Palladium-Catalyzed Synthesis of *N*-Aryl- and *N*-Heteroaryl-aza-crown Ethers *via* Cross-Coupling Reactions of Aryl- and Heteroaryl Bromides with Aza-crown Ethers

Bernhard Witulski*
Fachbereich Chemie, Universität Kaiserslautern, Erwin Schrödinger Straße, D-67663 Kaiserslautern, Germany
Fax +49 (0)631 205 3921; E-mail: Bernhard@chemie.uni-kl.de

Received 5 May 1999

Abstract: Palladium(0)-catalyzed cross-coupling reactions of electron deficient aryl- and heteroaryl bromides with aza-crown ethers of various ring sizes are described. The catalyst system Pd(OAc)$_2$/PPh$_3$ gave best results for cross coupling reactions of macrocyclic aza-crown ethers with electron poor aryl bromides.

Key words: crown ether, palladium, cross-coupling reaction, amination reaction, bipyridyl, macrocycles, supramolecular chemistry.

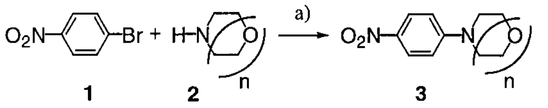
Macrocyclic ionophores based on aza-crown ether derivatives have attracted much attention because of their application as building blocks for artificial transmembrane ion channels, carrier systems for ion and molecule transport, supramolecular catalysts, and molecular elements for supramolecular assemblies.[1] Especially *N*-aryl-aza-crown ethers with defined ring sizes have been combined with photo- or redoxactive subunits and were recognized frequently as metal cation selective sensors.[2]

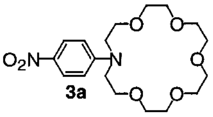
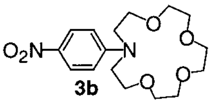
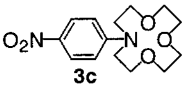
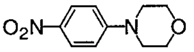
However in terms of efficiency and flexibility most syntheses of *N*-aryl-aza-crown ethers are not satisfying: either high dilution conditions often providing a low yielding ring closure of the crown ether moiety,[3] or high pressure conditions (>8 kbar) for achieving a S$_N$Ar reaction between the corresponding amine and an activated aryl halide are necessary.[4] Concerning strategy and synthesis the direct attachment of commercially or easily available aza-crown ethers to various aromatic components *via* a cross coupling reaction promises to be the most straightforward approach towards *N*-aryl- and *N*-heteroaryl-aza-crown ethers. Furthermore, such a strategy should ensure a high flexibility with respect to the ring size of the crown ether subunit, and the allowance for a multifold attachment of more than one aza-crown ether component to an aromatic core.[5]

We report here a new and efficient synthesis of *N*-aryl- and *N*-heteroaryl-crown ethers from aryl- or heteroaryl bromides and aza-crown ethers based on a Pd(0)-mediated cross coupling reaction inducing a carbon-nitrogen bond formation. This strategy follows our recent report on the synthesis of *N*-(9-anthryl) aza-18-crown-6, a novel chromo- and fluoroionophore.[6]

The intensive studies of Buchwald, Hartwig, and others on Pd(0)-catalyzed aryl aminations[7] have lead to a protocol that effects the coupling of primary and secondary amines with aryl bromides and chlorides. Whereas initially a Pd(0)/P(*o*-tol)$_3$ catalyst was used, more recently second generation catalysts based on chelating phosphine ligands have been proven to be superior in many cases.[8] Nevertheless, limitations towards sterically crowded amines were observed, and Pd-catalyzed aryl aminations have neither been studied with macrocyclic amines, nor with aza-crown ethers so far.

Table 1 Influence of the ligand and the ring size of the aza-crown ether **2** on the Pd-catalyzed cross-coupling reactions of **1** with **2**.

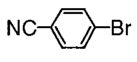
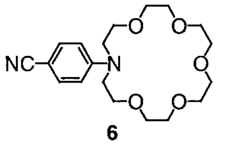
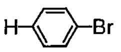
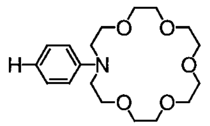
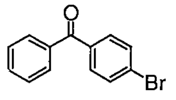
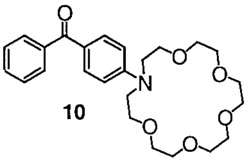
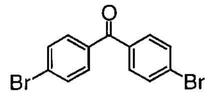
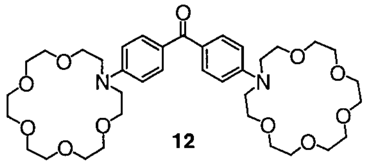
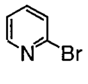
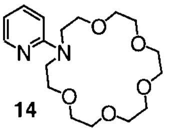
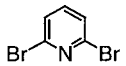
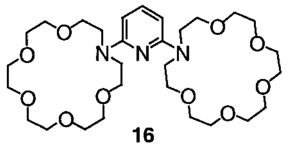
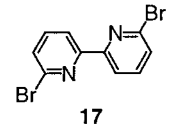
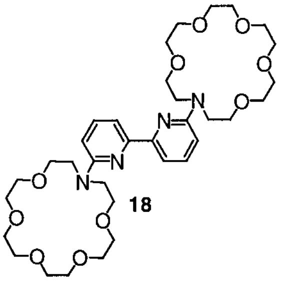


Entry	2	n	Product	Ligand[b)] L	Yield [%][c)]
1	**2a**	5	 **3a**	P(*o*-tol)$_3$	60
				P(^{t}Bu)$_3$	13
				PPh$_3$	84
2	**2b**	4	 **3b**	P(*o*-tol)$_3$	43
				PPh$_3$	88
3	**2c**	3	 **3c**	P(*o*-tol)$_3$	80
4	**2d**	1	 **3d**	P(*o*-tol)$_3$	83
				PPh$_3$	81

a) Reaction conditions: Pd-cat. (3 mol%), ligand **L** and yields see Table 1, 1.2 eq. **2**, 1.3 eq. NaO^{t}Bu, 100 °C, 12h, toluene, reaction carried out in a Schlenk tube with screw cap. b) Pd : **L** = 1 : 2, Pd(dba)$_2$ was used in combination with P(*o*-tol)$_3$ and Pd(OAc)$_2$ in combination with PPh$_3$ and P(^{t}Bu)$_3$; c) yield of isolated product.[11]

At the outset of our studies we investigated the influence of the steric properties of different monodentate phosphine ligands on the Pd(0)-catalyzed cross-coupling reaction between the electronically activated 4-nitrobromobenzene (**1**, 1 equiv) and aza-[18]-crown-6 (**2a**, 1.2 eq.) in the presence of NaO*t*-Bu (1.3 equiv) in toluene as solvent at 100 °C (Table 1). The catalyst combinations of

Table 2 Pd-catalyzed cross-coupling reactions of bromobenzenes and bromopyridines with aza-18-crown-6 (**2a**).[a), 11]

Entry	Arylbromide	Product	t [h]	Ligand[b)]	Yield [%][c)]
1	 **5**	 **6**	48 48	P(*o*-tol)$_3$ PPh$_3$	20 57
2	 **7**	 **8**	48 48	P(*o*-tol)$_3$ PPh$_3$	0 0
3	 **9**	 **10**	24 24	P(*o*-tol)$_3$ PPh$_3$	55 87
4	 **11**	 **12**	48 48	P(*o*-tol)$_3$ PPh$_3$	28[d)] 73[e)]
5	 **13**	 **14**	24 24	P(*o*-tol)$_3$ PPh$_3$	86 89
6	 **15**	 **16**	24	P(*o*-tol)$_3$	81[f), g)]
7[h)]	 **17**	 **18**	24	PPh$_3$	98

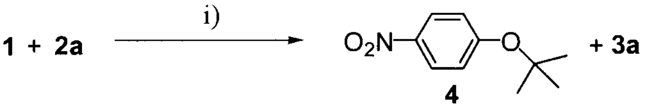
a) reaction conditions: toluene, 100 °C, 1.2 eq. **2a** and 1.3 eq. NaO^{t}Bu per bromine functionality, Pd(OAc)$_2$ or Pd(dba)$_2$ was used as Pd source with 3 mol% Pd-salt per bromine functionality; b) Pd : ligand = 1 : 2, Pd(dba)$_2$ was used in combination with P(*o*-tol)$_3$ and Pd(OAc)$_2$ in combination with PPh$_3$; c) yield of isolated products; d) crown ether **10** (50%) was formed as major product; e) crown ether **10** (25%) was formed as side product; f) crown ether **14** (10%) was formed as side product, g) PPh$_3$ as ligand was not investigated for this case; h) bipyridyl **17** was synthesized as described in ref. 21).

Pd(dba)$_2$, or Pd(OAc)$_2$ with P(*o*-tol)$_3$ and P(*t*-Bu)$_3$ respectively, gave only moderate to low yields of cross-coupling product **3a**. Whereas **3a** was obtained in 84% yield with the sterically small ligand PPh$_3$ and Pd(OAc)$_2$ (entry 1 in Table 1).[9, 10] Omitting the Pd-catalyst did not yield any product under otherwise identical reaction conditions.

Next, the interplay between the steric demand of the phosphine ligands P(*o*-tol)$_3$ and PPh$_3$,[12] and the bulkiness of the (macro)cyclic amine **2** was investigated. Cross-coupling reactions of **1** with macrocyclic amines (**2a** and **2b**), as well as with amines of medium ring sizes (**2c** and **2d**) could be achieved with both catalysts. However the catalyst based on the sterically smaller ligand PPh$_3$ gave significantly better results with the macrocyclic amines **2a** and **2b** (entry 1 and 2, Table 1). No difference in reactivity between a catalyst based on PPh$_3$ and P(*o*-tol)$_3$ was found in the arylamination of **1** with morpholine (**2d**) (entry 4,

Table 1), indicating that the bulkiness of the aza-crown ethers contribute to the observed differences in reactivity.

The catalyst system based on the bidentate ligand BINAP also led to the *N*-aryl-aza-crown ether **3a**, albeit in a diminished yield of 36% (Scheme 1). Surprisingly the phenol ether **4** was found as major product in 40% yield,[13] whereas this alkoxidation product was not observed with the catalysts based on the ligands PPh$_3$ and P(*o*-tol)$_3$. Since the alkoxide ion is less nucleophilic than the amine **2a** this result is remarkable.



Scheme 1 Catalyst and reaction conditions: i) Pd$_2$(dba)$_3$ (2 mol%), BINAP (6 mol%), 1.2 eq. **2a**, 1.3 eq. NaO^{t}Bu, 100 °C, 12h, toluene, reaction carried out in a Schlenk tube with screw cap, **4** (40%), **3a** (36%).

Scope and limitations of this new *N*-aryl-aza-crown ether synthesis were further demonstrated by the results given in Table 2, where commercially available aza-18-crown-6 (**2a**) was used as coupling partner.[14] The protocol could be extended to the synthesis of cyanobenzene **6**, benzophenone **10**,[15] and pyridine **14**[16, 17] with high efficiency. In all cases investigated, the use of the catalyst system based on PPh$_3$ gave consistently better results. The twofold cross-coupling reactions of aza-crown ether **2a** with the aryl bromides **11**, **15**, and **17** proceeded with high yields to give the crown ether **12**,[14] **16**,[18] and **18**[19] in 73%, 81%, and 98%, respectively. In the cases of **11** and **15** the mono-aminated products **10** and **14**, resulting from a β-hydride-elimination-reduction sequence of a Pd-imido intermediate,[20] could be isolated as side products respectively (entry 4 and 6, Table 2). However, the protocol is limited to electron deficient arenes and heteroarenes: a cross-coupling reaction between bromobenzene (**7**) and aza-18-crown-6 (**2a**) could not be achieved, neither with a Pd-catalyst based on PPh$_3$, nor with one based on P(*o*-tol)$_3$ (entry 2, Table 2).

Inasmuch that the reductive elimination of a Pd-imido-complex is accelerated when electron poor aryl species are involved,[20] and these electronic effects obviously support cross-coupling reaction with sterically encumbered and therefore less reactive amines, the results obtained here suggest furthermore, that the right interplay between the bulkiness of the macrocyclic amine paired with the reduced steric demand of the phosphine ligand PPh$_3$ is necessary for an efficient and high yielding *N*-aryl-aza-crown ether formation.

In conclusion, we have developed a protocol for the synthesis of *N*-aryl- and *N*-heteroaryl-aza crown ethers based on Pd-catalyzed cross coupling reactions of electron deficient aryl bromides with aza-crown ethers of various ring sizes. However, the working catalyst system Pd(OAc)$_2$/PPh$_3$ is limited to its use with electron poor aryl bromides. Molecule and cation binding studies and the application of these new macrocyclic ligands for the synthesis of novel chromo- and fluoroionophores are currently under investigation.

Acknowledgment

We would like to thank Prof. Dr. M. Regitz for his generous support. Financial support of the ‘Fonds der Chemischen Industrie’ is gratefully acknowledged.

References and Notes

(1) Lehn, J.-M. *Supramolecular Chemistry. Concepts and Perspectives*, VCH, Weinheim, 1995. Dietrich, B.; Viout, P.; Lehn, J.-M. *Macrocyclic Chemistry*, VCH, Weinheim, 1992. Weber, E.; Toner, J. L.; Goldberg, I.; Vögtle, F.; Laider, D. A.; Stoddart, J. F.; Bartsch, R. A.; Liotta, C. L. *Crown Ethers and Analogs*, Patai, S.; Rappoport, Z., Eds.; John Wiley, 1989. Gokel, G. *Crown Ethers & Cryptants*, Monograph in Supramolecular Chemistry, Stoddart, J. F., Ed.; Royal Society of Chemistry: Cambridge 1989. Cacciapaglia, R.; Di Stefano, S.; Kelderman, E.; Mandolini, L.; *Angew. Chem.* **1999**, *111*, 359; *Angew. Chem. Int. Ed. Engl.* **1999**, 348. Abel, E.; Maguire, G. E. M.; Meadows, E. S.; Murillo, O.; Jin, T.; Gokel, G. W. *J. Am. Chem. Soc.* **1997**, *119*, 9061. De Wall, S. L.; Wang, K.; Berger, D. R.; Watanabe, S.; Hernandez, J. C.; Gokel, G. W. *J. Org. Chem.* **1997**, *62*, 6784. Valeur, B.; Bardez, E. *Chem. Br.* **1995**, 216.

(2) *Chemosensors of Ions and Molecule Recognition*, Desvergne, J.-P.; Czarnik, A. W., Eds.; NATO Series C 492, Kluwer, Dordrecht, 1997. De Silva, A. P.; Gunaratne, H. Q. N.; Gunnlaugsson, T.; Huxley, A. J. M.; McCoy, C. P.; Rademacher, J. T.; Rice, T. E. *Chem. Rev.* **1997**, *97*, 1515. Bradshaw, J. S.; Izatt, R. *Acc. Chem. Res.* **1997**, *30*, 338. Lednev, I. K.; Hester, R. E.; Moore, J. N. *J. Chem. Soc., Faraday Trans.*, **1997**, *93*, 1551. Martin, M. M.; Plaza, P.; Meyer, Y. H.; Badaoui, F.; Bourson, J.; Lefèvre, J.-P.; Valeur, B. *J. Phys. Chem.* **1996**, *100*, 6879. Delmond, S.; Létard, J.-F.; Lapouyade, R.; Mathevet, R.; Jonusauskas, G.; Rulliére, C. *New. J. Chem.* **1996**, *20*, 861. Pleino, H.; Burth, D. *Organometallics* **1996**, *15*, 1151. Schmittel, M.; Ammon, H. *Chem. Commun.* **1995**, 687. Létard, J. F.; Lapouyade, R.; Rettig, W. *Pure & Appl. Chem.* **1993**, *65*, 1705. Löhr, H.-G.; Vögtle, F. *Acc. Chem. Res.* **1985**, *18*, 65.

(3) Liu, R. C. W.; Fung, P.-S.; Xue, F. Mak, T. C. W.; Ng, D. K. P. *J. Chem. Res. (S)* **1998**, 414. Bradshaw, J. S.; Krakowiak, K. E.; Izatt, R. M. *Aza-Crown Macrocycles*, Taylor, E. C., Ed.; *Heterocyclic Compounds*, Vol. 5; John Wiley, 1993. Schultz, R. A.; White, B. D.; Dishong, D. M.; Arnold, K. A.; Gokel, G. W. *J. Am. Chem. Soc.* **1989**, *107*, 6659. Dix, J. P.; Vögtle, F. *Chem. Ber.* **1980**, *113*, 457.

(4) Ciobanu, M.; Matsumoto, K. *Liebigs Ann. Chem.* **1997**, 623. Matsumoto, K.; Hashimoto, M.; Toda, M.; Tsukube, H. *J. Chem. Soc. Perkin Trans 1* **1995**, 2497.

(5) For a study of Pd-catalyzed multiple aryl aminations of polybromobenzenes see: Witulski, B.; Senft, S.; Thum, A. *Synlett* **1998**, 504.

(6) Witulski, B.; Zimmerman, Y.; Darcos, V.; Desvergne, J.-P.; Bassani, D. M.; Bouas-Laurent, H. *Tetrahedron Lett.* **1998**, *39*, 4807.

(7) Reviews and recent representative references: Hartwig, J. F. *Angew. Chem.* **1998**, *110*, 2154; *Angew. Chem. Int. Ed. Engl.* **1998**, 2046. Wolfe, J. P.; Wagaw, S.; Marcoux, J.-F.; Buchwald, S. L. *Acc. Chem. Res.* **1998**, *31*, 805. Frost, C. G.; Mendonça, P.; *J. Chem. Soc., Perkin Trans 1* **1998**, 2615.

Hartwig, J. F. *Synlett* **1997**, 329. Guari, Y.; van Es, D. S.; Reek, J. N. H.; Kamer, P. C. J.; van Leeuwen, P. W. N. M. *Tetrahedron Lett.* **1999**, *40* 3789. Wang, Z.; Skerlj, R. T.; Bridger, G. J. *Tetrahedron Lett.* **1999**, *40*, 3543. Shakespeare, W. C.; *Tetrahedron Lett.* **1999**, *40*, 2035. Bei, X.; Guram, A. S.; Turner, H. W.; Weinberg, W. H. *Tetrahedron Lett.* **1999**, *40*, 1237. Mendiratta, A.; Barlow, S.; Day, M. W.; Marder, S. R. *Organometallics* **1999**, *18*, 454. Old, D. W.; Wolfe, J. P.; Buchwald, S. L. *J. Am. Chem. Soc.* **1998**, *120*, 9722. Sadighi, J. P.; Harris, M. C.; Buchwald, S. L. *J. Am. Chem. Soc.* **1998**, *39*, 5327. Sadighi, J. P.; Singer, R. A.; Buchwald, S. L. *J. Am. Chem. Soc.* **1998**, *120*, 4960. Hori, K.; Mori, M. *J. Am. Chem. Soc.* **1998**, *120*, 7651. Mann, G.; Hartwig, J. F.; Driver, M. S.; Fernández-Rivas, C. *J. Am. Chem. Soc.* **1998**, *120*, 827. Nishiyama, M.; Yamamoto, T.; Koie, Y. *Tetrahedron Lett.* **1998**, *39*, 617. Yamamoto, T.; Nishiyama, M.; Koie, Y. *Tetrahedron Lett.* **1998**, *39*, 2367. Abouabdellah, A.; Dodd, R. H. *Tetrahedron Lett.* **1998**, *39*, 2119. Kerrigan, F.; Martin, C.; Thomas, G. H. *Tetrahedron Lett.* **1998**, 2219. Wüllner, G.; Jänsch, H.; Kannenberg, S.; Schubert, F.; Boche, G. *Chem. Commun.* **1998**, 1509. Blom, C.; Hildebrand, J. P. *Tetrahedron Lett.* **1998**, *39*, 5731. Kamikawa, K.; Sugimoto, S.; Uemura, M. *J. Org. Chem.* **1998**, *63*, 8407. Guram, S.; Rennels, R. A.; Buchwald, S. L. *Angew. Chem.* **1995**, *107*, 1456; *Angew. Chem. Int. Ed. Engl.* **1995**, *34*, 1348.

(8) Some representative references include the following: Hamann, B. C.; Hartwig, J. F. *J. Am. Chem. Soc.* **1998**, *120*, 7369. Driver, M. S.; Hartwig, J. F. *J. Am. Chem. Soc.* **1996**, *118*, 7217. Wolfe, J. P. Wagaw, S.; Buchwald, S. L. **1996**, *118*, 7215.

(9) The catalyst system Pd(0)/PPh_3 was used for intramolecular aryl amination reactions. However, it was described as less effective for intermolecular aminations with primary and secondary amines: Peat, A. J.; Buchwald, S. L. *J. Am. Chem. Soc.* **1996**, *118*, 1028. Wolfe, J. P.; Rennels, R. A.; Buchwald, S. L. *Tetrahedron* **1996**, *52*, 7525.

(10) It is assumed that $Pd(OAc)_2$ is reduced to a Pd(0) species under the reaction conditions.

(11) All new compounds were characterized by IR, MS, ^1H- and ^{13}C-NMR, elemental analysis and/or HRMS. **3a** and **3b** have been synthesized previously by other means: Dix, J. P.; Vögtle, F. *Angew. Chem.* **1978**, *90*, 893; *Angew. Chem. Int. Ed. Engl.* **1978**, *11*, 857.

(12) Cone angle θ [^{0}]: P(*o*-tol)$_3$ [194]; P(*t*-Bu)$_3$ [182]; PPh_3 [145]. Tolman, C. A. *Chem. Rev.* **1977**, *77*, 313.

(13) The same catalyst yielded **4** in 95% in the absence of an amine, whereas omitting the catalyst did not yield any **4**. Mixtures of aryl amines and aryl ethers were also found with other electron poor aryl bromides and BINAP as ligand indicating that reductive eliminations of Pd-alkoxide intermediates can compete with reductive eliminations of Pd-imido intermediates when electron poor aryl bromides are involved. (B. Witulski, S. Senft, A. Thum, unpublished results). For Pd-catalyzed cross-coupling reactions of aryl bromides with alkoxides see: Mann, G.; Incarvito, C.; Rheingold, A. L.; Hartwig, J. F. *J. Am. Chem. Soc.* **1999**, *121*, 3224. Palucki, M.; Wolfe, J. P.; Buchwald, S. L. *J. Am. Chem. Soc.* **1996**, *118*, 10333.

(14) ***Typical procedure:*** In a Schlenk tube with screw cap were introduced under argon 4,4´-dibromobenzophenone (**11**) (340 mg, 1 mmol), carefully dried aza-18-crown-6 (**2a**) (640 mg, 2.4 mmol), NaO*t*Bu (250 mg, 2.6 mmol), $Pd(OAc)_2$ (14 mg, 0.06 mmol), PPh_3 (32 mg, 0.12 mmol), and toluene (10 ml). The sealed tube was kept at 100 °C for 2 days. The reaction mixture was diluted with CH_2Cl_2 and filtered through a plug of celite. After evaporation of the solvent the organic residue was chromatographed. Column chromatography (Al_2O_3, AcOEt with 0.5% MeOH) gave **10** (115 mg, 0.26 mmol) [25%] as minor product and **12** (516 mg, 0.73 mmol) [73%] as major product.

12: colorless oil, R_f: 0.3 (Al_2O_3-TLC, AcOEt/MeOH = 95.5:0.5 (v/v)); ^1H NMR (400 MHz, $CDCl_3$) δ = 7.73 (d, J = 8.8 Hz, 4 H), 6.69 (d, J = 8.8 Hz, 4 H), 3.69 (m, 32 H), 3.72 (m, 16 H); ^{13}C NMR (200 MHz, $CDCl_3$/TMS) δ = 193.5 (s), 150.6 (s), 132.3 (d), 126.1 (s), 110.3 (d), 70.8 (t), 70.7 (t), 70.75 (t), 68.4 (t), 51.3 (t); MS (EI, 70 eV) m/z (%): 704 (100, M^+), 486 (15), 372 (10), 232 (45); $C_{37}H_{56}N_2O_{11}$ (704.86) calc.: 704.3884; found: 704.3884.

(15) **10**: colorless oil, R_f: 0.3 (Al_2O_3-TLC, hexanes/AcOEt = 4:6 (v/v)); ^1H NMR (400 MHz, $CDCl_3$) δ = 7.77 (d, J = 8.8 Hz, 2 H), 7.71 (d, J = 7.6 Hz, 2 H), 7.52 ("t", J ≈ 7.6 Hz, 2 H), 6.69 (d, J = 8.8 Hz, 2H), 3.5-3.7 (m, 24 H); ^{13}C NMR (200 MHz, $CDCl_3$/TMS) δ = 194.9 (s), 151.4 (s), 139.2 (s), 132.9 (d), 131.1 (d), 129.4 (d), 127.0 (d), 124.7 (s), 110.4 (d), 70.8 (t), 70.76 (t), 70.74 (t), 70.61 (t), 68.4 (t); $C_{25}H_{33}NO_6$ (443.54) calc.: C 67.70, H 7.50, N 3.16; found: C 67.29, H 7.51, N 3.10.

(16) **14**: colorless oil, R_f: 0.5 (Al_2O_3-TLC, hexanes/AcOEt = 1:1 (v/v)); ^1H NMR (400 MHz, $CDCl_3$) δ = 8.10 (ddd, J = 5.0 Hz, J = 2.0 Hz, J = 0.8 Hz, 1 H), 7.40 (ddd, J = 8.7 Hz, J = 7.0 Hz, J = 2.0 Hz, 1 H), 6.56 (d, J = 8.7 Hz, 1 H), 6.50 (ddd, J = 7.0 Hz, J = 5.0 Hz, J = 0.8 Hz, 1 H), 3.64-3.79 (m, 24 H); ^{13}C NMR (200 MHz, $CDCl_3$/TMS) δ = 157.8 (s), 147.8 (d), 137.0 (d), 111.3 (d), 105.7 (d), 70.8 (t), 70.7 (t), 70.65 (t), 70.6 (t), 69.2 (t); $C_{17}H_{28}N_2O_5$ (340.42) calc.: C 59.98, H 8.29, N 8.23; found: C 59.63, H 8.16, N 8.02.

(17) For cross coupling reactions of **13** with morpholine (**2d**) and allyl amines see: Wagaw, S.; Buchwald, S. L. *J. Org. Chem.* **1996**, *61*, 7240. Jaime-Figueroa, S.; Liu, Y.; Muchowski, J. M.; Putman, D. G. *Tetrahedron Lett.* **1998**, *39*, 1313.

(18) **16**: colorless oil; R_f: 0.25 (Al_2O_3-TLC, hexanes/AcOEt = 3:7 (v/v)); ^1H NMR (400 MHz, $CDCl_3$) δ = 7.22 (t, J = 8.0 Hz, 1H), 5.79 (d, J = 8.0 Hz, 2H), 3.62-3.70 (m, 48 H); ^{13}C NMR (200 MHz, $CDCl_3$/TMS) δ = 156.6 (s), 138.5 (d), 92.5 (d), 70.8 (t), 70.75 (t), 70.7 (t), 70.6 (t), 69.5 (t), 49.5 (t); $C_{29}H_{51}N_3O_{10}$ (601.74) calc.: C 57.89, H 8.54, N 6.98; found: C 57.85, H 8.55, N 6.81.

(19) **18**: colorless needles ($CHCl_3$/pentane); m.p. 86-87 °C; R_f: 0.25 (Al_2O_3-TLC, hexanes/AcOEt = 1:9 (v/v)); ^1H NMR (400 MHz, $CDCl_3$) δ = 7.58 ("d", J ≈ 7 Hz, 2 H), 7.50 ("t", J ≈ 8 Hz, 2 H); 6.55 (d, J = 8.3 Hz, 2 H, 3.67-3.86 (m, 48 H); ^{13}C NMR (200 MHz, $CDCl_3$/TMS) δ = 156.9 (s), 154.7 (s), 137.7 (d), 108.5 (d), 105.4 (d), 70.8 (t), 70.75 (t), 70.70 (t), 70.6 (t), 69.2 (t), 49.6 (t); $C_{34}H_{54}N_4O_{10}$ (678.82) calc.: C 60.16, H 8.02, N 8.25; found: C 60.11, H 7.89, N 8.14.

(20) Hamann, B. C.; Hartwig, J. F. *J. Am. Chem. Soc.* **1998**, *120*, 3694. Hartwig, J. F.; Richards, S.; Barañano, D.; Frédéric, P. *J. Am. Chem. Soc.* **1996**, *118*, 3629, and references therein.

(21) Kishii, N.; Araki, K.; Shiraishi, S. *Bull. Chem. Soc. Jpn.* **1984**, *57*, 2121.

Article Identifier:
1437-2096,E;1999,0,08,1223,1226,ftx,en;G13499ST.pdf