Tetrahedron Letters, Vol. 34, No. 22, pp. 3551-3554, 1993
Printed in Great Britain

0040-4039/93 $6.00 + .00
Pergamon Press Ltd

Palladium-Catalyzed Coupling of 2,2'-Dihalobiaryls with Metallated Cyclopentenes. An Easy Synthesis for Spiro[Cyclopentene-1,9'-[9*H*]Fluorene]s

Thomas J. Katz,[*a] **Adam M. Gilbert,**[a]
Monika E. Huttenloch,[b] **Gu Min-Min,**[b] **and Hans H. Brintzinger**[*b]

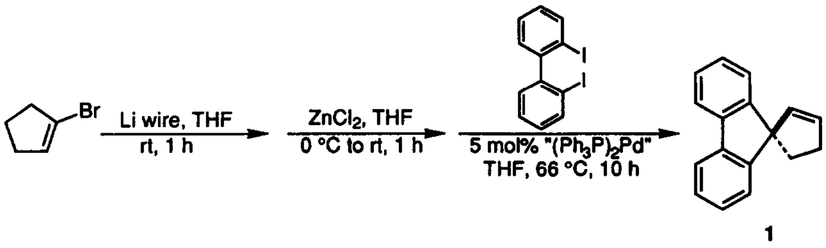
[a]Department of Chemistry, Columbia University
New York, New York 10027, USA, and

[b]Fakultät für Chemie, Universität Konstanz,
D-7750 Konstanz, FRG

Abstract: In the presence of palladium catalysts, one of the two carbons attached to halogen in 2,2'-diiodobiphenyl couples with unsaturated organometallics, after which the other adds to the newly incorporated double bond. Spiro[cyclopentene-1,9'-[9*H*]fluorene]s can be synthesized in this way.

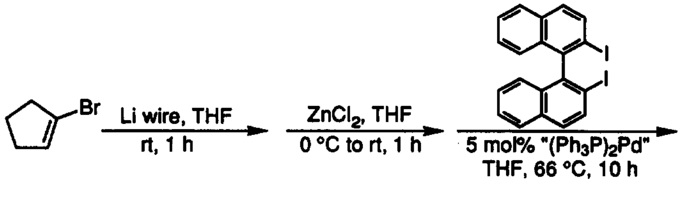
Since the combination of aryl (or vinyl) halides both with unsaturated organometallics by coupling[1] and with alkenes by addition and elimination (the Heck Reaction)[2] are catalyzed by palladium reagents, it should be possible to prepare cyclic structures by using the former reaction to generate the substrate for the latter. Equations 1-4, which we report here, are the first examples of this sequence.[3] We assume, using eq 1 as an illustration, that the key steps are those outlined in Scheme I. (Two moles of alkenylzinc chloride were used in eqs 1-3, and HI is probably consumed by the excess.)

The synthesis in eq 1, for which the zinc halide derivative was used because of its efficacy in couplings previously described,[1b,4] is considerably shorter than the classical sequence recently used to prepare the same structure.[5] It is also notable that the even though its formation causes benzene rings to clash, the same kind of product is formed by the analogous binaphthyl (eq 2).

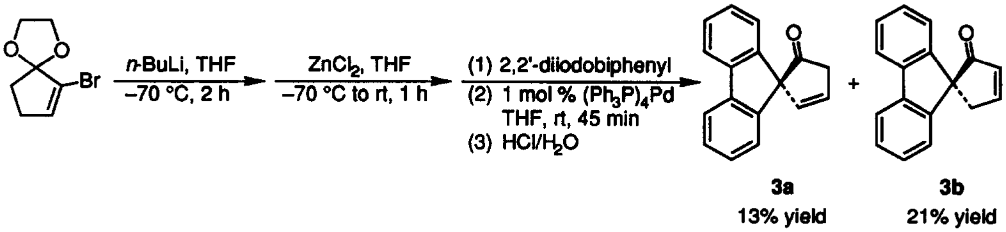


(1)

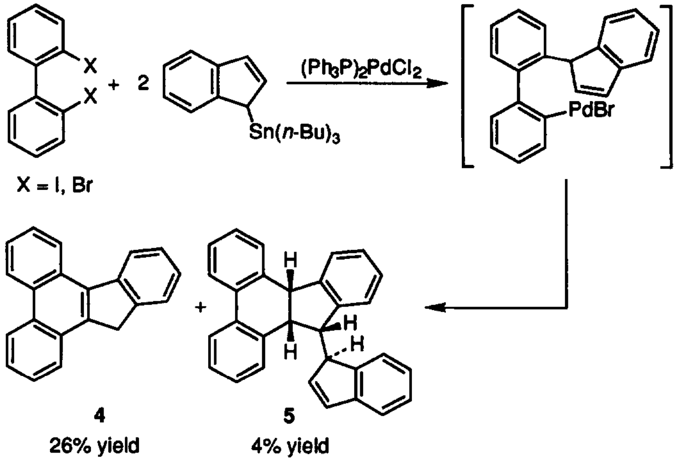
1
85% yield



(2)



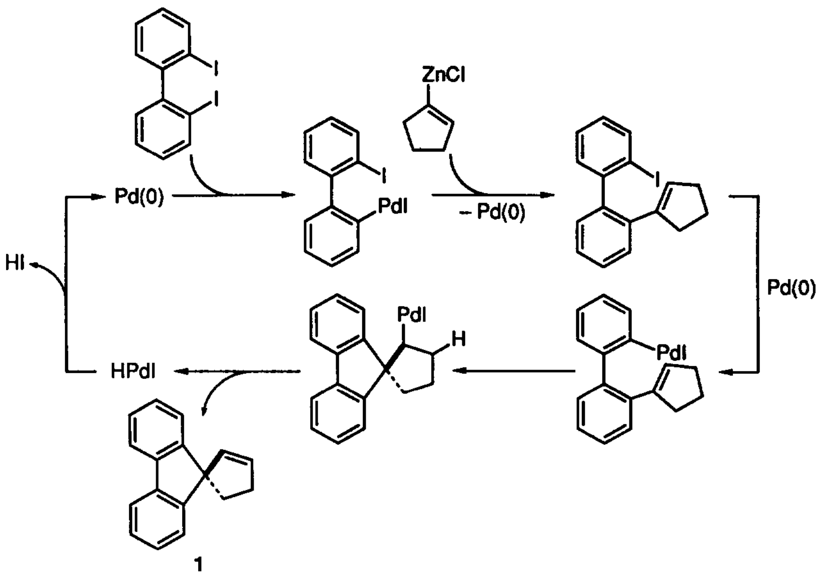
(3)



(4)

That the rings formed in Heck reactions are five-membered when the double bond is five atoms from the palladium (as in Scheme I and eqs 1-3), and six-membered when the double bond is six atoms from the palladium (as in eq 4), is well documented,[6,7] as are couplings with organotins like that giving the minor product (**5**) of eq 4.[8]

Scheme I



Acknowledgements. We thank Mr. Josef Diebold and Dr. Peter Burger for the X-ray diffraction analyses of compounds **3b** and **5**, Prof. Tomohiko Ohwada for the ^{13}C NMR spectrum of a sample of **1** prepared by his method, and the Volkswagen (I 65-627) and National Science (DMR 87-01968) Foundations for support.

REFERENCES AND NOTES

1. (a) Negishi, E.-i. *Accounts Chem. Res.* **1982**, *15*, 340. (b) Negishi, E.-i.; Takahashi, T.; King, A. O. *Org. Syn.* **1987**, *66*, 67. (c) Ref 2b, p. 208 ff.

2. (a) Heck, R. F. *Organic Reactions;* Wiley & Sons: New York, 1982; Vol. 27, Chapter 2. (b) Heck, R. F. *Palladium Reagents in Organic Syntheses*; Academic Press: New York, 1985.

3. **Starting Materials.**
(a) 2,2'-Diiodo- and 2,2'-dibromobiphenyl: Neugebauer, W.; Kos, A. J.; Schleyer, P. v. R. *J. Organomet. Chem.* **1982**, *228*, 107; Gilman, H.; Gaj, B. J. *J. Org. Chem.* **1957**, *22*, 447. (b) The ethylene ketal of 2-(ZnCl)-cyclopent-2-enone: Smith, A. B., III; Branca, S. J.; Guaciaro, M. A.; Wovkulich, P. M.; Korn, A. *Org. Syn.* **1990**, *Coll. Vol. VII*, 271. For couplings of the acetal with aryl and vinyl halides, see ref 4e. (c) 1*H*-Inden-1-yltributylstannane: Mack, P.; Parker, E. *U. S. Pat. 2,604,483* (July 22, 1952), *Chem. Abstr.* **1953**, *47*, 4358.
Reagent. "(Ph$_3$P)$_2$P" is the reagent prepared when (Ph$_3$P)$_2$PdCl$_2$ in THF is combined with 2 moles of (*i*-Bu)$_2$AlH (in hexanes). See Ref 1a and (a) Baba, S.; Negishi, E.-i. *J. Am. Chem. Soc.* **1976**, *98*, 6729, and (b) Negishi, E.-i.; Takahashi, T.; Akiyoshi, K. *Chem. Commun.* **1986**, 1138.
Products.
1—The ^{1}H NMR spectrum is the same as that published (ref 5); ^{13}C NMR (75 MHz, CDCl$_3$): δ 33.22 (CH$_2$), 37.45 (CH$_2$), 63.73 (C), 119.62 (CH), 123.71 (CH), 127.15 (CH), 127.41 (CH), 132.89 (CH), 136.33 (CH), 139.78 (C), 152.00 ppm (C); MS (EI) *m/z* 218 (M$^+$, 100%). The ^{13}C NMR spectrum is identical to one measured by Ohwada using a sample prepared by his method (ref 5).
2—^{1}H NMR (200 MHz, CDCl$_3$): δ 2.49 (t, 2H), 2.93 (m, 2H), 5.45 (td, 1H), 6.30 (td, 1H), 7.55 (m, 4H), 7.92

(m, 4H), 8.71 ppm (d, 2H)——this spectrum is appropriately similar to that of **1**; MS (CI, CH_4) *m/z* 319 (M^+ + 1, 100%), 347 (M^+ + 29, 25%).

3a—^1H NMR (250 MHz, $CDCl_3$): δ 3.28 (t, 2H), 6.10 (td, 1H), 6.68 (td, 1H), 7.25 (m, 4H), 7.40 (m, 2H), 7.77 ppm (d, 2H); ^{13}C NMR (62.5 MHz, $CDCl_3$): δ 42.6 (CH_2), 69.2 (C), 120.4, 123.6, 127.6, 128.3, 130.4, 135.0, 141.7, 145.1 (aromatic and vinyl C's), 214.2 ppm (C=O); MS (EI): *m/z* 232 (M^+, 47%), 203 (M^+ – 29, 100%); Anal. Calcd for $C_{17}H_{12}O$; C, 87.91; H, 5.21. Found: C, 87.90; H, 5.28.

3b—^1H NMR (250 MHz, $CDCl_3$): δ 3.34 (t, 2H), 6.50 (td, 1H), 7.25 (m, 4H), 7.38 (m, 2H), 7.75 (d, 2H), 8.18 ppm (td, 1H); ^{13}C NMR (62.5 MHz, $CDCl_3$): δ 42.6 (CH_2), 62.3 (C), 120.3, 122.1, 127.7, 127.9, 133.9, 141.6, 146.6, 164.4 (aromatic & vinyl C's), 207.4 ppm (C=O); MS (EI): *m/z* 232 (M^+, 100%), 203 (M^+ – 29, 87%); Anal. Calcd for $C_{17}H_{12}O$; C, 87.91; H, 5.21. Found: C, 87.93; H, 5.25. The structure was analyzed by X-ray diffraction. Details of the X-Ray diffraction analysis can be obtained from the Fachinformationszentrum, Karlsruhe, Gesellschaft für wissenschaftlich-technische Information mbH, D-7514 Eggenstein-Leopoldshafen 2, Germany, by quoting the depository number CSD-57109, the names of the authors, and the journal citation.

4—^1H NMR (250 MHz, $CDCl_3$): δ 4.18 (s, 2H), 7.31-8.8 (m, 12H); MS (EI): *m/z* 266 (M^+); Anal. Calcd for $C_{21}H_{14}$; C, 94.70; H, 5.30. Found: C, 94.33; H, 5.41; m.p. 157-159 °C.

5—^1H NMR (250 MHz, $CDCl_3$): δ 3.1 (s, 1H), 4.3 (m, 2H), 4.6 (dd, 1H), 4.7 (m, 1H), 6.1 (m, 2H), 6.9 (t, 1H), 7.1-7.8 (m, 14 H); MS (EI): *m/z* 382 (M^+); Anal. Calcd for $C_{30}H_{22}$; C, 94.20; H, 5.80. Found: C, 94.18; H, 5.87. The structure was analyzed by X-ray diffraction. If another diastereomer formed, it was removed during crystallization. Details of the diffraction analysis can be obtained as described for **3b**.

4. (a) Negishi, E.-i.; King, A. O.; Okukado, N. *J. Org. Chem.* **1977**, 42, 1821. (b) Negishi, E.-i.; Takahashi, T.; Baba, S.; Van Horn, D. E.; Okukado, N. *J. Am. Chem. Soc.* **1987**, *109*, 2393. (c) Negishi, E.-i.; Owczarczyk, Z. *Tetrahedron Lett.* **1991**, *32*, 6683. (d) Negishi, E.-i.; Okukado, N.; King, A. O.; Van Horn, D. E.; Spiegel, B. I. *J. Am. Chem. Soc.* **1978**, *100*, 2254. (e) Negishi, E.-i.; Akiyoshi, K. *Chem. Lett.* **1987**, 1007. (f) Gilchrist, T. L.; Summersell, R. J. *Tetrahedron Lett.* **1987**, *28*, 1469. (g) Negishi, E.-i.; Luo, F.-T. *J. Org. Chem.* **1983**, *48*, 1560. (h) Russell, C. E.; Hegedus, L. S. *J. Am. Chem. Soc.* **1983**, *105*, 943. (i) Lee, M.-T.; Foxman, B. M.; Rosenblum, M. *Organometallics* **1985**, *4*, 539, and later papers by Rosenblum. (j) Jabri, N.; Alexakis, A.; Normant, J. F. *Tetrahedron Lett.* **1981**, *22*, 959.

5. Ohwada, T. *J. Am. Chem. Soc.* **1992**, *114*, 8818. The only other method previously used to prepare some derivatives involves combining diazofluorene with a diene (Nishida, S.; Komiya, Z.; Mizuno, T.; Mikumi, A.; Fukui, T.; Tsuji, T.; Masashi, M.; Shimizu, N. *J. Org. Chem.* **1984**, *49*, 495).

6. (a) Grigg, R.; Stevenson, P.; Worakun, T. *Chem. Commun.* **1984**, 1073. (b) Grigg, R.; Sridharan, V.; Stevenson, P.; Worakun, T. *ibid.* **1986**, 1697. (c) Gaudin, J.-M. *Tetrahedron Lett.* **1991**, *32*, 6113. (d) Abelman, M. M.; Oh, T.; Overman, L. E. *J. Org. Chem.* **1987**, *52*, 4130. (e) Abelman, M.; Overman, L. E. *J. Am. Chem. Soc.* **1988**, *110*, 2328. (f) Carpenter, N. E.; Kucera, D. J.; Overman, L. E. *J. Org. Chem.* **1989**, *54*, 5846 (g) Madin, A.; Overman, L. E. *Tetrahedron Lett.* **1992**, *33*, 4859. (h) Abelman, M. M.; Overman, L. E.; Tranh, V. D. *J. Am. Chem. Soc.* **1990**, *112*, 6959. (i) Grigg, R.; Sridharan, V.; Stevenson, P.; Sukirthalingam, S. *Tetrahedron* **1989**, *45*, 3557. (j) Trost, B. M.; Dumas, J.; Villa, M. *J. Am. Chem. Soc.* **1992**, *114*, 9836, and references therein. (k) Trost, B. M.; Pfrengle, W.; Urabe, H.; Dumas, J. *ibid.* **1992**, *114*, 1923, and references therein. (l) Trost, B. M.; Shi, Y. *J. Am. Chem. Soc.* **1991**, *113*, 701, and references therein. (m) Nagasawa, K.; Zako, Y.; Ishihara, H.; Shimizu, I. *Tetrahedron Lett.* **1991**, *32*, 4937. (n) Fugami, K.; Oshima, K.; Utimoto, K. *ibid.* **1987**, *28*, 809. (o) Mori, M.; Kanda, N.; Oda, I.; Ban, Y. *Tetrahedron* **1985**, *41*, 5465. (p) Negishi, E.-i.; Zhang, Y.; O'Connor, B. *Tetrahedron Lett.* **1988**, *29*, 2915. (q) Wu, G.-z.; Lamaty, F.; Negishi, E.-i. *J. Org. Chem.* **1989**, *54*, 2507. (r) Larock, R. C.; Song, H.; Baker, B. E.; Gong, W. H. *Tetrahedron Lett.* **1988**, *29*, 2919.

7. That violations of the rule may be illusory was suggested in the splendid analysis of Owczarczyk, Z.; Lamaty, F.; Vawter, E. J.; Negishi, E.-i. *J. Am. Chem. Soc.* **1992**, *114*, 10091.

8. For organotins trapping organopalladium intermediates after Heck reactions see (a) Burns, B.; Grigg, R.; Ratananukul, P.; Sridharan, V.; Stevenson, P.; Sukirthalingam, S.; Worakun, T. *Tetrahedron Lett.* **1988**, *29*, 5565. (b) Grigg, R.; Sukirthalingam, S.; Sridharan, V. *ibid.* **1991**, *32*, 2545.

(Received in USA 1 February 1993)