7644 J. Org. Chem. 1996, 61, 7644−7645

Benzannulation via Sequential Metal-Promoted Higher-Order Cycloaddition−Ramberg−Bäcklund Rearrangement

James H. Rigby* and Namal C. Warshakoon

Department of Chemistry, Wayne State University, Detroit, Michigan 48202-3489

Received August 26, 1996

Aromatic ring assembly from acyclic precursors (benzannulation) has been the subject of considerable study in recent years.[1] Advances in this field based on Fischer carbene complexes (the Dötz reaction),[2] cobalt-mediated alkyne cyclotrimerization,[3] cyclobutenone and cyclobutenedione rearrangements,[4] vinyl ketene cycloaddition,[5] as well as other cyclization protocols[6] permit construction of a wide range of fused arene ring systems, often of considerable complexity.

We now disclose a novel benzannulation sequence based on chromium(0)-promoted [6π + 4π] cycloaddition[7] followed by a Ramberg−Bäcklund rearrangement[8] (Scheme 1). A noteworthy feature of this two-operation methodology that sets it apart from many related annulation procedures is the *simultaneous production of two rings* during the cyclization event. The high level of convergency that characterizes the overall process is also significant; for instance, all of the carbon atoms comprising the arene substructures are introduced in a single step via the thiepin dioxide triene system. Furthermore, since a wide range of diene partners are known to participate in metal-mediated higher-order cycloaddition, the methodology offers versatility with regard to potential target structures. These aspects of the chemistry combine to render the sequence particularly amenable to the rapid buildup of molecular complexity.

Scheme 1

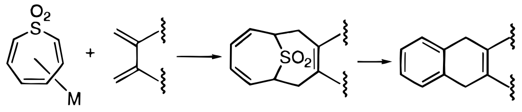
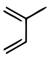
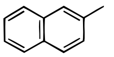
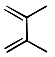
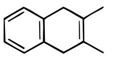
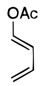
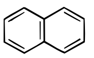
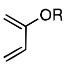
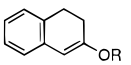
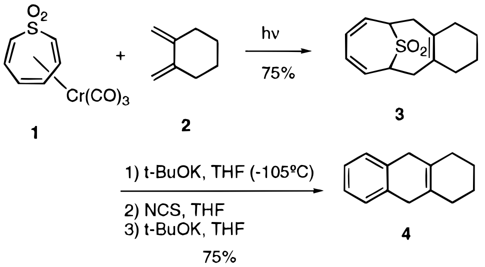


Table 1. Cr(0)-Promoted Cycloaddition−Ramberg−Bäcklund

Entry	Complex	Diene	Conditions[a]	Product	Yield(%)[b]
1	**1**		A		38[c]
2	**1**		A		36[c,d]
3	1	 OAc	A		38[c]
4	1	 OR R = TBDMS	A	 OR	81

[a] Typical reaction conditions: (A) $h\nu$ (U-glass), $ClCH_2CH_2Cl$; (ii) *t*-BuOK/THF, −105 °C; (iii) *N*-chlorosuccinimide, THF; (iv) *t*-BuOK/THF, −105 °C. [b] Overall isolated yield for entire sequence. [c] Yields depressed due to product volatility. [d] Reference 14.

Equation 1 presents a typical benzannulation sequence. Irradiation (uranium glass filter) of readily available (η^6-thiepin 1,1-dioxide)tricarbonylchromium(0) (**1**)[9] in the presence of diene **2**[10] provided cycloadduct **3**[11] in 75% yield. Treatment of this tricycle in one pot with *t*-BuOK in THF at −105 °C[12] followed by trapping of the intermediate carbanion with *N*-chlorosuccinimide and exposure of the resultant mixture to a second equivalent of *t*-BuOK afforded the known hexahydroanthracene **4** in quite good yield.[13]



(1)

A noteworthy feature of this benzannulation sequence is the capability of assembling polycyclic products as single diastereoisomers. This point is illustrated in eqs 2 and 3 wherein cycloaddition of chiral, nonracemic

---

(1) For a review covering certain aspects of this chemistry, see: Bamfield, P.; Gordon, P. F. *Chem. Soc. Rev.* **1984**, *13,* 441.

(2) Reviews: (a) Dötz, K. H. *Angew Chem., Int. Ed. Engl.* **1984**, *23* 587. (b) Wulff, W. D. In *Advances in Metal−Organic Chemistry*; Liebeskind, L. S., Ed.; JAI Press: Greenwich, CT, 1989; Vol. 1, pp 209−393. Selected recent developments: (c) Hsung, R. P.; Wulff, W. D.; Rheingold, A. L. *J. Am. Chem. Soc.* **1994**, *116*, 6449. (d) Semmelhack, M. F.; Ho, S.; Cohen, D.; Steigerwald, M.; Lee, M. C.; Lee, G.; Gilbert, A. M.; Wulff, W. D.; Ball, R. G. *Ibid.* **1994**, *116*, 7108. (e) Chamberlain, S.; Waters, M. L.; Wulff, W. D. *Ibid.* **1994**, *116*, 3113. (f) Gross, M. F.; Finn, M. G. *Ibid.* **1994**, *116,* 10921. (g) Painter, J. E.; Quayle, P.; Patel, P. *Tetrahedron Lett.* **1995**, *36,* 8089. (h) Hsung, R. P.; Xu, Y. -C.; Wulff, W. D. *Ibid.* **1995**, *36* 8159. (i) Dötz, K. H.; Pfeiffer, J. *J. Chem. Soc., Chem. Commun.* **1996**, 895.

(3) (a) Vollhardt, K. P. C. *Angew Chem., Int. Ed. Engl.* **1984**, *23,* 539. (b) Earl, R. A.; Vollhardt, K. P. C. *J. Org. Chem.* **1984**, *49,* 4786. (c) Liebeskind, L. S.; Leeds, J. P.; Baysdon, S. L.; Iyer, S. *J. Am. Chem. Soc.* **1984**, *106,* 6451. (d) Johnson, E. P.; Vollhardt, K. P. C. *Ibid.* **1991**, *113,* 381. (e) Saito, S.; Salter, M. M.; Genorgyan, V.; Tsuboya, N.; Tando, K.; Yamamoto, Y. *J. Am. Chem. Soc.* **1996**, *118,* 3970.

(4) (a) Liebeskind, L. S.; Wang, J. *J. Org. Chem.* **1993**, *58,* 3550. (b) Krysan, D. J.; Gurski, A.; Liebeskind, L. S. *J. Am. Chem. Soc.* **1992**, *114,* 1412. (c) Liebeskind, L. S. *Tetrahedron* **1989**, *45,* 3053. (d) Foland, L. D.; Karlsson, J. O.; Perri, S. T.; Schwabe, R.; Xu, S. L.; Patil, S.; Moore, H. W. *J. Am. Chem. Soc.* **1989**, *111,* 975.

(5) (a) Danheiser, R. L.; Brisbois, R. G.; Kowalczyk, J. J.; Miller, R. F. *J. Am. Chem. Soc.* **1990**, *112,* 3093. (b) Danheiser, R. L.; Miller, R. F.; Brisbois, R. G.; Park, S. Z. *J. Org. Chem.* **1990**, *55,* 1959. (c) Danheiser, R. L.; Sard, H. *Ibid.* **1980**, *45,* 4810.

(6) (a) Chen, Y. P.; Chantegrel, B.; Deshayes, C. *Heterocycles* **1995**, *41,* 175. (b) Ciufolini, M. A.; Weiss, T. J. *Tetrahedron Lett.* **1994**, *35,* 1127. (c) Hauser, F. M.; Rhee, R. P. *J. Org. Chem.* **1978**, *43,* 178. (d) Hauser, F. M.; Caringal, Y. *J. Org. Chem.* **1990**, *55,* 555. (e) Kraus, G. A.; Cho, H.; Crowley, S.; Roth, B.; Sugimoto, H.; Prugh, S. *Ibid.* **1983**, *48,* 3439. (f) Tius, M. A.; Ali, S. *Ibid.* **1982**, *47,* 3163.

(7) For reviews, see: (a) Rigby, J. H. *Acc. Chem. Res.* **1993**, *26,* 579. (b) Rigby, J. H. In *Advances in Metal−Organic Chemistry*; Liebeskind, L. S., Ed.; JAI Press: Greenwich, CT, 1995; Vol. 4, pp 89−127.

(8) Review: (a) Paquette, L. A. *Org. React.* **1977**, *25,* 1. Recent uses in synthesis: (b) Grumann, A.; Marley, H.; Taylor, R. J. K. *Tetrahedron Lett.* **1995**, *36,* 7767. (c) Doomes, E.; McKnight, A. A. *J. Heterocycl. Chem.* **1995**, *32,* 1467. (d) Alvarez, E.; Diaz, M. T.; Hanxing, L; Martin, J. D. *J. Am. Chem. Soc.* **1995**, *117,* 1437. (e) Trost, B. M.; Shi, Z. *Ibid.* **1994**, *116,* 7459. (f) Nicolaou, K. C.; Zuccarello, G.; Riemer, C.; Estevez, V. A.; Dai, W.-M. *Ibid.* **1992**, *114,* 7360.

(9) Rigby, J. H.; Ateeq, H. S.; Krueger, A. C. *Tetrahedron Lett.* **1992**, *23,* 5873.

(10) Block, E.; Aslam, M. *Org. Synth.* **1987**, *65,* 90.

(11) This compound exhibited spectral (^{1}H NMR, ^{13}C NMR, IR) and analytical (combustion analysis and/or HRMS) data consistent with the assigned structure.

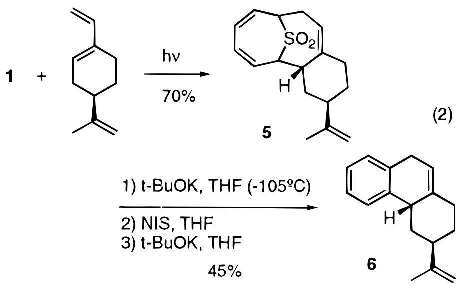
(12) Metalated dihydrothiepin 1,1-dioxides rapidly decompose at temperatures above −105 °C: Rigby, J. H.; Kreuger, A. C. *Synlett* **1993**, 829.

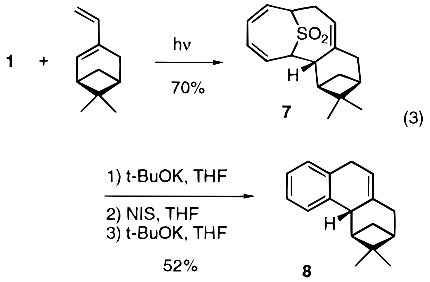
(13) Thummel, R. P.; Cravey, W. E.; Cantu, D. B. *J. Org. Chem.* **1980**, *45,* 1633.

(14) Yasuda, M.; Pac, C.; Sakurai, H. *J. Org. Chem.* **1981**, *46,* 788.

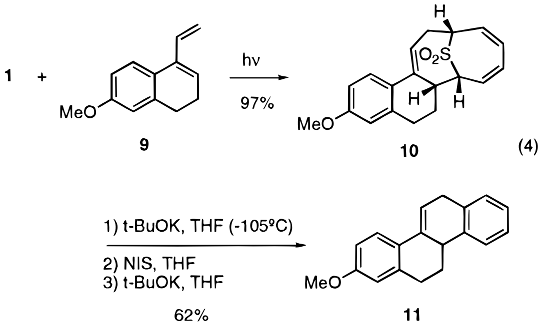
S0022-3263(96)01641-6 CCC: $12.00 © 1996 American Chemical Society

dienes provided diastereomerically homogeneous adducts (via an endo transition state). The newly created stereogenic centers in **5**[11] and **7**[11] are transferred to the benzo-fused products **6**[11] and **8**[11] with complete integrity. The reactions in eqs 2 and 3 also reveal that replacing *N*-chlorosuccinimide (NCS) with *N*-iodosuccinimide (NIS) during the Ramberg–Bäcklund step can facilitate difficult arene ring constructions. Indeed, efforts to convert **7** into **8** employing NCS were ineffectual. It appears that steric congestion in the vicinity of the ring contraction events can be overcome by the intervention of an iodinating agent. In this regard, iodide is known to be a superior leaving group in these types of transformations.[8a]





The results of several benzannulations employing relatively simple diene partners are compiled in Table 1. Several points are worthy of note in this collection. For example, the formation of the fully aromatized naphthalene product in entry 1 (Table 1) is presumably due to adventitious air oxidation. This is the only case to date in which this apparently spontaneous dehydrogenation has occurred. In contrast, direct conversion to fully aromatic naphthalene was the anticipated outcome of the sequence employing 1-acetoxybutadiene as the diene partner (Entry 3). Elimination of the elements of acetic acid during the Ramberg–Bäcklund protocol is presumably involved. In entry 4 (Table 1), the isomerization of the enol silyl ether double bond to the more conjugated location is assumed to be a base-mediated event that occurs during the course of the ring contraction step.



The sequence of reactions depicted in eq 4 represents an interesting example of how this benzannulation process can be profitably employed to rapidly assemble structurally complex target molecules. Photocycloaddition of complex **1** with the methoxytetralone-derived diene **9**[15] afforded the tetracyclic adduct **10**[11] as a single diastereomer in virtually quantitative yield. Subsequent one-pot conversion via Ramberg–Bäcklund rearrangement into the chrysene derivative **11**[11] completed the sequence. Once again, the efficiency of the ring contraction step in this instance was dramatically improved by employing *N*-iodosuccinimide in place of NCS as the positive halogen source.

In summary, rapid access to a number of benzo-fused polycyclic materials can be easily achieved employing a sequence of steps initiated by a Cr(0)-mediated $[6\pi + 4\pi]$ cycloaddition of thiepin 1,1-dioxide with various diene partners followed by a Ramberg–Bäcklund rearrangement procedure.

Acknowledgment. We thank the National Institutes of Health (GM-30771) for generous financial support of this research.

Supporting Information Available: Typical experimental procedures and complete spectroscopic data for all new compounds (7 pages).

JO9616419

---

(15) Woski, S. A.; Koreeda, M. *J. Org. Chem.* **1992**, *57*, 5736.