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Synthesis and Evaluation of a New Chiral Arsine Ligand; 2,2'-bis(diphenylarsino)-1,1'-binaphthyl (BINAs)

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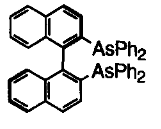
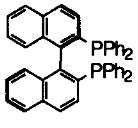
Abstract : Chiral 2,2'-bis(diphenylarsino)-1,1'-binaphthyl (BINAs) was synthesized and found to be an effective ligand in an alkenyl iodide-using intramolecular asymmetric Heck reaction. © 1997 Elsevier Science Ltd.

In a previous paper we reported that triphenylarsine is an effective ligand for tandem Suzuki cross-coupling-Heck reactions.[1] This discovery prompted us to investigate the possibility of developing and deploying suitable chiral arsine ligands, in order to obtain homochiral tandem reaction products by asymmetrisation of the Heck step. Although several chiral arsine compounds have been reported,[2] their efficacy as ligands has been highly variable, and so we decided to begin our investigation by preparing 2,2'-bis(diphenylarsino)-1,1'-binaphthyl (BINAs), the arsine analogue of BINAP,[3] which in homochiral form has proven to be a highly effective ligand for catalytic asymmetric inductions. In this paper we report a successful preparation of homochiral BINAs, which compares favourably with BINAP when used in an intramolecular asymmetric Heck reaction using an alkenyl iodide.

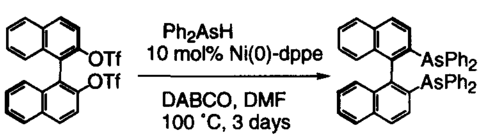


(R)-BINAs

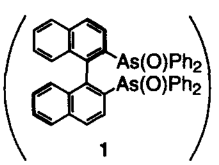


(R)-BINAP

BINAs was prepared using a slight modification of a method reported by a group at Merck.[4] Heating a mixture of the chiral ditriflate of binaphthol, diphenylarsine[5] and 1,4-diazabicyclo[2.2.2]octane (DABCO) with 10 mol% bis(1,5-cyclooctadiene)nickel and 11 mol% bis(diphenylphosphino)ethane in DMF at 100 °C for 3 days provided desired BINAs in 34% isolated yield.[6] The optical purity of the isolated material was >95% ee,[7] as determined by DAICEL CHIRALPAK OP(+) using the dioxide **1**, readily derived from BINAs



(R)-BINAs



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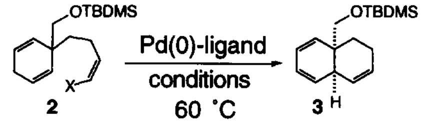
We next evaluated the effectiveness of BINAs using a well-studied asymmetric Heck reaction system.[8,9] The results (Table 1) obtained when using BINAs in an alkenyl iodide-using system (entry 1) clearly show an increased reaction rate comparing with that seen when using BINAP (entry 2), and moreover a superior chemical yield (90%) and enantiomeric excess (82%) was obtained. However, for the corresponding alkenyl triflate system (entries 4, 5), BINAs appears to be less effective than BINAP.

Table 1



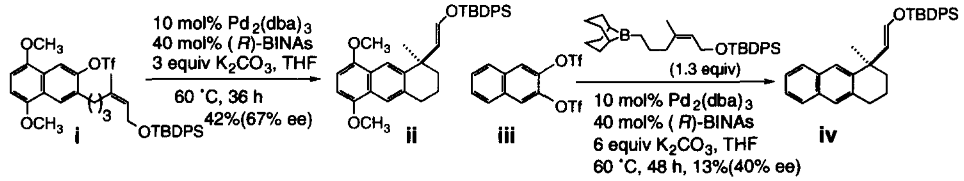
entry	X	"Pd"-ligand	time (h)	yield(%) (recov. 2)	ee (%)
1[a]	I	5 mol % $Pd_2(dba)_3$-15 mol % (*R*)-BINAs	24	90	82
2[a]	I	5 mol % $Pd_2(dba)_3$-15 mol % (*R*)-BINAP	24	55 (30)	32
3[a]	I	10 mol % Cl_2Pd[(*R*)-binap]	84	67	80
4[b]	OTf	5 mol % $Pd_2(dba)_3$-15 mol % (*R*)-BINAs	24	5 (80)	82
5[b]	OTf	5 mol % $Pd_2(dba)_3$-15 mol % (*R*)-BINAP	24	21 (52)	93
6[b]	OTf	5 mol % $Pd(OAc)_2$-10 mol % (*R*)-BINAP	74	35	92

Entries 3, 6 were the previous best results: see ref. 8, 9.
a: 2 equiv Ag_3PO_4, 2.2 equiv $CaCO_3$ in 1-methyl-2-pyrrolidinone
b: 2 equiv K_2CO_3 in toluene

In summary, we have synthesized the chiral arsine ligand (*R*)-BINAs, and found it to be an effective ligand for an alkenyl iodide-using intramolecular asymmetric Heck reaction. The comparative results for iodide and triflate substrates suggest that BINAs may play a useful complementary role to that of BINAP as a chiral ligand for asymmetric Heck reactions. Other uses of BINAs are under investigation.[10]

References and Notes

1. Kojima, A.; Honzawa, S; Boden, C. D.J.; Shibasaki, M., preceding paper in this issue.
2. For a review see: *The Chemistry of Organic Arsenic, Antimony and Bismuth Compounds*; Wild, S. B. edited by Patai, S. John Wiley & Sons, Ltd.: Chichester, 1994, pp. 89-152.
3. Noyori, R. *Asymmetric Catalysis in Organic Synthesis*; John Wiley & Sons, Inc.: New York, 1994.
4. Cai, D.; Payack, J. F.; Bender, D. R.; Hughes, D. L.; Verhoeven, T. R.; Reider, P. J. *J. Org. Chem.* **1994**, *59*, 7180.
5. Mann, F. G.; Pragnell, M. J. *J. Chem. Soc.* **1965**, 4120.
6. Preparation of (*R*)-BINAs: A solution of dppe (43.8 mg, 0.11 mmol), and $Ni(cod)_2$ (27.5 mg, 0.10 mmol) in degassed DMF (2 ml) was heated at 100 °C for 30 min under Ar. A solution of the ditriflate of (*R*)-binaphthol (550 mg, 1.0 mmol), DABCO (450 mg, 4.0 mmol) in degassed DMF (3 ml) was then added, and three additional portions of diphenylarsine (0.169 ml X 3, 2.2 mmol) were added at 5 min, 2, and 6 h later. The reaction mixture was kept at 100 °C for 3 days, and then DMF was removed *in vacuo*. The residue was triturated with MeOH to give a solid, which was washed with cold MeOH. The solid was dissolved in CH_2Cl_2, and passed through a short silica gel column with CH_2Cl_2 eluate. After removal of CH_2Cl_2 the residue was again triturated with MeOH to give (*R*)-BINAs (243 mg, 34%) as a white powder.
mp 220-222 °C; IR (KBr) 3048, 1654, 1500, 1480 cm^{-1}; ^{1}H-NMR (270 MHz, $CDCl_3$): 6.90-6.97(m, 4H), 7.04-7.23(m, 20H), 7.34(ddd, *J* = 2.6, 5.0, 7.9 Hz, 2H), 7.44(d, *J* = 8.6 Hz, 2H), 7.84(d, *J* = 8.2 Hz, 2H), 7.87(d, *J* = 8.6 Hz, 2H). ^{13}C-NMR (68 MHz, $CDCl_3$): 125.9, 126.3, 127.1, 127.8, 127.9, 128.1, 128.2, 128.4, 130.6, 133.2, 133.3, 133.5, 133.7, 138.9, 139.9, 140.2, 144.4. Anal. calcd for $C_{44}H_{32}As_2$, C; 74.37, H; 4.54. Found, C; 74.09, H; 4.44. Mass (*m/z*): 710 (M^+). $[\alpha]_D^{25}$ +111.7 (*c* = 0.50, benzene, >95% ee).
7. Generally it is difficult to determine optical purities precisely using DAICEL CHIRALPAK OP(+).
8. For the alkenyl iodide system: see Sato, Y.; Nukui, S.; Sodeoka, M.; Shibasaki, M. *Tetrahedron* **1994**, *50*, 371.
9. For the alkenyl triflate system: see Sato, Y.; Watanabe, S.; Shibasaki, M.; *Tetrahedron Lett.* **1992**, *33*, 2589.
10. For example, we have investigated the asymmetric Heck reaction (**i**→**ii**), and also a tandem Suzuki-Heck reaction (**iii**→**iv**); so far the preliminary results shown below have been obtained.



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