Synthesis of Chiral Bis(dihydrooxazolylphenyl)oxalamides, a New Class of Tetradentate Ligands for Asymmetric Catalysis

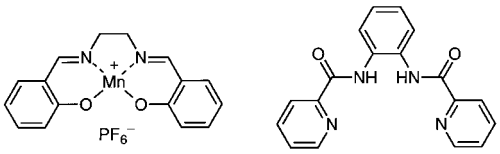
Nicole End, Ludwig Macko, Margareta Zehnder, and Andreas Pfaltz*

Abstract: Enantiomerically pure *N*,*N*′-bis[2-(4,5-dihydrooxazol-2-yl)phenyl]oxalamides are readily prepared from 2-(2-aminophenyl)-4,5-dihydrooxazoles and oxalyl chloride. The structures of the corresponding nickel and copper complexes were determined by X-ray analysis. Ruthenium complexes, prepared in situ from $RuCl_3$ and the corresponding ligands, catalyze the enantioselective epoxidation of *trans*-stilbene to afford *trans*-1,2-diphenyloxirane with up to 69% *ee*. The cobalt complexes were tested as catalysts in Michael reactions of malonates with chalcone (up to 89% *ee*).

Keywords: amides · asymmetric catalysis · N ligands · epoxidations · Michael additions · transition metals

Introduction

The development of suitable chiral ligands is a central issue in the research of asymmetric catalysis.[1] Originally, chiral phosphanes dominated this field, however, other classes of ligands with coordinating nitrogen or oxygen atoms are now attracting increasing attention. Among the many known nitrogen ligands,[1c] the Schiff base and bis-amide ligands are of particular interest because the corresponding metal complexes resemble metalloporphyrins which play an important role as catalysts, both in the laboratory and in biological systems. Manganese–salen complexes, such as **1**, are efficient catalysts for the epoxidation of C–C double bonds.[2] The development of chiral salen derivatives[3,4] has led to the well-known Jacobsen epoxidation,[3] a highly enantioselective and practical catalytic process. Dianionic bis-amide ligands, such as **2**, are known to stabilize high oxidation states of coordinated metal ions.[5–7] A variety of metal complexes of ligand **2** catalyze the epoxidation of alkenes with iodosylbenzene as an oxidant.[8] However, to our knowledge, enantioselective epoxidation reactions with chiral bis-amide ligands have not yet been reported. Herein we describe the synthesis of a new class of chiral tetradentate bis-amide ligands **3** and the preparation and crystal structures of the nickel(II) and copper(II) complexes. We also report preliminary experiments indicating possible applications of such ligands in asymmetric catalysis.



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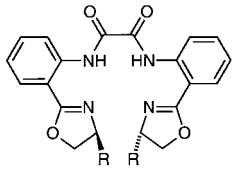

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Results and Discussion

Synthesis of chiral oxalamide ligands 3a–e: The synthesis of various oxalamide ligands is summarized in Scheme 1. Condensation of isatoic anhydride (**4**) with amino alcohols **5a–e** afforded the corresponding hydroxyamides **6a–e** in 60–92% yield. The required enantiomerically pure amino alcohols **5a–e** were either commercially available or could be easily prepared from α-amino acids by reduction with $NaBH_4$-H_2SO_4.[9] The hydroxyamides **6a–e** were converted to the corresponding oxazolines **8a–e** by treatment with $SOCl_2$ followed by base-induced cyclization of the chloroamide intermediates **7a–e**. The oxazolines **8a–e** were purified by flash chromatography and were obtained in 39–76% overall yield from **6**. Another convenient route[10] to oxazolines **8a–e** is based on the zinc-catalyzed condensation of 2-aminobenzonitrile with amino alcohols **5a–e** according to the method of Witte and Seeliger.[11] Treatment of oxazolines

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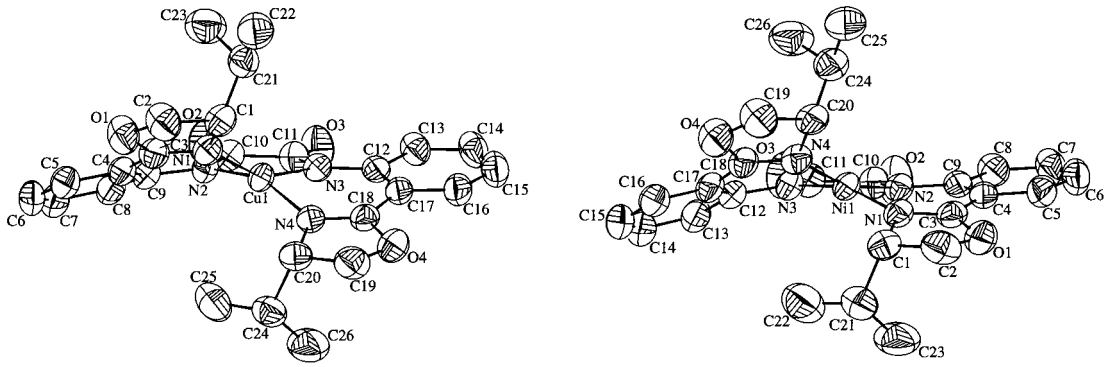
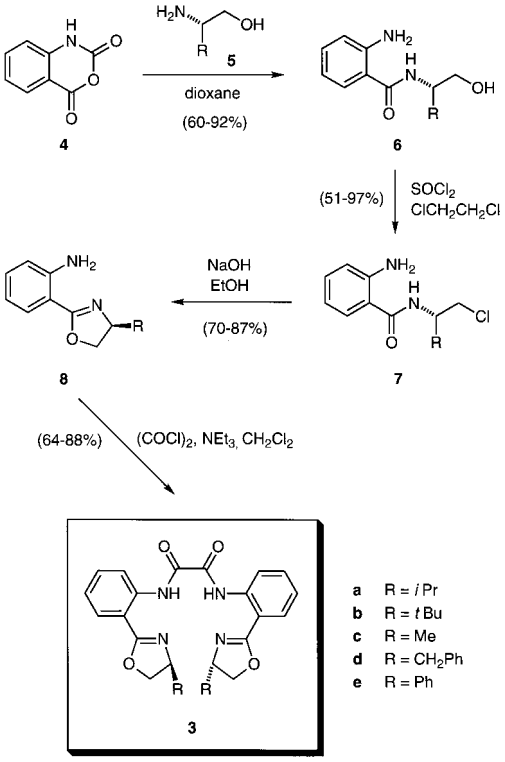


Figure 1. Crystal structures of the Cu^{II} and Ni^{II} complexes **9** and **10**.

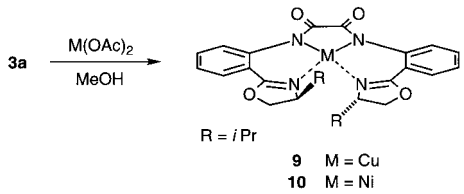


Scheme 1. Synthesis of chiral oxalamide ligands **3a–e**

8a–e with oxalyl chloride in the presence of triethylamine gave the desired oxalamides **3a–e** in 64–88% yield. All these ligands are crystalline compounds and can easily be purified by recrystallization from dichloromethane/hexane.

Abstract in German: *Enantiomerenreine N,N′-Bis[2-(4,5-dihydrooxazol-2-yl)phenyl]oxalamide sind aus 2-(2-Aminophenyl)-4,5-dihydrooxazolen und Oxalylchlorid leicht und in guter Ausbeute zugänglich. Die Strukturen von Ni^{II}- und Cu^{II}-Komplexen dieser Liganden wurden durch Röntgenstrukturanalyse bestimmt. Mit Rutheniumkomplexen, die aus $RuCl_3$ und den entsprechenden Liganden in situ generiert wurden, konnte trans-Stilben mit $NaIO_4$ enantioselektiv epoxidiert werden (bis zu 69% ee). Cobaltkomplexe wurden als enantioselektive Katalysatoren in der Michael-Addition von Malonestern an Chalkon getestet (bis zu 89% ee).*

Preparation of the Cu^{II} and Ni^{II} complexes: In order to investigate the structures and coordination behavior of these sterically hindered oxalamide ligands, the copper and nickel complexes **9** and **10** were synthesized. Oxalamide **3a** was heated with one equivalent of the corresponding metal acetate in methanol (Scheme 2) to give dark green complexes which, on recrystallization from dichloromethane/hexane, gave dark green needles.



Scheme 2. Synthesis of the Cu^{II} and Ni^{II} complexes **9** and **10** from oxalamide **3a**.

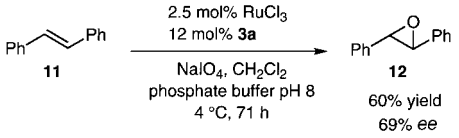
The structures of the two complexes were determined by single-crystal X-ray analysis (Figure 1).[12] As expected, both Cu^{II} and Ni^{II} form a 1:1 complex with ligand **3a**. The three-dimensional structures of these complexes are very similar with a distorted square-planar coordination geometry of the $[MN_4]$ core. The metal ion is surrounded by two oxazoline nitrogen atoms and the two anionic nitrogen atoms of the oxalamide bridge.[13] The C_2 symmetry of the ligand is largely retained, although small deviations from symmetry can be seen in the crystal structures. The deviation of the chelate ring from planarity is expressed by the angles between the M–N(oxazoline) bonds and the coordination plane (M-N2-C10-C11-N3). Angles of 31° and 35° were determined for the copper complex **9**, whereas for the analogous nickel complex **10** the corresponding values are 24° and 28° (Table 1). The distance between the copper atom and the amide nitrogens is 1.939(2) Å and 1.934(3) Å, which is slightly longer than the average $Cu–N_{amide}$ distance in related complexes.[14] The Ni–N bond lengths in complex **10** are in the range expected for diamagnetic Ni^{II} complexes with an unstrained square-planar $[NiN_4]$ core.[15]

Enantioselective catalysis: The use of ruthenium complexes prepared from $RuCl_3$ and bipyridines or substituted phenanthrolines as catalysts in the epoxidation of alkenes was first

Table 1. Selected bond lengths [Å] and angles [°] in complexes **9** and **10.**

	9	**10**
M – N1	1.967(3)	1.878(4)
M – N2	1.939(2)	1.884(4)
M – N3	1.934(3)	1.884(4)
M – N4	1.933(3)	1.892(4)
N2 – C10	1.337(4)	1.356(6)
N3 – C11	1.357(4)	1.338(6)
O2 – C10	1.237(4)	1.211(6)
O3 – C11	1.210(4)	1.226(6)
N1-M-N2	91.3(1)	93.3(2)
N2-M-N3	87.0(1)	87.4(2)
N1-M-N4	98.8(1)	93.5(2)
N3-M-N4	93.4(1)	91.9(2)
N2-C10-C11-N3	– 4.375	– 1.343

reported by Balavoine et al.[16] Several attempts were made to render this system enantioselective by means of chiral ligands.[17] However, the enantioselectivities were rather low (8 – 21 % *ee* for *trans*-stilbene (**11**)[17a]). Ruthenium complexes, prepared in situ from $RuCl_3$ and the oxalamide ligands **3**, proved to be more efficient catalysts in this case. The highest enantioselectivity (69 % *ee* for *trans*-stilbene) was obtained with a catalyst derived from the isopropyl-substituted ligand **3a** (Scheme 3).[18] Under optimized conditions,



Scheme 3. Ru-catalyzed enantioselective epoxidation of *trans*-stilbene (**11**).

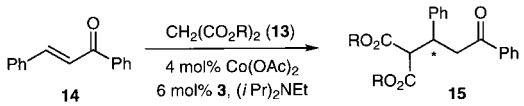
the epoxide **12** was formed in good yield, whereas only small amounts of benzaldehyde (ca. 10 %) were detected, which is usually produced as a side product in these reactions by cleavage of the C=C bond.

As another possible application of oxalamide ligands **3**, we studied Michael additions of malonic acid esters to chalcone (**14**) (Table 2). The most promising enantioselective catalysts reported to date for this class of reactions are the heterobimetallic binaphthol complexes (Li-Al/Na-La) developed by Shibasaki et al.[19] Yamaguchi et al.[20] found that the rubidium salt of L-proline catalyzes the addition of malonates to various prochiral enones with moderate to high enantioselectivity. On the other hand, chiral transition metal complexes have mainly been used as catalysts for the addition of prochiral enolates to Michael acceptors with two homotopic faces.[21]

Preliminary results obtained with oxalamide ligand **3** in cobalt-catalyzed Michael additions of dialkyl malonates **13a – c** to chalcone **14** are summarized in Table 2. The reactions were performed with 4 mol % of catalyst, generated in situ from cobalt acetate and oxalamide **3** in the presence of 1.2 equiv *N*,*N*-diisopropylethylamine in ethanol at room temperature. The analogous copper or nickel complexes did not catalyze the reaction.

By far the best enantioselectivities were obtained with the *tert*-butyl-substituted ligand **3b**. The enantioselectivities increased when bulkier ester groups were used (entries 2, 5 and 6). The highest *ee* was obtained with di-*tert*-butyl malonate. At present, however, a wider application of this reaction is compromised by the low conversion obtained in all reactions. Longer reaction times led to a significant decrease in the enantioselectivity. The reason for the low turnover numbers in this reaction is not clear at present. With cyclic enones, such as cyclohexenone, no reaction was observed.

Table 2. Enantioselective cobalt-catalyzed Michael addition of malonates to chalcone.



a R = Et
b R = *i*Pr
c R = *t*Bu

Entry	R	Ligand	yield [%]	*ee* [%]
1	Et	**3a**	17	32
2	Et	**3b**	17	75
3	Et	**3d**	30	26
4	Et	**3e**	12	31
5	*i*Pr	**3b**	12	82
6	*t*Bu	**3b**	13	89

Conclusion

In summary, we have developed a short and efficient synthesis of chiral C_2-symmetric bis-amides **3**. This route can be used to prepare various derivatives of these new ligands in an enantiomerically pure form from commercially available inexpensive precursors. The formation of stable Ni^{II} and Cu^{II} complexes proves that the bis-amides **3** can function as dianionic tetradentate ligands. The enantioselectivities obtained in the ruthenium-catalyzed epoxidation of *trans*-stilbene and cobalt-catalyzed Michael addition to chalcone are encouraging, as they demonstrate that significant enantiocontrol is possible with these ligands.

Experimental Section

General: Specific rotation: Perkin Elmer 241 polarimeter; 1 dm, 23 °C, concentration in g per 100 mL of solution, estimated error: ±5 %. NMR: ^1H: δ relative to TMS as the internal standard; ^{13}C: δ relative to $CDCl_3$ (77.0 ppm). MS: Varian VG-70-250 (NBA = 4-nitrobenzyl alcohol). Flash column chromatography was performed on Merck Kieselgel 60 (0.040 – 0.063 mm).

General procedure for the preparation of hydroxyamides 6a – e: A suspension of isatoic anhydride (**4**) (Fluka, pract.; 16.3 g, 0.10 mol) and (*S*)-2-amino-3-methyl-1-butanol (**5a**) (L-valinol;[9] 10.8 g, 0.105 mol) in anhydrous dioxane (100 mL) was heated for 2.5 h at 60 °C. The mixture was stirred for a further 16 h at room temperature. Removal of the solvent under reduced pressure, and purification of the residue by flash chromatography (7 × 30 cm, CH_2Cl_2/MeOH 100:4) afforded hydroxyamide **6a**.

***N*-[(1*S*)-1-Hydroxymethyl-2-methylpropyl]-2-aminobenzamide (6a)**: Yield: 15.6 g (70 %); pale yellowish solid; m.p. 107 – 108 °C; TLC: R_f = 0.50 (CH_2Cl_2/MeOH 9:1); $[\alpha]_D = -48.0$ (c = 1.01 in EtOH); ^1H NMR (300 MHz, $CDCl_3$): δ = 0.98 (d, J = 4.9 Hz, 3H; $CH(CH_3)_2$), 1.01 (d, J = 4.9 Hz, 3H; $CH(CH_3)_2$), 1.91 – 2.01 (m, 1H; $CH(CH_3)_2$), 2.14 – 2.80 (brs, 1H; OH), 3.68 – 3.78 (m, 2H; CH_2O), 3.84 – 3.90 (m, 1H; CHN), 5.41 (brs,

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2H; NH_2), 6.36 (d, $J = 8.4$ Hz, 1H; NH), 6.59–6.67 (m, 2H; HC-5, HC-3, Ar), 7.20 (ddd, $J = 8.5$, 7.2, 1.6 Hz, 1H; HC-4, Ar), 7.33 (dd, $J = 7.8$, 1.4 Hz, 1H; HC-6, Ar); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 19.2$, 19.6 ($CH(CH_3)_2$), 29.2 ($CH(CH_3)_2$), 56.9 (CHN), 63.4 (CH_2O), 116.6 (C-1, Ar), 116.7, 116.8 (HC-5, HC-3, Ar), 117.3 (HC-6, Ar), 132.2 (HC-4, Ar), 148.3 (C-2, Ar), 170.0 (CON); IR ($CHCl_3$): $\tilde{\nu} = 3444$ (m), 3369 (m), 1643 (s), 1614 (m), 1587 (s), 1553 (m), 1513 (s), 1487 (m), 1316 (w), 1390 (w), 1371 (w), 1316 (w), 1224 (w), 1160 (m), 1061 (w), 798 (w) cm^{-1}; MS (70 eV, EI): m/z (%): 222 (9, [M^+]), 191 (8), 161 (5), 121 (8), 120 (100), 119 (5), 92 (16), 65 (13), 39 (5); anal. calcd. for $C_{12}H_{18}N_2O_2$ (222.29): C 64.84, H 8.16, N 12.60; found C 64.72, H 8.06, N 12.50.

***N*-[(1*S*)-1-Hydroxymethyl-2,2-dimethylpropyl]-2-aminobenzamide (6b)**: Yield: 92%; orange oil; TLC: $R_f = 0.45$ (CH_2Cl_2/MeOH 9:1); ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 1.04$ (s, 9H; $C(CH_3)_3$), 3.63 (dd, $J = 11.2$, 7.6 Hz, 1H; CH_2O), 3.90 (dd, $J = 11.2$, 3.5 Hz, 1H; CH_2O), 3.97–4.04 (m, 1H; CHN), 5.41–6.00 (br, $\approx$2H; NH_2), 6.29 (d, $J = 8.9$ Hz, 1H; NH), 6.60–6.67 (m, 2H; HC-5, HC-3, Ar), 7.16–7.24 (m, 1H; HC-4, Ar), 7.36 (dd, $J =$ 8.3, 1.2 Hz, 1H; HC-6, Ar).

***N*-[(1*S*)-2-Hydroxy-1-methylethyl]-2-aminobenzamide (6c)**: Yield: 60%; colorless needles; m.p. 121–122 °C; TLC: $R_f = 0.45$ (hexane/AcOEt 4:1); $[\alpha]_D = -22.5$ ($c = 1.01$ in MeOH); ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 1.27$ (d, $J = 6.8$ Hz, 3H; CH_3), 2.83–2.87 (m, 1H; OH), 3.59–3.66 (m, 1H; CH_2O), 3.73–3.80 (m, 1H; CH_2O), 4.18–4.30 (m, 1H; CHN), 5.47 (br s, 2H; NH_2), 6.19–6.22 (m, 1H; NH), 6.62–6.69 (m, 2H; HC-5, HC-3, Ar), 7.18–7.24 (m, 1H; HC-4, Ar), 7.33 (dd, $J = 7.9$, 1.5 Hz, 1H; HC-6, Ar); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 17.1$ (CH_3), 47.7 (CHN), 66.8 (CH_2O), 116.1 (C-1, Ar), 116.7 (HC-3, Ar), 117.3 (HC-5, Ar), 127.3 (HC-6, Ar), 132.4 (HC-4, Ar), 148.5 (C-2, Ar), 169.8 (CON); IR (KBr): $\tilde{\nu} = 3411$ (s), 3300 (s), 3068 (w), 2968 (m), 2928 (w), 2877 (w), 1620 (s), 1588 (s), 1568 (m), 1539 (s), 1491 (m), 1449 (m), 1355 (w), 1314 (m), 1261 (m), 1154 (m), 1043 (s), 888 (w), 858 (w), 748 (s), 692 (m) cm^{-1}; MS (70 eV, EI): m/z (%): 194 (15, [M^+]), 163 (12), 121 (8), 120 (100), 119 (7), 92 (18), 65 (13); anal. calcd. for $C_{10}H_{14}N_2O_2$ (194.24): C 61.84, H 7.27, N 14.42; found C 62.07, H 7.32, N 14.43.

***N*-[(1*S*)-1-Benzyl-2-hydroxyethyl]-2-aminobenzamide (6d)**: Yield: 91%; pale yellow crystals; m.p. 123–124 °C; TLC: $R_f = 0.42$ (CH_2Cl_2/MeOH 9:1); $[\alpha]_D = -39.8$ ($c = 1.01$ in EtOH); ^{1}H NMR (300 MHz, $CDCl_3$): $\delta =$ 1.55–2.05 (br s, $\approx$1H; OH), 2.88–3.03 (m, 2H; CH_2Ph), 3.66 (dd, $J = 11.1$, 5.2 Hz, 1H; CH_2O), 3.76 (dd, $J = 11.0$, 3.7 Hz, 1H; CH_2O), 4.29–4.36 (m, 1H; CHN), 5.38 (br s, 2H; NH_2), 6.33 (d, $J = 7.2$ Hz, 1H; NH), 6.57–6.68 (m, 2H; HC-5, HC-3, Ar), 7.14–7.34 (m, 7H; HC-4, HC-6, Ar, CH, Bn); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 37.0$ (CH_2Ph), 52.9 (CHN), 64.1 (CH_2O), 116.2 (C-1, Ar), 116.8, 117.3, 126.7, 127.3, 128.7, 129.2, 132.4 (CH, Ar, Bn), 137.7 (C-1, Bn), 148.4 (C-2, Ar), 169.8 (CON); IR ($CHCl_3$): $\tilde{\nu} = 3640$ (w), 3501 (w), 3457 (m), 3377 (m), 1651 (s), 1622 (m), 1599 (m), 1560 (m), 1517 (s), 1492 (m), 1451 (w), 1320 (w), 1299 (w), 1262 (m), 1171 (m), 1040 (m) cm^{-1}; MS (70 eV, EI): m/z (%): 270 (6, [M^+]), 179 (16), 161 (5), 136 (9), 120 (100), 119 (6), 92 (17), 91 (6), 65 (12); anal. calcd. for $C_{16}H_{18}N_2O_2$ (270.33): C 71.09, H 6.71, N 10.36; found C 71.13, H 6.78, N 10.28.

***N*-[(1*S*)-2-Hydroxy-1-phenylethyl]-2-aminobenzamide (6e)**: Yield: 77%; pale yellow crystals; m.p. 91–92 °C; TLC: $R_f = 0.43$ (CH_2Cl_2/MeOH 9:1); $[\alpha]_D = +45.2$ ($c = 1.00$ in EtOH); ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 3.90$ (s, 1H; OH), 4.23–4.45 (m, 2H; CH_2O), 5.15–5.21 (m, 1H; CHN), 5.31–5.70 (br s, 2H; NH_2), 6.62–6.66 (m, 2H; CH, Ar), 6.85 (d, $J = 6.9$ Hz, 1H; NH), 7.17–7.41 (m, 7H; CH, Ar); ^{13}C NMR (75 MHz, $CDCl_3$, the signals of all C atoms appeared as two lines with an intensity of 1:2): $\delta = 54.7$, 55.8 (CHN), 66.4, 69.1 (CH_2O), 110.4, 115.6 (C-1, Ar), 116.3, 116.7, 116.7, 117.4, 126.7, 126.8, 127.4, 127.8, 127.9, 128.7, 128.9, 131.1, 132.6, 134.3 (CH, Ar, Ph), 139.3, 141.1 (C-1, Ph), 148.8, 150.6 (C-2, Ar), 167.8, 169.6 (CON); IR ($CHCl_3$): $\tilde{\nu} =$ 3600 (w), 3500 (m), 3440 (m), 3382 (m), 1788 (m), 1642 (s), 1612 (s), 1577 (s), 1553 (m), 1500 (s), 1451 (m), 1319 (w), 1290 (m), 1241 (s), 1160 (m), 1101 (m), 1049 (m) cm^{-1}; MS (70 eV, EI): m/z (%): 256 (6, [M^+]), 226 (5), 225 (19), 121 (8), 120 (100), 119 (5), 106 (9), 104 (7), 92 (28), 91 (7), 77 (9), 65 (26), 51 (6), 38 (9); anal. calcd. for $C_{15}H_{16}N_2O_2$ (256.30): C 70.29, H 6.29, N 10.93; found C 70.15, H 6.27, N 10.74.

General procedure for the preparation of chloroamides 7a–e: The hydroxyamide **6a** (15.6 g, 70.2 mmol) was dissolved in 1,2-dichloroethane (270 mL) and treated with thionyl chloride (12.4 mL, 0.17 mol). The suspension was heated for 3 h at 70 °C. After cooling to room temperature, the mixture was treated with a saturated solution of $NaHCO_3$ (250 mL) and extracted three times with CH_2Cl_2. The combined extracts were dried over Na_2SO_4 and evaporated. The crude product was used in the next step without purification.

General procedure for the preparation of oxazolines 8a–e: To a solution of NaOH (2.85 g, 71.4 mmol) in EtOH (470 mL) was added chloroamide **7a** (16.3 g, 67.7 mmol). After refluxing for 3 h, the mixture was cooled to room temperature and evaporated. The residue was dissolved in CH_2Cl_2 (300 mL), washed with a saturated solution of $NaHCO_3$, and dried over Na_2SO_4. Evaporation of the solvent in vacuo, and flash chromatography of the residue (7 × 21 cm, hexane/AcOEt 20:1) afforded oxazoline **8a**.

2-[(4*S*)-4-Isopropyl-4,5-dihydro-1,3-oxazol-2-yl]aniline (8a): Yield: 10.1 g (70%); colorless needles; m.p. 67–69 °C; TLC: $R_f = 0.51$ (hexane/AcOEt 4:1); $[\alpha]_D = +8.7$ ($c = 1.00$ in EtOH); ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 0.93$ (d, $J = 6.7$ Hz, 3H; $CH(CH_3)_2$), 1.02 (d, $J = 6.7$ Hz, 3H; $CH(CH_3)_2$), 1.75–1.82 (m, 1H; $CH(CH_3)_2$), 4.00 (dd, $J = 7.8$, 7.8 Hz, 1H; CH_2O), 4.07–4.15 (m, 1H; CHN), 4.32 (dd, $J = 9.2$, 7.8 Hz, 1H; CH_2O), 6.10 (br s, 2H; NH_2), 6.62–7.60 (m, 2H; HC-4, HC-6, Ar), 7.19 (ddd, $J = 8.2$, 7.2, 1.6 Hz, 1H; HC-5, Ar), 7.68 (dd, $J = 7.9$, 1.6 Hz, 1H; HC-3, Ar); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 18.6$, 18.9 ($CH(CH_3)_2$), 33.2 ($CH(CH_3)_2$), 68.7 (CH_2O), 72.8 (CHN), 109.1 (C-2, Ar), 115.6, 116.0 (HC-4, HC-6, Ar), 129.6 (HC-3, Ar), 131.9 (HC-5, Ar), 148.6 (C-1, Ar), 163.6 (C=N); IR (KBr): $\tilde{\nu} = 3399$ (s), 3262 (w), 3070 (w), 2993 (m), 2881 (m), 1642 (s), 1606 (m), 1593 (m), 1492 (m), 1468 (w), 1455 (w), 1372 (m), 1358 (w), 1309 (m), 1255 (m), 1167 (w), 1079 (w), 1045 (m), 976 (m), 908 (w), 748 (m) cm^{-1}; MS (70 eV, EI): m/z (%): 204 (37, [M^+]), 162 (11), 161 (100), 133 (31), 120 (5), 119 (6), 118 (8), 106 (8), 92 (6), 65 (6); anal. calcd. for $C_{12}H_{16}N_2O$ (204.27): C 70.56, H 7.90, N 13.71; found C 70.38, H 7.85, N 13.66.

2-[(4*S*)-4-(*tert*-Butyl)-4,5-dihydro-1,3-oxazol-2-yl]aniline (8b): Yield: 76%; pale yellow crystals; m.p. 64–65 °C; TLC: $R_f = 0.59$ (hexane/AcOEt 4:1); $[\alpha]_D = +33.0$ ($c = 1.015$ in EtOH); ^{1}H NMR (300 MHz, $CDCl_3$): $\delta =$ 0.94 (s, 9H; $C(CH_3)_3$), 4.06–4.14 (m, 2H; CHN, CH_2O), 4.20–4.28 (m, 1H; CH_2O), 6.14 (br s, 2H; NH_2), 6.62–6.70 (m, 2H; HC-4, HC-6, Ar), 7.16–7.25 (m, 1H; HC-5, Ar), 7.67 (dd, $J = 7.9$, 1.6 Hz, 1H; HC-3, Ar); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 33.8$ ($C(CH_3)_3$), 66.9 (CH_2O), 76.2 (CHN), 109.1 (C-2, Ar), 115.6, 115.9 (HC-4, HC-6, Ar), 129.6 (HC-3, Ar), 131.9 (HC-5, Ar), 148.7 (C-1, Ar), 163.5 (C=N); IR (KBr): $\tilde{\nu} = 3428$ (s), 3274 (m), 3062 (w), 2961 (s), 2901 (m), 2864 (m), 1641 (s), 1609 (m), 1587 (s), 1490 (s), 1468 (m), 1454 (m), 1362 (s), 1345 (w), 1327 (s), 1307 (m), 1257 (s), 1210 (w), 1160 (m), 1093 (m), 1052 (s), 1034 (m), 971 (s), 907 (m), 815 (m), 750s; MS (70 eV, EI): m/z (%): 218 (25, [M^+]), 162 (11), 161 (100), 133 (25), 120 (5), 118 (5), 106 (6), 92 (5); anal. calcd. for $C_{13}H_{18}N_2O$ (218.30): C 71.53, H 8.32, N 12.83; found C 71.38, H 8.29, N 12.81.

2-[(4*S*)-4-Methyl-4,5-dihydro-1,3-oxazol-2-yl]aniline (8c): Yield: 87%; colorless oil; TLC: $R_f = 0.51$ (hexane/AcOEt 4:1); $[\alpha]_D = -38.2$ ($c = 2.008$ in $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 1.31$ (d, $J = 6.2$ Hz, 3H; CH_3), 3.77–3.81 (m, 1H; CH_2O), 4.31–4.42 (m, 2H; CH_2O, CHN), 6.07 (br s, 2H; NH_2), 6.61–6.66 (m, 2H; HC-4, HC-6, Ar), 7.17 (ddd, $J = 7.8$, 7.8, 1.5 Hz, 1H; HC-5, Ar), 7.68 (dd, $J = 8.0$, 1.4 Hz, 1H; HC-3, Ar); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 21.6$ (CH_3), 62.0 (CHN), 72.1 (CH_2O), 109.0 (C-2, Ar), 115.5, 115.8 (HC-4, HC-6, Ar), 129.4 (HC-3, Ar), 131.8 (HC-5, Ar), 148.4 (C-1, Ar), 163.4 (C=N); IR ($CHCl_3$): $\tilde{\nu} = 3482$ (m), 3286 (m), 3022 (m), 2971 (m), 2920 (w), 2898 (w), 1639 (s), 1632 (s), 1596 (s), 1564 (m), 1493 (s), 1454 (m), 1370 (w), 1362 (m), 1338 (w), 1325 (m), 1305 (m), 1255 (m), 1161 (m), 1113 (m), 1071 (m), 1047 (s), 977 (m), 892 (w), 688 (w) cm^{-1}; MS (70 eV, EI): m/z (%): 177 (11), 176 (100, [M^+]), 162 (5), 161 (59), 133 (29), 132 (5), 131 (36), 120 (10), 119 (18), 118 (94), 106 (9), 92 (17), 91 (15), 90 (5), 65 (19), 64 (8), 63 (7), 52 (6).

2-[(4*S*)-4-Benzyl-4,5-dihydro-1,3-oxazol-2-yl]aniline (8d): Yield: 36%; pale yellow needles; m.p. 56–57 °C; TLC: $R_f = 0.45$ (hexane/AcOEt 5:1); $[\alpha]_D = +24.8$ ($c = 1.25$ in $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 2.75$ (dd, $J = 13.7$, 8.0 Hz, 1H; CH_2Ph), 3.11 (dd, $J = 13.7$, 6.3 Hz, 1H; CH_2Ph), 4.01 (dd, $J = 8.3$, 7.4 Hz, 1H; CH_2O), 4.25 (dd, $J = 8.8$, 8.8 Hz, 1H; CH_2O), 4.54–4.64 (m, 1H; CHN), 6.08 (br s, 2H; NH_2), 6.61–6.69 (m, 2H; HC-4, HC-6, Ar), 7.16–7.32 (m, 6H; CH, Bn, HC-5, Ar), 7.67 (dd, $J = 7.9$, 1.5 Hz, 1H; HC-3, Ar); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 42.2$ (CH_2Ph), 68.1 (CHN), 70.2 (CH_2O), 109.0 (C-2, Ar), 115.6, 115.9 (HC-4, HC-6, Ar), 126.4, 128.5, 129.2 (CH, Bn), 129.6 (HC-3, Ar), 132.0 (HC-5, Ar), 138.3 (C-1, Bn), 148.6 (C-1, Ar), 164.9 (C=N); IR (KBr): $\tilde{\nu} = 3395$s, 3274 (m), 3064 (w), 3028 (w), 2977 (m), 2909 (m), 1630 (s), 1604 (m), 1564 (m), 1490 (s), 1455 (m), 1362 (m), 1323 (m), 1264 (m), 1230 (m), 1165 (m), 1094 (m), 1056 (m), 1033 (m), 968 (m), 751 (s), 728 (m), 698 (m), 683 (m), 537 (m) cm^{-1}; MS (70 eV,

EI): *m/z* (%): 252 (20, [M^+]), 162 (10), 161 (100), 133 (25), 118 (7), 106 (7), 91 (6), 65 (5); anal. calcd. for $C_{16}H_{16}N_2O$ (252.32): C 76.16, H 6.39, N 11.10; found C 76.05, H 6.31, N 11.16.

2-[(4*S*)-4-Phenyl-4,5-dihydro-1,3-oxazol-2-yl]aniline (**8e**): Yield: 76%; pale yellow needles; m.p. 73–74 °C; TLC: $R_f = 0.42$ (hexane/AcOEt 5:1); $[\alpha]_D = +190.1$ ($c = 1.25$ in $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 4.11$ (dd, $J = 8.2$, 8.2 Hz, 1H; CH_2O), 4.67 (dd, $J = 10.0$, 8.3 Hz, 1H; CH_2O), 5.43 (dd, $J = 10.0$, 8.2 Hz, 1H; CHN), 5.83 (br s, ≈2H; NH_2), 6.64–6.72 (m, 2H; HC-4, HC-6, Ar), 7.18–7.40 (m, 6H; Ph, HC-5, Ar), 7.76 (dd, $J = 8.3$, 1.5 Hz, 1H; HC-3, Ar); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 70.2$ (CHN), 73.0 (CH_2O), 108.7 (C-2, Ar), 115.7, 116.0 (HC-4, HC-6, Ar), 126.6, 127.5, 128.7 (HC, Ph), 129.8 (HC-3, Ar), 132.3 (HC-5, Ar), 142.7 (C-1, Ph), 148.8 (C-1, Ar), 165.0 (C=N); IR (KBr): $\tilde{\nu} = 3464$ (m), 3295 (m), 3062 (w), 3030 (w), 2969 (w), 2898 (w), 1634 (s), 1608 (m), 1595 (m), 1562 (m), 1491 (s), 1454 (m), 1363 (m), 1332 (w), 1309 (w), 1265 (m), 1162 (m), 1085 (w), 1065 (m), 1033 (m), 978 (w), 954 (m), 899 (w), 751 (s), 700 (m), 686 (w) cm^{-1}; MS (70 eV, EI): *m/z* (%): 239 (17), 238 (100, [M^+]), 237 (8), 208 (15), 207 (30), 161 (5), 147 (10), 131 (11), 121 (5), 120 (26), 119 (12), 118 (41), 104 (5), 103 (7), 92 (9), 91 (13), 90 (7), 89 (9), 77 (5), 65 (9); anal. calcd. for $C_{15}H_{14}N_2O$ (238.29): C 75.61, H 5.92, N 11.76; found C 75.51, H 6.05, N 11.77.

General procedure for the preparation of oxalamide ligands 3a–e: A solution of oxazoline **8a** (1.84 g, 9.0 mmol) and Et_3N (1.29 mL, 9.27 mmol) in anhydrous CH_2Cl_2 (30 mL) was cooled to 0 °C under Ar. After dropwise addition of oxalyl chloride (0.39 mL, 4.5 mmol) in anhydrous CH_2Cl_2 (30 mL), the mixture was allowed to warm to room temperature and was then stirred overnight. The solution was diluted with CH_2Cl_2 (80 mL) and washed with 1M HCl (100 mL). After separation of the organic phase, the aqueous layer was extracted with CH_2Cl_2 twice. The combined organic layers were dried over Na_2SO_4 and concentrated in vacuo. Filtration over silica gel (5 × 4 cm, CH_2Cl_2) afforded the oxalamide ligand **3a**.

***N,N′*-Bis-[2-((4*S*)-4-isopropyl-4,5-dihydro-1,3-oxazol-2-yl)phenyl]oxalamide** (**3a**): Yield: 1.83 g (88%); colorless crystals; m.p. 220–222 °C; TLC: $R_f = 0.54$ (CH_2Cl_2); $[\alpha]_D = +26.2$ ($c = 0.994$ in $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 1.05$ (d, $J = 6.8$ Hz, 6H; $CH(CH_3)_2$), 1.17 (d, $J = 6.8$ Hz, 6H; $CH(CH_3)_2$), 1.88–1.94 (m, 2H; $CH(CH_3)_2$), 4.09 (dd, $J = 7.7$, 7.7 Hz, 2H; CH_2O), 4.27–4.35 (m, 2H; CHN), 4.42 (dd, $J = 9.6$, 7.8 Hz, 2H; CH_2O), 7.16 (ddd, $J = 7.6$, 7.6, 1.2 Hz, 2H; HC-4, Ar), 7.51 (ddd, $J = 8.7$, 8.7, 1.6 Hz, 2H; HC-5, Ar), 7.90 (dd, $J = 7.8$, 1.6 Hz, 2H; HC-3, Ar), 8.90 (dd, $J = 8.4$, 1.1 Hz, 2H; HC-6, Ar), 13.71 (s, 2H; NH); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta =$ 18.7 ($CH(CH_3)_2$), 33.2 ($CH(CH_3)_2$), 69.4 (CH_2O), 73.0 (CHN), 114.9 (C-2, Ar), 120.1 (HC-6, Ar), 123.4 (HC-4, Ar), 129.3 (HC-3, Ar), 132.2 (HC-5, Ar), 138.7 (C-1, Ar), 159.3 (CONH), 162.7 (C=N); IR (KBr): $\tilde{\nu} = 3084$ (w), 2952 (m), 2871 (w), 1689 (s), 1638 (s), 1601 (m), 1580 (s), 1512 (s), 1470 (w), 1447 (s), 1355 (m), 1300 (s), 1260 (m), 1235 (m), 1161 (w), 1222 (m), 1062 (m), 1052 (m), 1041 (m), 974 (m), 900 (w), 861 (w), 840 (w), 771 (w), 750 (m), 705 (w), 671 (w) cm^{-1}; MS (CI, NH_3): *m/z* (%): 464 (30), 463 (100, [M+H]$^+$), 232 (5), 231 (32), 205 (12), 146 (5); anal. calcd. for $C_{26}H_{30}N_4O_4$ (462.55): C 67.51, H 6.54, N 12.11; found C 67.53, H 6.51, N 11.91.

***N,N′*-Bis-[2-((4*S*)-4-(*tert*-butyl)-4,5-dihydro-1,3-oxazol-2-yl)phenyl]oxalamide** (**3b**): Yield: 79%; colorless needles; m.p. 173–175 °C; TLC: $R_f =$ 0.52 (hexane/AcOEt 4:1); $[\alpha]_D = +42.1$ ($c = 2.16$ in $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 1.07$ (s, 18H; $C(CH_3)_3$), 4.16–4.37 (m, 6H; CH_2O, CHN), 7.16 (ddd, $J = 8.2$, 8.2, 1.1 Hz, 2H; HC-4, Ar), 7.51 (ddd, $J = 8.7$, 8.7, 1.6 Hz, 2H; HC-5, Ar), 7.90 (dd, $J = 7.9$, 1.6 Hz, 2H; HC-3, Ar), 8.90 (dd, $J = 8.5$, 1.1 Hz, 2H; HC-6, Ar), 13.73 (s, 2H; NH); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 25.9$ ($C(CH_3)_3$), 34.0 ($C(CH_3)_3$), 67.5 (CH_2O), 76.5 (CHN), 114.8 (C-2, Ar), 120.0 (HC-6, Ar), 123.3 (HC-4, Ar), 129.3 (HC-3, Ar), 132.2 (HC-5, Ar), 138.7 (C-1, Ar), 159.3 (CONH), 162.6 (C=N); IR (KBr): $\tilde{\nu} = 3086$ (w), 2956 (m), 2904 (m), 2868 (m), 1687 (s), 1641 (s), 1601 (s), 1581 (s), 1518 (s), 1474 (m), 1448 (s), 1358 (m), 1341 (s), 1299 (m), 1260 (m), 1234 (m), 1209 (w), 1196 (w), 1162 (m), 1127 (m), 1074 (w), 1053 (s), 1042 (m), 1030 (m), 970 (m), 861 (m), 789 (m), 772 (m), 752 (s), 694 (w), 668 (w) cm^{-1}; MS (FAB, NBA): *m/z* (%): 492 (9), 491 (27, [M+H]$^+$), 246 (16), 245 (100), 163 (5), 161 (7), 146 (29), 145 (5), 119 (5), 90 (5), 83 (7), 77 (6), 57 (17), 55 (29), 51 (4), 43 (12), 41 (17), 39 (8); anal. calcd. for $C_{28}H_{34}N_4O_4$ (490.61): C 68.55, H 6.99, N 11.42; found C 68.23, H 7.14, N 11.30.

***N,N′*-Bis-[2-((4*S*)-4-methyl-4,5-dihydro-1,3-oxazol-2-yl)phenyl]oxalamide** (**3c**): Yield: 73%; colorless crystals; m.p. 213–216 °C; TLC: $R_f = 0.37$ (CH_2Cl_2); $[\alpha]_D = +9.7$ ($c = 1.015$ in $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 1.47$ (d, $J = 6.5$ Hz, 6H; CH_3), 3.96 (dd, $J = 7.7$, 7.7 Hz, 2H; CH_2O), 4.49 (dd, $J = 9.3$, 8.0 Hz, 2H; CH_2O), 4.58–4.63 (m, 2H; CHN), 7.17 (ddd, $J =$ 8.2, 8.2, 1.2 Hz, 2H; HC-4, Ar), 7.52 (ddd, $J = 8.7$, 8.7, 1.6 Hz, 2H; HC-5, Ar), 7.90 (dd, $J = 7.9$, 1.6 Hz, 2H; HC-3, Ar), 8.88 (dd, $J = 8.4$, 0.8 Hz, 2H; HC-6, Ar), 13.69 (s, 2H; NH); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 21.6$ (CH_3), 62.2 (CHN), 72.9 (CH_2O), 115.0 (C-2, Ar), 120.2 (HC-6, Ar), 123.5 (HC-4, Ar), 129.3 (HC-3, Ar), 132.2 (HC-5, Ar), 138.4 (C-1, Ar), 159.3 (CONH), 162.6 (C=N); IR (KBr): $\tilde{\nu} = 3082$ (w), 2977 (m), 2887 (m), 1691 (s), 1643 (s), 1602 (m), 1514 (s), 1472 (m), 1445 (s), 1360 (m), 1340 (m), 1298 (s), 1262 (m), 1232 (m), 1162 (m), 1128 (m), 1086 (w), 1042 (s), 966 (m), 882 (w), 866 (m), 830 (w), 771 (m), 752 (m), 687 (w), 663 (w) cm^{-1}; MS (CI, NH_3): *m/z* (%): 408 (25), 407 (100, [M+H]$^+$), 396 (5), 204 (6), 203 (49), 177 (6), 146 (5); anal. calcd. for $C_{22}H_{22}N_4O_4$ (406.44): calcd C 65.01, H 5.46, N 13.78; found C 64.72, H 5.46, N 13.69.

***N,N′*-Bis-[2-((4*S*)-4-benzyl-4,5-dihydro-1,3-oxazol-2-yl)phenyl]oxalamide** (**3d**): Yield: 64%; colorless needles; m.p. 206–209 °C; TLC: $R_f = 0.79$ (CH_2Cl_2/MeOH 99:1); $[\alpha]_D = +72.4$ ($c = 1.06$ in $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): $\delta = 2.89$ (dd, $J = 13.9$, 8.6 Hz, 2H; CH_2Ph), 3.40 (dd, $J = 14.0$, 5.0 Hz, 2H; CH_2Ph), 4.10 (dd, $J = 8.0$, 8.0 Hz, 2H; CH_2O), 4.31 (dd, $J = 9.0$, 9.0 Hz, 2H; CH_2O), 4.78–4.87 (m, 2H; CHN), 7.11–7.34 (m, 12H; CH, Ph, HC-4, Ar), 7.49–7.55 (m, 2H; HC-5, Ar), 7.86 (dd, $J = 7.9$, 1.6 Hz, 2H; HC-3, Ar), 8.93 (dd, $J = 8.5$, 0.8 Hz, 2H; HC-6, Ar), 13.72 (s, 2H; NH); ^{13}C NMR (75 MHz, $CDCl_3$): $\delta = 41.4$ (CH_2Ph), 67.6 (CHN), 70.4 (CH_2O), 114.8 (C-2, Ar), 120.1 (HC-6, Ar), 123.4 (HC-4, Ar), 126.4, 128.5 (CH, Ph), 129.3 (HC-3, Ar), 129.3 (CH, Ph), 132.3 (HC-5, Ar), 137.5 (C-1, Ar), 138.4 (C-1, Ph), 159.2 (CONH), 163.1 (C=N); IR (KBr): $\tilde{\nu} = 3084$ (w), 3024 (w), 2983 (w), 2891 (w), 1686 (s), 1643 (s), 1603 (m), 1582 (s), 1514 (s), 1446 (s), 1352 (m), 1300 (m), 1273 (m), 1234 (m), 1162 (w), 1129 (m), 1048 (m), 973 (m), 918 (w), 863 (w), 834 (w), 788 (w), 769 (w), 747 (m), 717 (w), 704 (m), 677 (w) cm^{-1}; MS (FAB, NBA): *m/z* (%): 560 (14), 559 (34, [M+H]$^+$), 280 (22), 279 (100), 253 (9), 187 (8), 163 (11), 161 (16), 155 (8), 147 (8), 146 (52), 145 (71), 139 (10), 138 (16), 137 (28), 136 (13), 133 (7), 132 (8), 120 (12), 119 (12), 118 (8), 117 (42), 115 (11), 107 (10), 91 (50), 90 (9), 89 (11), 78 (8), 77 (23), 69 (8), 65 (14), 63 (9), 55 (16), 53 (10), 51 (15), 50 (7); anal. calcd. for $C_{34}H_{30}N_4O_4$ (558.64): C 73.10, H 5.41, N 10.03; found C 72.94, H 5.38, N 10.00.

***N,N′*-Bis-[2-((4*S*)-4-phenyl-4,5-dihydro-1,3-oxazol-2-yl)phenyl]oxalamide** (**3e**): Yield: 72%; colorless needles; m.p. 220–222 °C; TLC: $R_f = 0.43$ (hexane/AcOEt 5:1); $[\alpha]_D = +379$ ($c = 1.00$ in $CHCl_3$); ^{1}H NMR (200 MHz, $CDCl_3$): $\delta = 4.27$ (dd, $J = 8.3$, 8.3 Hz, 2H; CH_2O), 4.81 (dd, $J = 9.3$, 8.3 Hz, 2H; CH_2O), 5.66–5.75 (m, 2H; CHN), 7.17 (ddd, $J = 7.6$, 7.6, 1.1 Hz, 2H; HC-4, Ar), 7.24–7.54 (m, 12H; CH, Ph, HC-5, Ar), 7.96 (dd, $J = 7.9$, 1.6 Hz, 2H; HC-3, Ar), 8.85 (dd, $J = 8.4$, 1.0 Hz, 2H; HC-6, Ar), 13.68 (s, 2H; NH); ^{13}C NMR (50 MHz, $CDCl_3$): $\delta = 69.7$ (CHN), 73.2 (CH_2O), 114.7 (C-2, Ar), 120.2 (HC-6, Ar), 123.5 (HC-4, Ar), 126.4, 126.8, 128.7 (CH, Ph), 129.5 (HC-3, Ar), 132.5 (HC-5, Ar), 138.6 (C-1, Ar), 141.9 (C-1, Ph), 159.2 (CONH), 163.9 (C=N); IR (KBr): $\tilde{\nu} = 3089$ (w), 3031 (m), 2981 (w), 2887 (w), 2866 (w), 1687 (s), 1636 (s), 1582 (s), 1519 (s), 1447 (s), 1361 (m), 1347 (m), 1304 (m), 1278 (m), 1259 (m), 1237 (m), 1219 (m), 1165 (w), 1129 (m), 1063 (m), 1047 (m), 983 (w), 962 (m), 861 (w), 841 (w), 821 (w), 788 (w), 769 (m), 750 (s), 699 (m), 689 (w), 665 (w) cm^{-1}; MS (70 eV, EI): *m/z* (%): 530 (0.1, [M^+]), 266 (18), 265 (100), 238 (3), 147 (4), 146 (46), 103 (6), 91 (4), 90 (9), 77 (4); anal. calcd. for $C_{32}H_{26}N_4O_4$ (530.59): calcd C 72.44, H 4.94, N 10.56, C 72.29, H 4.85, N 10.41.

Preparation of 9: A solution of **3a** (118 mg, 0.277 mmol) and $Cu(OAc)_2 \cdot H_2O$ (61 mg, 0.305 mmol) in methanol (13 mL) was heated to reflux for 2 h. After cooling, the green solution was diluted with CH_2Cl_2 (50 mL), washed with water (1 × 10 mL), and dried over Na_2SO_4. After filtration, the solvent was removed in vacuo and the residue dissolved in CH_2Cl_2 (10 mL). Et_2O (4 mL) and then hexane (5 mL) were carefully added to the top of the solution. The mixture was kept at room temperature in a closed vessel and **9** crystallized after several days.

[*N,N′*-Bis-(2-((4*S*)-4-isopropyl-4,5-dihydro-1,3-oxazol-2-yl)phenyl)oxamidato]-copper(II) monohydrate (**9**): Yield: 58 mg (40%); dark green needles; m.p. >300 °C; $[\alpha]_D = +1611$ ($c = 0.10$ in $CHCl_3$); IR (KBr): $\tilde{\nu} =$ 3446 (m br), 2958 (m), 1654 (s), 1619 (s), 1560 (s), 1482 (m), 1439 (m), 1386 (m), 1368 (m), 1303 (m), 1238 (m), 1164 (w), 1081 (w), 956 (w), 920 (w), 755 (m), 690 (w), 669 (m) cm^{-1}; MS (FAB, NBA): *m/z* (%): 524 (100, [M+H]$^+$, ^{63}Cu), isotope cluster 524–528; calcd. (obsd.): 100 (100), 31 (46), 50 (54), 15 (14), 3 (1); anal. calcd. for $C_{26}H_{28}CuN_4O_4 \cdot H_2O$ (542.10): C 57.61, H 5.58, N 10.34; found C 56.56, H 5.26, N 10.00.

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(*N*,*N*′-Bis-[2-((4*S*)-4-isopropyl-4,5-dihydro-1,3-oxazol-2-yl)phenyl)oxamidato]-nickel(II) monohydrate (**10**): The complex was prepared as described for **9** and crystallized from CH_2Cl_2/THF/hexane. Yield: 32%; dark green needles; m.p. >300 °C; $[\alpha]_D = +1803$ ($c = 0.051$ in $CHCl_3$); IR (KBr): $\tilde{\nu}$ = 3441 (m br), 2956 (m), 2872 (w), 1659 (s), 1631 (s), 1564 (m), 1484 (s), 1440 (m), 1401 (m), 1376 (s), 1303 (m), 1253 (s), 1163 (m), 1084 (m), 959 (w), 926 (m), 871 (w), 817 (w), 754 (m), 688 (w) cm^{-1}; MS (FAB, NBA): *m*/*z* (%): 519 (100, $[M+H]^+$, ^{58}Ni), isotope cluster 519–524; calcd (obsd): 100 (100), 31 (41), 44 (44), 14 (15), 8 (10) 2 (2); anal. calcd. for $C_{26}H_{28}N_4NiO_4 \cdot H_2O$ (519.23): C 58.13, H 5.63, N 10.43; found C 57.81, H 5.67, N 10.24.

Crystal structure determinations: The crystals were glued onto a glass fiber and mounted on a Enraf–Nonius CAD4 four-circle diffractometer, equipped with a $Cu_{K\alpha}$ fine-focus sealed tube ($\lambda = 1.5418$) and a graphite monochromator. Unit cell parameters were determined by the careful centering of 23 independent, strong reflections. Data collection was carried out at 293 K. Three reflections, monitored every 2 h, showed no intensity loss. The usual corrections were applied. The structures were solved by direct methods using the program SIR92.[22] Anisotropic least-squares full-matrix refinement was carried out on all non-hydrogen atoms with the program CRYSTALS.[23] The positions of the H atoms were determined geometrically. Chebychev weights[24] were used to complete the refinements. Scaling factors were taken from ref. [25] (Table 3).

Table 3. Crystal data of complexes **9** and **10.**

	9	**10**
Molecular formula	$C_{26}H_{28}CuN_4O_4 \cdot H_2O$	$C_{26}H_{28}NiN_4O_4 \cdot H_2O$
Crystal system	tetragonal	tetragonal
Space group	$P4_1$	$P4_1$
a [Å]	13.466(2)	13.527(2)
b [Å]	13.466(2)	13.527(2)
c [Å]	14.466(1)	14.346(2)
V [Å^3]	2623.4(5)	2625.3(7)
Z	4	4
Crystal dimensions [mm]	0.24 × 0.35 × 0.46	0.10 × 0.18 × 0.32
Temperature [*K*]	293	293
θ_{max} [°]	77.50	77.50
Radiation [Å]	$Cu_{K\alpha}$, $\lambda = 1.54180$	$Cu_{K\alpha}$, $\lambda = 1.54180$
Scan type	$\omega/2\theta$	$\omega/2\theta$
No. of independent refl.	2781	2604
No. of refl. in refinement	2598	2225
No. of variables	353	327
Final *R*	0.0347	0.0455
Final R_w	0.0404	0.0526
Weighting scheme	Chebychev polynomial[24]	Chebychev polynomial[24]

General procedure for the Co-catalyzed enantioselective Michael addition of malonates to chalcone: A glass flask (10 mL) with a magnetic stirring bar was charged in air with $[Co(OAc)_2 \cdot 4H_2O]$ (7.5 mg, 30.0 μmol, 4 mol%), oxalamide ligand **3b** (22.1 mg, 45.0 μmol, 6 mol%), and ethanol (3 mL). After stirring for 0.5 h at room temperature, the solution was filtered and treated sequentially with chalcone (0.156 g, 0.75 mmol), diethyl malonate (0.3 mL, 1.98 mmol), and *N*,*N*-diisopropylethylamine (0.15 mL, 0.9 mmol). The reaction mixture was stirred for 15 h at room temperature. After evaporation of the solvent, the residue was purified by chromatography (2 × 14 cm, hexane/AcOEt 10:1) to afford **15a**.

Diethyl 2-(3-oxo-1,3-diphenylpropyl)propanedioate (**15a**): Yield: 47 mg (17%); colorless, opaque oil (the product solidified upon standing at room temperature); $C_{22}H_{24}O_5$ (368.43); m.p. 71–72 °C; TLC: $R_f = 0.27$ (hexane/AcOEt 10:1); HPLC (Daicel Chiralcel OJ column, 254 nm, 0.5 mL min^{-1}, *n*-heptane/2-propanol 7:3; $t_R = 15.9$ and 22.0 min): 75% *ee*; ^{1}H NMR (200 MHz, $CDCl_3$): $\delta = 1.00$ (t, $J = 7.1$ Hz, 3H; CH_2CH_3), 1.24 (t, $J = 7.1$ Hz, 3H; CH_2CH_3), 3.44 (dd, $J = 16.6$, 8.6 Hz, 1H; CH_2CO), 3.56 (dd, 16.6, 5.0 Hz, 1H; CH_2CO), 3.83 (d, $J = 9.7$ Hz, 1H; $CH(CO)_2$), 3.95 (q, J = 7.1 Hz, 2H; CH_2CH_3), 4.13–4.27 (m, 3H; CH_2CH_3, *CH*-Ph), 7.13–7.29 (m, 5H; CH, Ph), 7.37–7.56 (m, 3H; CH, Ph), 7.87–7.91 (m, 2H; CH, Ph); ^{13}C NMR (50 MHz, $CDCl_3$): $\delta = 13.7$, 14.0 (CH_2CH_3), 40.8 (*CH*-Ph), 42.6 (CH_2CO), 57.5 ($CH(CO)_2$), 61.3, 61.6 (CH_2CH_3), 127.1 (HC-4, *Ar*-CH), 128.0, 128.2, 128.3, 128.5 (CH, *Ar*-CH), 133.0 (HC-4, *Ar*-CO), 136.8 (C-1, *Ar*-CO), 140.4 (C-1, *Ar*-CH), 167.7, 168.3 (*C*OOEt), 197.5 (CO); IR (KBr): $\tilde{\nu}$ = 2994 (m), 2907 (m), 1728 (s), 1680 (s), 1597 (m), 1449 (m), 1368 (s), 1293 (s), 1241 (s), 1168 (s), 1089 (m), 1033 (s), 1004 (m), 952 (w), 765 (m), 747 (s), 701 (s), 689 (s) cm^{-1}; MS (70 eV, EI): *m*/*z* (%): 368 (12, $[M^+]$), 323 (5), 277 (15), 276 (5), 250 (8), 249 (45), 221 (5), 220 (8), 210 (13), 209 (76), 203 (21), 171 (7), 131 (7), 106 (8), 105 (100), 103 (6), 77 (28).

Diisopropyl 2-(3-oxo-1,3-diphenylpropyl)propanedioate (**15b**): $C_{24}H_{28}O_5$ (396.49); colorless solid; m.p. 85–87 °C; TLC: $R_f = 0.25$ (hexane/AcOEt 10:1); HPLC (Daicel Chiralcel OJ column, 254 nm, 0.5 mL min^{-1}, *n*-heptane/2-propanol 85:15; $t_R = 13.1$ and 24.1 min): 82% *ee*; ^{1}H NMR (200 MHz, $CDCl_3$): $\delta = 0.96$ (d, $J = 6.3$ Hz, 3H; $CH(CH_3)_2$), 1.03 (d, J = 6.3 Hz, 3H; $CH(CH_3)_2$), 1.23 (d, $J = 6.3$ Hz, 6H; $CH(CH_3)_2$), 3.42 (dd, J = 16.8, 9.1 Hz, 1H; CH_2CO), 3.55 (dd, $J = 16.5$, 4.6 Hz, 1H; CH_2CO), 3.78 (d, $J = 9.9$ Hz, 1H; $CH(CO)_2$), 4.11–4.26 (m, 1H; *CH*-Ph), 4.69–4.88 (m, 1H; $CH(CH_3)_2$), 4.98–5.16 (m, 1H; $CH(CH_3)_2$), 7.13–7.29 (m, 5H; CH, Ph), 7.35–7.54 (m, 3H; CH, Ph), 7.86–7.91 (m, 2H; CH, Ph); ^{13}C NMR (50 MHz, $CDCl_3$): $\delta = 21.2$, 21.3, 21.5, 21.7 ($CH(CH_3)_2$), 40.7 (*CH*-Ph), 42.8 (CH_2CO), 57.7 ($CH(CO)_2$), 68.7, 69.1 ($CH(CH_3)_2$), 126.9, 128.0, 128.2, 128.3, 128.4, 132.8 (CH, Ph), 136.8 (C-1, *Ph*-CO), 140.4 (C-1, *Ph*-CH), 167.1, 167.8 (*COO*i*Pr*), 197.5 (CO); IR (KBr): $\tilde{\nu} = 3451$ (w), 3345 (w), 3066 (w), 3043 (w), 2984 (m), 2935 (w), 1961 (w), 1894 (w), 1746 (s), 1723 (s), 1682 (s), 1596 (m), 1580 (w), 1497 (w), 1468 (m), 1449 (m), 1413 (m), 1371 (m), 1342 (m), 1291 (s), 1241 (s), 1213 (s), 1167 (m), 1146 (m), 1102 (s), 1062 (m), 1030 (w), 1004 (m), 973 (m), 954 (m), 915 (m), 848 (w), 827 (w), 811 (w), 764 (m), 746 (s), 702 (s), 686 (s), 659 (w), 608 (w), 595 (w), 560 (m), 544 (w) cm^{-1}; MS (70 eV, EI): *m*/*z* (%): 396 (16, $[M^+]$), 337 (7), 295 (5), 291 (6), 277 (20), 276 (10), 275 (10), 250 (9), 249 (47), 221 (5), 217 (7), 210 (15), 209 (96), 203 (6), 175 (10), 131 (7), 120 (7), 106 (8), 105 (100), 104 (5), 103 (5), 77 (23), 43 (9).

Di-*tert*-butyl 2-(3-oxo-1,3-diphenylpropyl)propanedioate (**15c**): $C_{26}H_{32}O_5$ (424.54); colorless solid; m.p. 117–118 °C; TLC: $R_f = 0.30$ (hexane/AcOEt 10:1); HPLC (Daicel Chiralcel OJ column, 254 nm, 0.5 mL min^{-1}, *n*-heptane/2-propanol 85:15; $t_R = 10.3$ and 17.2 min): 89% *ee*; ^{1}H NMR (200 MHz, $CDCl_3$): $\delta = 1.15$ (s, 9H; $C(CH_3)_3$), 1.46 (s, 9H; $C(CH_3)_3$), 3.39 (dd, $J = 16.4$, 9.5 Hz, 1H; CH_2CO), 3.53 (dd, $J = 16.3$, 4.2 Hz, 1H; CH_2CO), 3.65 (d, $J = 10.2$ Hz, 1H; $CH(CO)_2$), 4.08 (ddd, $J = 9.6$, 9.6, 4.2 Hz, 1H; *CH*-Ph), 7.13–7.27 (m, 5H; CH, Ph), 7.35–7.50 (m, 3H; CH, Ph), 7.86–7.92 (m, 2H; CH, Ph); ^{13}C NMR (50 MHz, $CDCl_3$): $\delta = 27.4$, 27.8 ($C(CH_3)_3$), 40.8 (*CH*-Ph), 43.2 (CH_2CO), 59.2 ($CH(CO)_2$), 76.4, 77.0 ($C(CH_3)_3$), 126.8, 128.0, 128.4, 128.5, 128.7, 132.8 (CH, Ph), 136.9 (C-1, *Ph*-CO), 140.7 (C-1, *Ph*-CH), 166.9, 167.7 (*COO*t*Bu*), 197.7 (CO); IR (KBr): $\tilde{\nu} = 3063$ (w), 3030 (w), 2982 (w), 2928 (w), 1736 (s), 1722 (s), 1683 (s), 1597 (w), 1580 (w), 1495 (w), 1477 (w), 1450 (m), 1394 (w), 1368 (m), 1338 (m), 1304 (m), 1274 (s), 1156 (s), 1225 (w), 1156 (s), 1140 (s), 1097 (w), 1071 (w), 1004 (w), 970 (w), 920 (w), 850 (w), 748 (m), 702 (m), 688 (m), 562 (w) cm^{-1}; MS (70 eV, EI): *m*/*z* (%): 424 (1.5, $[M^+]$), 368 (18), 313 (20), 312 (100), 296 (7), 295 (32), 277 (15), 176 (10), 249 (26), 210 (16), 209 (96), 208 (6), 193 (16), 175 (13), 144 (7), 131 (7), 120 (36), 106 (6), 105 (76), 77 (17), 57 (44), 41 (11).

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