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Enantioselective addition of organolithium reagents to quinoline catalyzed by 1,2-diamines

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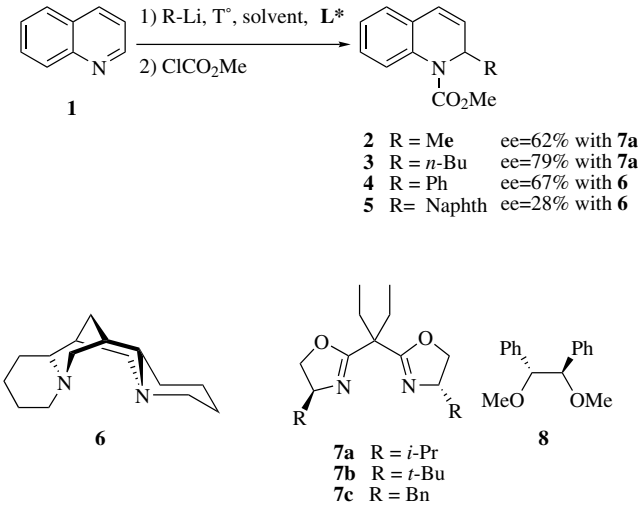
Abstract—Some enantiomerically enriched 2-substituted-1,2-dihydroquinolines were obtained by the enantioselective addition of organolithium reagents to quinoline. 1,2-Diamines were used as external chiral ligands and enantiomeric excesses up to 64% were obtained.

1. Introduction

Substituted 1,2-dihydro- and 1,2,3,4-tetrahydro quinoline moieties are present in many natural alkaloids[1–5] such as martinelline (and martinellic acid),[1] virantmycin[2] or dynemicin[3] and display a broad range of physiological and biological activities in diverse domains of industrial and pharmacological interest. In the context of new drug discovery, the synthesis of optically active hydroquinolines is of great interest for pharmaceutical research and many approaches have been disclosed to prepare these compounds. Moreover, these enantiomerically pure compounds have been synthesized by countless methods such as aza-Diels–Alder,[6] Michael-Aldol reactions,[1c,d] rearrangement of indolines,[2a] intramolecular ring opening of epoxides,[2b] radical addition,[1b] ring-closing metathesis,[7] intramolecular cyclization,[8] cycloaddition[9] or hydrogenation of substituted quinolines.[4] However, few approaches rely upon enantioselective addition to quinoline. Exceptions are the synthesis of the alkaloid isolated from *Galipea officinalis* Hancock, which was prepared by catalytic asymmetric hydrogenation[4] of quinolines, using $[Ir(COD)Cl]_2$/MeO-Biphep/I_2 as catalyst, or dynemicin[3] prepared by enantioselective addition of Grignard reagent to quinoline.

Previously,[10] we have reported the first results obtained for the enantioselective addition of organolithium reagents to quinoline, with catalytic amounts of ligands, such as (−)-sparteine **6**, bisoxazolines **7a–c** and Tomioka's diether **8**. The reactions with these external chiral ligands gave enantioenriched 2-substituted-1,2-dihydroquinolines with an enantiomeric excess of 79% for *n*-butyllithium (with the isopropylbisoxazoline **7a**) and up to 67% with phenyllithium in presence of (−)-sparteine **6** (Scheme 1).



Scheme 1. Addition of organolithium reagents to quinoline with (−)-sparteine **6**, bisoxazolines **7a–c** and (*R*,*R*)-dimethoxydiphenylethane **8**.

Herein, we report our latest results obtained on the addition of other aryllithium reagents to quinoline in the presence of (−)-sparteine and/or other diamines as external ligands. Continuing our general interest in the

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enantioselective addition of organolithium reagents to imines, with C_2 symmetric 1,2-diamines as ligands,[11] we tested these new ligands **9a–d** and **10a–c** (Fig. 1).

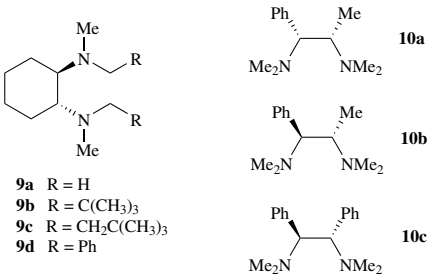


Figure 1. *N*,*N*′-Dimethylcyclohexane-1,2-diamines **9a–d** and *N*,*N*′-tetramethylethane-1,2-diamines **10a–c**.

2. Results and discussion

In our previous report, we showed that isopropylbisoxazoline **7a** was more appropriate for the addition of alkyllithiums (methyl- and butyllithium) whereas for phenyllithium (−)-sparteine **6** was better. With this observation in mind, we first tested 1- and 2-naphthyllithiums with both stoichiometric or catalytic amount of (−)-sparteine **6**. These results (Table 1) could serve as a basis for comparison with the new chiral diamines **9a–d** and **10a–c**.

Entries 1–3 are taken from our previous data. At first, we observe that 1-naphthyllithium afforded much lower enantioselectivity than phenyllithium. 2-Naphthyllithium was more extensively studied. At −78 °C, we could obtain 78% enantiomeric excess in the presence of a stoichiometric (1 equiv) amount of (−)-sparteine **6** in ether (entry 5). Interestingly, in the same solvent, under catalytic conditions, the yield increased to 78%, and the ee decreased only slightly to 72% (entry 6). Changing the solvent to toluene gave better yield (84%), but the enantiomeric excess did not increase (72%, entry 7). If the temperature is increased to −50 °C, a similar yield of 87% was observed but, as expected, the ee was worse with 64% (entry 9). With substoichiometric amounts of (−)-sparteine (20%) at −78 or −50 °C, the enantiomeric excesses were lowered by about 10% (61% and 59%, respectively; entries 8 and 10), but the yield strongly decreased to 33% at −78 °C (entry 8) and 63% at −50 °C (entry 10).

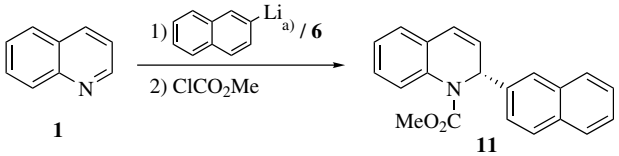
Finally, we could conclude that, unlike 1-naphthyllithium, phenyl- and 2-naphthyllithium reagents gave the same level of enantioselectivity with (−)-sparteine.

In the addition of aryllithium reagents to acyclic imines, we had found that *N*,*N*′-tetramethylcyclohexane-1,2-diamine **9a** (TMCDA) was the ligand of choice, affording up to 91% ee with 1-naphthyllithium.[11b] In that case, (−)-sparteine was not an efficient ligand. We wondered if this would also be the case with quinoline. Accordingly, we extensively tested *N*,*N*′-tetramethylcyclohexane-1,2-diamine **9a** (TMCDA) with a variety of organolithium reagents (Table 2).

The results are rather puzzling. In toluene, phenyllithium gave lower ee's than with (−)-sparteine **6**, both at −78 or −40 °C (45% and 40%). With substoichiometric amounts of TMCDA **9a**, the ee fell dramatically to 10% and 26%, respectively (entries 2 and 4), whatever the solvent, toluene or ether.

Surprisingly, it was 1-naphthyllithium which gave the best results with TMCDA, much better than with (−)-sparteine. Under similar conditions (ether, −78 °C, 1 equiv of ligand), the ee amounts to 61% (entry 10) instead of 28% (entry 4, Table 1). Slightly better ee was obtained in a less coordinating solvent such as toluene (64%, entry 6). The effect of the temperature is not critical, since, at −40 °C, the ee is still at 59% (entry 8).

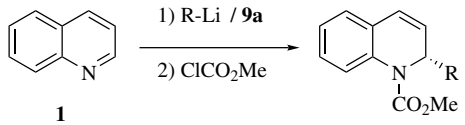
Table 1. Enantioselective addition of 2-naphthyllithium[a] on quinoline in the presence of (−)-sparteine **6**



Entry	R	Solvent	*T* (°C)	Ligand	Yield (%)	Ee (%)[c]
1	Me[b]	Et_2O	−20, 1 h	1 equiv	69	5
2	*n*-Bu[b]	Toluene	−80, 1 h	1 equiv	86	19
3	Ph[b]	Et_2O	−78, 1 h	1 equiv	55	67
4	1-Naphth	Et_2O	−78, 2 h	1 equiv	86	28
5	2-Naphth	Et_2O	−78, 2 h	1 equiv	61	**78**
6	2-Naphth	Et_2O	−78, 2 h	0.2 equiv	78	72
7[12]	2-Naphth	Toluene	−78, 2 h	1 equiv	84	72
8	2-Naphth	Toluene	−78, 2 h	0.2 equiv	33	61
9	2-Naphth	Toluene	−50, 2 h	1 equiv	87	64
10	2-Naphth	Toluene	−50, 2 h	0.2 equiv	63	59

[a] 2-NaphthLi was prepared at −50 °C by halogen–metal exchange between 2-NaphthBr and *n*-BuLi.
[b] Reaction described in the previous report.[10]
[c] Ee were determined by supercritical fluid chromatography (SFC) with column chiralcel OJ.

Table 2. Enantioselective addition of aryl- and alkyllithium to quinoline in the presence of TMCDA **9a**



1

2 R = **Me**
3 R = *n*-Bu
4 R = Ph
5 R= 1-Naphth
11 R= 2-Naphth

Entry	R	Solvent	*T* (°C)	Ligand	Yield (%)	Ee (%)
1	Ph	Toluene	−78	1 equiv	29	45[d]
2	Ph	Toluene	−78	0.2 equiv	32	10[d]
3	Ph	Toluene	−40	1 equiv	59	40[d]
4	Ph	Toluene	−40	0.2 equiv	71	26[d]
5	Ph	Et_2O	−78	0.2 equiv	37	8[d]
6	1-Naphth[a]	Toluene	−78	1 equiv	75	**64**[e]
7	1-Naphth[a]	Toluene	−78	0.2 equiv	86	58[e]
8	1-Naphth[a]	Toluene	−40	1 equiv	47	59[e]
9	1-Naphth[a]	Toluene	−40	0.2 equiv	86	45[e]
10	1-Naphth[a]	Et_2O	−78	1 equiv	90	61[e]
11	1-Naphth[a]	Et_2O	−78	0.2 equiv	52	46[e]
12	2-Naphth[b]	Toluene	−78	1 equiv	19	28[e]
13	2-Naphth[c]	Toluene	−30	1 equiv	73	41[e]
14	2-Naphth[b]	Et_2O	−70	1 equiv	26	50[e]
15	2-Naphth[b]	Et_2O	−70	0.2 equiv	36	<4[e]
16	Me	Toluene	−20	1 equiv	93	13[f]
17	Me	Et_2O	−20	1 equiv	68	10[f]
18	*n*-Bu	Toluene	−78	1 equiv	83	10[f]
19	*n*-Bu	Toluene	−78	0.2 equiv	34	0[f]

[a] 1-NaphthLi was prepared at −70 °C by halogen–metal exchange between 1-NaphthI and *n*-BuLi.
[b] 2-NaphthLi was prepared at −50 °C by halogen–metal exchange between 2-NaphthBr and *n*-BuLi.
[c] 2-NaphthLi was prepared at −30 °C by halogen–metal exchange between 2-NaphthBr and *n*-BuLi.
[d] Ee were determined by supercritical fluid chromatography (SFC) with column chiralcel OD–H.
[e] Ee were determined by supercritical fluid chromatography (SFC) with column chiralcel OJ.
[f] Ee were determined by Chiral with column Lipodex E.

Even substoichiometric amount of ligand (20%) is tolerated, the ee dropping only from 64% to 58% (entry 7).

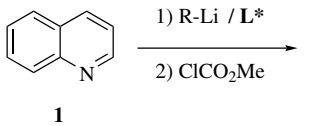
The addition of 2-naphthyllithium (entries 12–15) gave similar results as for phenyllithium. Consequently, the best ee (50%, entry 14) of compound **5** was obtained with 1 equiv of ligand in ether at −70 °C. The low yield (26%) could be improved if the temperature of halogen–metal exchange was higher, near −30 °C (entry 13). Again, a dramatic drop in ee occurs under substoichiometric conditions (entry 15).

Although we knew that TMCDA was not an efficient ligand for alkyllithium reagents,[11a] we briefly tested their behaviour. As expected (entries 16–19), the ee's are very low (10–13%) with BuLi and MeLi, both in ether or toluene.

Diamine **9a** having given interesting results, particularly for the addition of 1-naphthyllithium, we decided to study cyclohexane diamines **9b–d** with bulkier substituents on the nitrogen atom (Table 3).

Conceptually, with the replacement of the two methyl groups in TMCDA by CH_2tBu **9b**, $(CH_2)_2t$Bu **9c** or benzyl **9d** groups, each nitrogen of diamines **9b–d**, bearing two different substituents, becomes a stereogenic centre, acting as a relay of the chiral information of the carbon backbone.[11a] We recently reported that diamine **9c** had the best balance between steric hindrance and coordination ability in the addition of MeLi to imines.[11a] Therefore, it is not a surprise to observe that butyllithium gave the best enantioselectivity (63%) with ligand **9c** under substoichiometric conditions (entry 7). This interesting result was comparable with the one obtained in the presence of bisoxazoline **7a**.[10] Diamines **9b** and **9d** gave almost racemic material. In view of this result, the stoichiometric version was not attempted. The low reactivity of methyllithium needed a higher reaction temperature (−20 °C). That may explain the low enantioselectivity obtained with any ligand (entries 9 and 10). As expected, the results with phenyllithium and 1-naphthyllithium do not afford high enantioselectivities, whatever the ligand (entries 1–5).

Table 3. Enantioselective addition of organolithium reagent to quinoline in the presence of substituted *N*,*N*′-dimethylcyclohexane-1,2-diamines **9b–d**



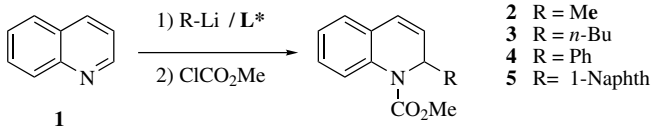
1

2 R = **Me**
3 R = *n*-Bu
4 R = Ph
5 R= 1-Naphth

Entry	R	Ligand	Solvent	*T* (°C)	Time (h)	Yield (%)	Ee (%), (configuration)
1	Ph	**9b** (0.2 equiv)	Toluene	−70	2	47	10,[b] (*R*)
2	Ph	**9c** (0.2 equiv)	Toluene	−70	3	39	17,[b] (*R*)
3	1-Naphth[a]	**9b** (0.2 equiv)	Toluene	−70	2	33	<4,[c] (nd)
4	1-Naphth[a]	**9c** (0.2 equiv)	Toluene	−70	2	51	13,[c] (*R*)
5	1-Naphth[a]	**9d** (0.2 equiv)	Toluene	−70	2	35	5,[c] (*S*)
6	*n*-Bu	**9b** (0.2 equiv)	Toluene	−70	3	53	<4,[d] (nd)
7	*n*-Bu	**9c** (0.2 equiv)	Toluene	−70	3	67	**63**,[d] (*S*)
8	*n*-Bu	**9d** (0.2 equiv)	Toluene	−70	3	58	5,[d] (nd)
9	Me	**9c** (0.2 equiv)	Toluene	−20	3	99	8,[d] (*S*)
10	Me	**9d** (0.2 equiv)	Toluene	−20	3	73	<4,[d] (nd)

[a] 1-NaphthLi was prepared at −70 °C by halogen–metal exchange between 1-NaphthI and *n*-BuLi.
[b] Ee were determined by supercritical fluid chromatography (SFC) with column chiralcel OD–H.
[c] Ee were determined by supercritical fluid chromatography (SFC) with column chiralcel OJ.
[d] Ee were determined by Chiral with column Lipodex.

Table 4. Enantioselective addition of organolithium reagent to quinoline in the presence of substituted *N*,*N*′-tetramethylethane-1,2-diamines **10a–c**



1

2 R = Me
3 R = *n*-Bu
4 R = Ph
5 R= 1-Naphth

Entry	R	Ligand	Solvent	*T* (°C)	Time (h)	Yield (%)	Ee (%), (configuration)
1	Ph	**10a** (0.2 equiv)	Toluene	−70	3	68	<4,[b] (nd)
2	Ph	**10b** (1 equiv)	Toluene	−78	2	44	27,[b] (*S*)
3	Ph	**10b** (0.2 equiv)	Toluene	−78	2	44	<4,[b] (nd)
4	Ph	**10b** (1 equiv)	Et_2O	−78	2	20	45,[b] (S)
5	Ph	**10c** (0.2 equiv)	Toluene	−78	2	14	23,[b] (*S*)
6	1-Naphth[a]	**10a** (0.2 equiv)	Toluene	−70	2	46	<4,[c] (nd)
7	1-Naphth[a]	**10b** (1 equiv)	Et_2O	−70	2	70	**58**,[c] (*S*)
8	1-Naphth[a]	**10c** (0.2 equiv)	Toluene	−70	2	35	23,[c] (*S*)
9	*n*-Bu	**10a** (0.2 equiv)	Toluene	−70	3	55	5,[d] (*R*)
11	*n*-Bu	**10b** (1 equiv)	Toluene	−70	2	94	8,[d] (*S*)
12	*n*-Bu	**10b** (1 equiv)	Et_2O	−70	2	63	8,[d] (*S*)
13	*n*-Bu	**10c** (0.2 equiv)	Toluene	−70	2	95	5,[d] (*R*)
14	Me	**10a** (0.2 equiv)	Toluene	−20	3	99	0[d]
15	Me	**10b** (1 equiv)	Toluene	−20	2	98	7,[d] (*S*)

[a] 1-NaphthLi was prepared at −70 °C by halogen–metal exchange between 1-NaphthI and *n*-BuLi.
[b] Ee were determined by supercritical fluid chromatography (SFC) with column chiralcel OD–H.
[c] Ee were determined by supercritical fluid chromatography (SFC) with column chiralcel OJ.
[d] Ee were determined by Chiral with column Lipodex E.

Other non-cyclic 1,2-diamines having an *N*,*N*′-tetramethyl substitution, such as **10a–10c** were known for having a different behaviour than the cyclic diamines **9a–9d**.[11] It was of interest to see if they could induce better enantioselectivities. The results are given in Table 4.

Diamines **10a** and **10b** are derived from inexpensive ephedrine and pseudo-ephedrine, respectively. Only diamine **10c** has a C_2 axis of symmetry, whereas diamine **10b**, with its *trans* substituents, has a close resemblance but not true C_2 symmetry.

With its two *cis* substituents it is clear that there is not a clear differentiation of space for good stereodiscrimination with diamine **10a**. Indeed, all the results obtained with this diamine are close to racemic (entries 1, 6, 9 and 14). The C_2 symmetric diamine **10c** was tested in substoichiometric amounts only. It gave moderate ee's with phenyl- (23%, entry 5) and 1-naphthyllithium (23%, entry 9), but very low yields with butyllithium. Finally, diamine **10b** behaves like a pseudo-C_2 symmetric diamine. It gives comparable results as the true C_2-diamine **10b**. With stoichiometric amounts, the enantioselectivities reach 45% with phenyllithium in ether (entry 4) and 58% with 1-naphthyllithium (entry 7). However, in substoichiometric amounts the results are much poorer. Equally disappointing (ee <10%) results were obtained with butyllithium and methyllithium, whatever the solvent or the diamines (entries 9–15).

3. Conclusion

In conclusion, these different studies have shown that *N*, *N*′-tetramethylcyclohexane-1,2-diamine **9a** was the best ligand for the addition of 1-naphthyllithium since an enantiomeric excess up to 58% could be obtained in catalytic version, and up to 64 in stoichiometric version. For 2-naphthyllithium, (−)-sparteine remains the best ligand with 78% ee in stoichiometric version and 72% in the catalytic one. It should be noticed that the easily available new diamine **9c** allows the addition of butyllithium with 63% ee. Work is in progress to find new more efficient diamine ligands of more general applicability.

Acknowledgements

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References

1. (a) Witherup, K. M.; Ransom, R. W.; Graham, A. C.; Bernard, A. M.; Salvatore, M. J.; Lumma, W. C.; Anderson, P. S.; Pitzenberger, S. M.; Varga, S. L. *J. Am. Chem. Soc.* **1995**, *117*, 6682–6685; (b) Takeda, Y.; Nakabayashi, T.; Shirai, A.; Fukumoto, D.; Kiguchi, T.; Naito, T. *Tetrahedron Lett.* **2004**, *45*, 3481–3484; (c) Makino, K.; Hara, O.; Takiguchi, Y.; Katano, T.; Asakawa, Y.; Hatano, K.; Hamada, Y. *Tetrahedron Lett.* **2003**, *44*, 8925–8929; (d) Hara, O.; Sugimoto, K.; Makino, K.; Hamada, Y. *Synlett* **2004**, 1625–1627.
2. (a) Ori, M.; Toda, N.; Takami, K.; Tago, K.; Kogen, H. *Angew. Chem., Int. Ed.* **2003**, *42*, 2540–2543; (b) Goujon, J.-Y.; Zammattio, F.; Chrétien, J.-M.; Beaudet, I. *Tetrahedron* **2004**, *60*, 4037–4049.
3. (a) Guanti, G.; Riva, R. *Chem. Commun.* **2000**, *13*, 1171–1172; (b) Banfi, L.; Basso, A.; Gandolfo, V.; Guanti, G.; Riva, R. *Tetrahedron Lett.* **2004**, *45*, 4221–4223.

4. (a) Wang, W.-B.; Lu, S.-M.; Yang, P.-Y.; Han, X.-W.; Zhou, Y.-G. *J. Am. Chem. Soc.* **2003**, *125*, 10536–10537; (b) Yang, P.-Y.; Zhou, Y.-G. *Tetrahedron: Asymmetry* **2004**, *15*, 1145–1149; (c) Lu, S.-M.; Han, X.-W.; Zhou, Y.-G. *Adv. Synth. Catal.* **2004**, *346*, 909–912; (d) Jacquemond-Collet, I.; Hannedouche, S.; Fabre, N.; Fourasté, I.; Moulis, C. *Phytochemistry* **1999**, *51*, 1167–1169.
5. (a) Kam, T.-S.; Subramaniam, G. *Tetrahedron Lett.* **2004**, *45*, 3521–3524; (b) Kam, T.-S.; Subramaniam, G.; Lim, T.-M. *Tetrahedron Lett.* **2001**, *42*, 5977–5980; (c) Ding, K.; Flippen-Anderson, J.; Deschamps, J. R.; Wanga, S. *Tetrahedron Lett.* **2004**, *45*, 1027–1029.
6. (a) Fadel, F.; Titouani, S. L.; Soufiaoui, M.; Ajamay, H.; Mazzah, A. *Tetrahedron Lett.* **2004**, *45*, 5905–5908; (b) Magesh, C. J.; Makesh, S. V.; Perumal, P. T. *Bioorg. Med. Chem. Lett.* **2004**, *14*, 2035–2040.
7. Evans, P. A.; Robinson, J. E.; Moffett, K. K. *Org. Lett.* **2001**, *3*, 3269–3271.
8. (a) Hara, O.; Sugimoto, K.; Hamada, Y. *Tetrahedron* **2004**, *60*, 9381–9390; (b) Smith, H. C.; Cavanaugh, C. K.; Friz, J. L.; Thompson, C. S.; Saggers, J. A.; Michelotti, E. L.; Garcia, J.; Ticea, C. M. *Bioorg. Med. Chem. Lett.* **2003**, *13*, 1943–1946; (c) Hatano, M.; Mikami, K. *J. Am. Chem. Soc.* **2003**, *125*, 4704–4705.
9. (a) Pohlhaus, P. D.; Bowman, R. K.; Johnson, J. S. *J. Am. Chem. Soc.* **2004**, *126*, 2294–2295; (b) Kamal, A.; Prasad, B. R.; Ramana, A. V.; Babu, A. H.; Reddy, K. S. *Tetrahedron Lett.* **2004**, *45*, 3507–3509; (c) Wiebe, J. M.; Caillé, A. S.; Trimble, L.; Lau, C. K. *Tetrahedron* **1996**, *52*, 11705–11724.
10. Amiot, F.; Cointeaux, L.; Jan Silve, E.; Alexakis, A. *Tetrahedron* **2004**, *60*, 8221–8231.
11. (a) Kizirian, J.-C.; Caille, J.-C.; Alexakis, A. *Tetrahedron Lett.* **2003**, *44*, 8893–8895; (b) Cabello, N.; Kizirian, J.-C.; Alexakis, A. *Tetrahedron Lett.* **2004**, *45*, 4639–4642.
12. Compound **11** analysis according to entry 7, Table 1: To a solution of 2-bromonaphthalene (247.4 mg, 1.2 mmol, 1.2 equiv) and (−)-sparteine (0.23 mL, 1 mmol, 1 equiv) in dried toluene (8 mL) was added dropwise *n*-BuLi (0.75 mL, 1.2 mmol, as a 1.6 M solution in hexane) at −50 °C under an argon atmosphere. The solution was stirred during 40 min at −50 °C, and the temperature was raised to −78 °C. Then quinoline (0.12 mL, 1 mmol, 1 equiv) was added, and the yellow reaction turned red, with time. After 2 h at −78 °C, methylchloroformate (0.09 mL, 1.2 mmol, 1.2 equiv) was added and the solution became yellow. After 15 min, the solution was quenched with a solution of NH_4Cl, extracted with ether (2 × 8 mL) and dichloromethane (2 × 8 mL). The organic layers were dried over $MgSO_4$, filtered and evaporated. The crude oil was purified by chromatography on silica gel with cyclohexane/ether (95/5) as eluent, and the product **11** was obtained in 84% yield as yellow oil. An enantiomeric excess of 72% was determined by chiral SFC analysis. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.83–7.69 (m, 4H); 7.58 (br s, 1H); 7.32 (d, 1H, J = 8.8 Hz); 7.47–7.42 (m, 2H); 7.22 (t, 1H, J = 7.8 Hz); 7.17 (d, 1H, J = 7.3 Hz); 7.09 (t, 1H, J = 7.5 Hz); 6.44–6.40 (m, 1H); 6.31 (dd, 1H, J = 9.6 Hz, J = 6.3 Hz); 3.89 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 155.1; 136.7; 134.4; 133.0; 132.8; 128.2; 127.9; 127.6; 127.4; 127.0; 126.2; 125.9; 125.8; 125.7; 125.5; 125.0; 124.4; 124.2; 55.5; 53.1. IR: 2953; 1694; 1488; 1437; 1325; 1299; 1267; 1123; 1029; 793; 746 cm^{-1}. $[\alpha]_D^{26} = -535.6$ (c 1.42, $CHCl_3$) for an ee of 72%. MS-EI: m/z (relative intensity) 315 (56); 270 (11); 256 (100); 188 (96); 144 (51); 128 (22); 84 (43); 77 (10); 59 (11). HRMS: calcd for $C_{21}H_{17}NO_2$ ($M^{+\cdot}$) 315.12593, found 315.12587. Chiral SFC: chiralcel OJ column, program: OJ 10%-2-1-25%; elute: MeOH; pressure: 175 bar; flow rate: 2 mL/min; 30 °C, rt (min): 10.69 (85.8%), 13.44 (14.2%). TLC: R_f = 0.29 using cyclohexane/Et_2O (95/5).