play a very important role. In view of this, we conducted the AKR of *trans*-stilbene oxide with various substituted anilines under our optimized reaction conditions. Out of the *ortho*- and *para*-methoxy anilines used as nucleophile, the latter gave aminoalcohol with somewhat higher ee (Table 2, entry 6) with catalyst **2**, while for catalyst **1** the results are at par for both *ortho*- and *para*-methoxy anilines. On the other hand, *para*-methyl aniline produced aminoalcohol with excellent ee (94%) with catalyst **1** (Table 2, entry 7). *Para*-chloroaniline inducted poor ee (Table 2, entries 9 and 10) possibly because of its poor nucleophilicity. In the case of anilines having strongly electron withdrawing group such as in the case of *para*-nitro aniline AKR, reaction with

TABLE 2. Aminolytic kinetic resolution (AKR) of *trans*-aromatic epoxides using recyclable catalysts with, anilines under microwave irradiations under optimized condition[a]



3 R = Ph
4 R = CH_3

5a, R_1 = H, R_2 = H
5b, R_1 = OMe, R_2 = H
5c, R_1 = H, R_2 = OMe
5d, R_1 = H, R_2 = Me
5e, R_1 = H, R_2 = Cl
5f, R_1 = H, R_2 = NO_2

3-(*1R,2R*)
3-(*1R,2R*)

6a, R =Ph, R_1 = H, R_2 = H
6b, R = Ph R_1 = OMe, R_2 = H
6c, R = Ph, R_1 = H, R_2 = OMe
6d, R = Ph, R_1 = H, R_2 = Me
6e, R = Ph, R_1 = H, R_2 = Cl
6f, R = Ph, R_1 = H, R_2 = NO_2
7a, R =CH_3, R_1 = H, R_2 = H
7b, R =CH_3, R_1 = OMe, R_2 = H
7c R =CH_3, R_1 = H, R_2 = OMe

Entry	Epoxide	Amine	*trans*-Epoxide ee[c] (%)	*trans*-Epoxide Yield[d] (%)	*anti*-β-Amino alcohols ee[c] (%)	*anti*-β-Amino alcohols Yield[d] (%)	*s*[b]
1 (2)	**3**	**5a**	90 (72)	48 (48)	92 (78)	49 (49)	31 (10)
3 (4)	**3**	**5b**	80 (65)	47 (46)	88 (67)	45 (39)	20 (5)
5 (6)	**3**	**5c**	82 (68)	48 (47)	89 (70)	47 (38)	22 (7)
7 (8)	**3**	**5d**	92 (69)	48 (48)	94 (78)	49 (47)	43 (10)
9 (10)	**3**	**5e**	65 (81)	86 (83)	19 (30)	25 (13)	2 (1)
11 (12)	**3**	**5f**	–	–	–	–	–
13 (14)	**4**	**5a**	86	40	59 (46)	46 (45)	5 (3)
15 (16)	**4**	**5b**	85	38	62 (47)	48 (46)	5 (2)
17 (18)	**4**	**5c**	88	36	69 (53)	49 (47)	7 (4)

[a]0.01 mmol catalyst was taken in 200 μl CH_2Cl_2:MeOH (9:1), 0.2 mmol epoxides and 0.1 mmol aniline were added and the reaction mixture was irradiated for 2 min in a microwave oven at 70°C. Data presented in parentheses are for catalyst **2**.
[b]s = selectivity factor = $\ln[1 - c(1 + ee)]/\ln[1 - c(1 - ee)]$, where ee is enantiomeric excess of the amino alcohol product and c is the conversion (set to the isolated yield).[23]
[c]The diastereoselectivity of the product was found to be >99% determined by ^{1}H NMR and HPLC. The ee of aminoalcohols and epoxides are determined on Chiralpak OD column and the absolute configuration was assigned by comparing the optical rotation with literature.[23]
[d]The conversion of the product **7a** was determined on ChiralPak OD column, using a calibration curve of epoxide and amino alcohols and rest given as isolated yield.

TABLE 3. Recycling data of catalyst 1/(2) for AKR of *trans*-stilbene oxide, using aniline as nucleophile[a]

		Epoxide **3**		*anti*-β-Amino alcohol **6a**	
Run	Time (min)	ee (%)	Yield (%)	ee (%)	Yield (%)
1	2.0	90 (72)	48 (48)	92 (78)	49 (49)
2	2.0	89 (70)	47 (49)	91 (78)	48 (48)
3	2.0	89 (71)	46 (48)	92 (77)	48 (48)
4	2.0	90 (72)	46 (48)	91 (76)	47 (47)
5	2.0	90 (72)	48 (48)	92 (77)	46 (46)

[a]The 0.01 mmol catalyst was taken in 200 μl CH_2Cl_2:MeOH (9:1), 0.2 mmol epoxides and 0.1 mmol aniline were added and the reaction mixture was irradiated for 2 min in a microwave oven at 70°C. Results in parantheses is for catalyst **2**.

trans-stilbene oxide does not commence (Table 2, entries 11 and 12). AKR of *trans*-β-methyl styrene oxide with aniline gave exclusively *anti*-β-aminoalcohol with moderate ee and yield (Table 2, entries 13–18). Based on the optical rotation studies for the products **7b–7c**, their absolute configuration was shown to be 1*S*,2*R*.[23]

The catalyst recycle experiments were conducted for the AKR of *trans*-stilbene oxide, using aniline as a nucleophile with dimeric and polymeric Cr(III) salen complexes **1** and **2** as catalysts. In the postcatalysis work-up step, the catalysts were precipitated out by the addition of hexane: diethylether (1:1), which were filtered, washed with *n*-hexane, and dried in vacuum. The recovered catalysts were repeatedly used for four more catalysis runs which showed no apparent loss in the reactivity and enantioselectivity of the catalysts. However, there was some physical loss in the quantity of the catalysts during the catalyst recovery process (Table 3).

CONCLUSION

In summary, we have developed an efficient AKR protocol for the ring opening of *trans*-stilbene oxide, *trans*-β-methyl styrene oxide with various aromatic amines, to achieve respective *trans* β-amino alcohols in high enantio and diastereoselectivity and yields in a very short time under microwave irradiation. Unlike the monomeric Cr(III) salen complex, catalyst **1** gave higher enantioselectivity up to 94% with 4-methylaniline. Both dimeric and polymeric Cr(III) salen complexes were easily recyclable and were reused five times with retention of enantioselectivity.

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