J. Org. Chem. **1993**, *58*, 1659–1660

Dicobaltoctacarbonyl-Mediated Cyclizations of Electron-Deficient Alkynones

Thomas R. Hoye* and Joseph A. Suriano[1]

Department of Chemistry, University of Minnesota, Minneapolis, Minnesota 55455

Received January 15, 1993

Summary: Bicyclic enediones have been synthesized via inter- and intramolecular dicobaltoctacarbonyl-mediated cyclizations (Pauson–Khand reactions) of electron-deficient alkynones. These transformations are most efficient when the reaction solvent is acetonitrile.

Since its original discovery in 1973[2] the Pauson–Khand cyclization reaction (PKCR) has been widely investigated.[3] The early examples of this reaction generally were performed under an atmosphere of carbon monoxide in hexane at elevated temperatures for prolonged reaction times. Advances by Smit and Caple[4a] through the use of silica gel catalysis and by Billington and Pauson[5] involving ultrasonication have allowed for lower reaction temperatures and considerably shorter reaction times. More recently, Schreiber[6a] and then Jeong and Chung[6b] and co-workers have discovered that tertiary amine *N*-oxides effectively promote the PKCR of enynes at room temperature. A limitation of the $Co_2(CO)_8$-mediated reaction has been that electron-deficient alkenes are poor cyclization substrates.[3,4b] Also, there are very few reports on the successful cyclization of electron-deficient alkynes in the PKCR.[7-9] We have recently discovered that $W(CO)_5{\cdot}THF$ effectively cyclizes a variety of 1,6-enynes containing both electron-deficient alkenes and alkynes to generate bicyclo[3.3.0]oct-1-en-3-ones.[10] In connection with that work we have demonstrated and describe here the inter- and intramolecular $Co_2(CO)_8$-mediated cyclizations of a series of electron-deficient *alkynones* to produce bicyclic enediones.

The 1,6-enynes **1a–g** were treated with 1.1 equiv of $Co_2(CO)_8$ in acetonitrile (~0.1 M) at 75 °C for 6–12 h to produce the bicyclic enediones **2a–g** as recorded in Table I. Intermolecular reactions, pairs **1h–j**, proceeded under similar reaction conditions to produce cyclopentenones **2h–j**. The benefit of the *gem*-dialkyl substituents[11] on the efficiency of this transformation is evidenced by the poor yield for cyclization of substrate **1c** (vis-a-vis **1a**). Increased steric hindrance of the terminal alkyl group on the alkyne caused only slight decreases in yield. The presence of other functionality, such as a remote halide or ester moiety, has no deleterious effect on the cyclization (cf. **1e**/**1f** with **1d**). The vinylogous ynone **1g** is also smoothly cyclized to produce the tricyclic dienedione **2g** in good yield (62%, 2.7:1 cis/trans ratio).

Moretó and co-workers have demonstrated that alkynes conjugated to transition metal carbene species can be efficiently cyclized by dicobaltoctacarbonyl in THF at room temperature.[8] The reactions of these electron-deficient alkynes were performed without the use of additives such as phosphine oxides[3d] or amine *N*-oxides.[6] More recently, Krafft and co-workers have shown that conjugated alkynoates can be cyclized with alkenes to yield cyclopentenones by taking advantage of the mild amine oxide promoted reaction conditions.[9] Key to the success of our reactions was the choice of solvent.[3d,12] The results recorded in Table I were from experiments carried out *in acetonitrile*. Specifically, the yields of transformations of **1b** to **2b** and **1f** to **2f** were substantially lower (30–45%) and the reaction times considerably longer (2–3 days at the reflux temperature) when they were performed in ether, THF, or heptane. Acetonitrile has previously been observed to be beneficial in PKCR's.[6a]

Representative Experimental Procedure. To dicobaltoctacarbonyl (248 mg, 0.726 mmol) under a nitrogen atmosphere was added a solution of enynone **1b** (100 mg, 0.66 mmol) in ~5 mL of dry acetonitrile at room temperature. The solution was stirred for 10 min at room temperature, at which time TLC analysis indicated conversion to a less polar, purple cobalt–alkyne complex. The reaction vessel (a screw-capped culture tube) was then sealed and heated to 75 °C (external bath temperature) until TLC analysis indicated complete consumption of the purple complex (6 h). The cooled mixture was passed through a small plug of silica gel with hexane/ethyl acetate (~2:1) elution, and the filtrate was concentrated. The resulting residue was purified by MPLC on silica gel [hexane/ethyl acetate (3:1)] to give the bicyclic enedione

---

[1] University of Minnesota Graduate School Predoctoral Dissertation Fellow 1992–1993.

[2] Khand, I. U.; Knox, G. R.; Pauson, P. L.; Watts, W. E.; Foreman, M. I. *J. Chem. Soc., Perkin Trans. 1* **1973**, 977.

[3] (a) Pauson, P. L.; Khand, I. U. *Ann. N.Y. Acad. Sci.* **1977**, *295*, 2. (b) Pauson, P. L *Tetrahedron* **1985**, *41*, 5855. (c) Schore, N. E. *Chem. Rev.* **1988**, *88*, 1081. (d) Pauson, P. L. In *Organometallics in Organic Synthesis. Aspects of a Modern Interdisciplinary Field*; de Meijere, A.; tom Dieck, H. Eds.; Springer: Berlin, 1987; p 233. (e) Schore, N. E. *Org. React.* **1991**, *40*, 1. (f) Schore, N. E. In *Comprehensive Organic Synthesis*; Trost, B. M., Ed.; Pergamon: Oxford, 1991; Vol. 5, p 1037.

[4] (a) Simomian, S. O.; Smit, W. A.; Gybin, A. S.; Shashkov, A. S.; Mokaelian, G. S.; Tarasov, V. A.; Ibragimov, I. I.; Caple, R.; Froen, D. E. *Tetrahedron Lett.* **1986**, *27*, 12245. (b) For a protocol for successful cyclization of electron-deficient alkenes: Veretenov, A. L.; Smit, W. A.; Vorontsova, M. G.; Kurella, M. G.; Caple, R.; Gybin, A. S. *Tetrahedron Lett.* **1991**, *32*, 2109.

[5] Billington, D. C.; Helps, I. M.; Pauson, P. L.; Thomson, W.; Willison, D. J. *Organomet. Chem.* **1988**, *354*, 233.

[6] (a) Shambayati, S.; Crowe, W. E.; Schreiber, S. L. *Tetrahedron Lett.* **1990**, *31*, 5289. (b) Jeong, N.; Chung, Y. K.; Lee, B. Y.; Lee, S. H.; Yoo, S.-E. *Synlett* **1991**, 204.

[7] (a) Jaffer, H. J. Ph. D. Thesis, Strathclyde University, 1982. (b) Khand, I. U.; Pauson, P. L. *J. Chem. Soc., Chem. Commun.* **1974**, 379. (c) Khand, I. U.; Pauson, P. L. *Heterocycles* **1978**, *11*, 59.

[8] (a) Camps, F.; Moretó, J. M.; Ricart, S.; Viñas, J. M. *Angew. Chem., Int. Ed. Engl.* **1991**, *30*, 1470. (b) Lluch, A-M.; Jordi, L.; Sanchez-Baeza, F.; Ricart, S.; Camps, F.; Messeguer, A.; Moretó, J. M. *Tetrahedron Lett.* **1992**, *33*, 3021.

[9] (a) Krafft, M. E.; Romero, R. H.; Scott, I. L. *J. Org. Chem.* **1992**, *57*, 5277. (b) Krafft, M. E.; Romero, R. H.; Scott, I. L. Abstracts of Papers, 204th National Meeting of the American Chemical Society, Washington, DC, 1992; ORGN no. 256.

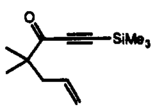
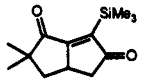
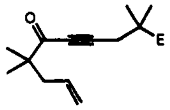
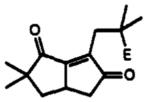
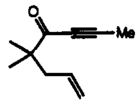
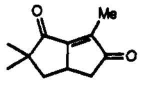
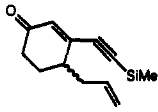
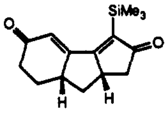
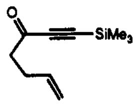
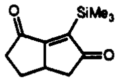
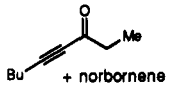
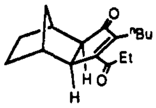
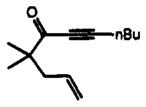
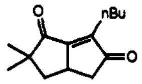
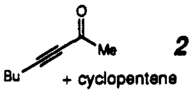
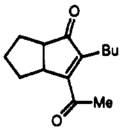
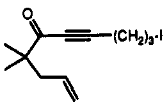
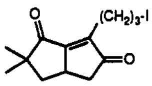
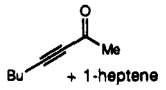
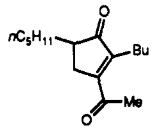
[10] (a) Hoye, T. R.; Suriano, J. A. *Organometallics* **1992**, *11*, 2044. (b) Hoye, T. R.; Suriano, J. A. *J. Am. Chem. Soc.* **1993**, *115*, 1154. (c) Hoye, T. R.; Suriano, J. A. Abstracts of Papers, 204th National Meeting of the American Chemical Society, Washington, DC, 1992; ORGN no. 214.

[11] (a) Jung, M. E. *Synlett* **1990**, 186. (b) de Tar, D. F.; Luthra, N. P. *J. Am. Chem. Soc.* **1980**, *102*, 4505.

[12] (a) Krafft, M. E.; Juliano, C. A.; Scott, I. A.; Wright, C.; McEaching, M. *J. Am. Chem. Soc.* **1991**, *113*, 1693. (b) Chung, Y. K.; Lee, B. Y.; Jeong, N.; Hudecek, M.; Pauson, P. L. *Organometallics* **1993**, *12*, 220.

0022-3263/93/1958-1659$04.00/0

Table I. Reactions[a] of Cobaltoctacarbonyl with Ynones 1 To Produce Cyclopentenones 2

ynone 1	product 2	yield,[b] %	ynone 1	product 2	yield,[b] %
1a 	**2a** 	82	**1f** 	**2f** 	68
1b 	**2b** 	91	**1g** 	**2g** 	62[c]
1c 	**2c** 	32	**1h** 	**2h** 	75
1d 	**2d** 	74	**1i** 	**2i** 	43
1e 	**2e** 	66	**1j** 	**2j** 	32

[a] Reactions were performed according to the representative procedure in the text with varying reaction times (6–12 h). [b] Yields stated are of materials purified by MPLC on SiO_2 and have not been optimized. [c] Major diastereomer shown (2.7:1 cis/trans as determined by ^1H NMR and capillary GC analysis).

2b as a slightly yellow oil in 91% yield.

Acknowledgment. This investigation was supported by grant GM-38854 awarded by the DHHS. We thank Professors Marie E. Krafft and Neil E. Schore and Dr. Christopher J. Dinsmore for providing relevant information prior to publication.

Supplementary Material Available: Representative experimental procedures for starting enynes (**1f** and **g**) and characterization data for all new compounds (6 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.