vanadium(II) reagent, **1**, with the intent that any ketyl generated upon reaction with one vanadium(II) center might be rapidly reduced by the second vanadium(II) leading to an organometallic intermediate.[12] Controlled coupling by insertion of a second carbonyl might then be possible (see Scheme I, path C). Reagent **1** is readily prepared from $VCl_3(THF)_3$[13] and zinc dust (95%, >100 g).[9] More importantly, this reagent may also be generated and used in situ.[14]

We began our studies with a general survey of pinacol coupling reactions.[15] Reagent **1** couples aryl aldehydes in high yield (>90%) and with *high diastereoselectivity* (i.e., 12:1-100:1; *d,l*:meso). However, non-aryl aldehydes such as isobutyraldehyde do not couple at an appreciable rate (13% after 12 h). Aryl as well as dialkyl ketones give little or no coupling products under the same conditions. An important observation made during these initial studies was that 2-methoxybenzaldehyde couples much more rapidly (<2 h; >90%) than 4-methoxybenzaldehyde (>24 h; >90%). This dramatic difference in the rate of coupling is best ascribed to the ability of 2-methoxybenzaldehyde to form a chelate with a vanadium(II) center.[16]

The above experiments suggested that the rate of coupling for non-aryl aldehydes might be accelerated if they contained an appropriately placed chelating group. This was found to be true for several functionalized aldehydes, in particular, compounds capable of forming stable six- and seven-membered chelate rings with a vanadium center (such aldehydes will be referred to as chelation-accelerated aldehydes or CA aldehydes).[17]

It was apparent that intermolecular cross coupling might be possible if a CA aldehyde was slowly added to a solution of **1** and 1 equiv of a less reactive aldehyde assuming that either pathway B or C (Scheme I) were operative. We began our investigations with a variety of 3-formylpropanamides.[18] As indicated in Table I such reactions do provide 1,2-diols in good-to-excellent yields. The major diastereomer in all of the cross coupling reactions is a threo diol and the threo:erythro ratio increases as α-branching in either aldehyde increases (entries 2, 3, 6, and 8). The origin of the threo selectivity can be rationalized by invoking either a ketyl radical or organometallic intermediate. In both cases, the less reactive aldehyde would bind to the metal and prefer to orient its substituent away from the chelate ring formed from the CA aldehyde.

When a 3-formyl-*N,N*-dialkylbutanamide is employed, only two major products are obtained after workup: a threo and an erythro diol (entries 5 and 6). The relative configuration between the 3-methyl and 4-hydroxy groups is "anti" in both diastereomers. In one case (entry 5), a third diastereomer has been detected in trace quantities and shown to be the "syn" threo diol (anti:syn = 35:1). Beginning with a 3-formyl-2-methylpropanamide the minor threo isomer becomes more prominent (major:minor = 12:1; entry 7). Attempts to improve the diastereoselectivity of these reactions by going to lower temperature (-30 °C) have proven unsuccesful due to a preponderance of CA aldehyde homo coupling. A detailed explanation for the observed face selectivity in the above set of CA aldehydes will ultimately depend on the intermediate(s) involved. However, from the standpoint of predicting the stereochemical outcome of these reactions, one can conclude that the less reactive aldehyde reacts with the least hindered face of a vanadium bound CA aldehyde. Studies aimed at elucidating the reactive intermediates involved in these reactions are underway.

Being that **1** is one of the few, *well-characterized*, and homogeneous low-valent metal halides available in large quantities, we anticipate many further applications of this reagent within the general realm of cross coupling reactions. Furthermore, this vanadium(II) reagent is clearly a mild reducing agent, a feature which will provide the opportunity for coupling highly functionalized substrates.

Acknowledgment. S.F.P. is grateful to the National Institutes of Health (GM38735), the National Science Foundation for a Presidential Young Investigator Award (Grant No. CHE-8552735), and Eli Lilly and Company for financial support. J.H.F. thanks the Miller Institute of U.C. Berkeley for a Postdoctoral Fellowship.

Supplementary Material Available: NMR, IR, and mass spectral data and C, H, and N analysis information and stereochemical assignments for diols and a detailed experimental procedure for the synthesis of 1,2-diols via pinacol cross coupling (9 pages). Ordering information is given on any current masthead page.

(11) See ref 6d and Clerici, A.; Porta, O.; Riva, M. *Tetrahedron Lett.* **1981**, *22*, 1043.

(12) For examples of early transition-metal aldehyde or ketone complexes (metallaoxiranes), see: (a) Waymouth, R. M.; Grubbs, R. H. *Organometallics* **1988**, *7*, 1631. (b) Bryan, J. C.; Mayer, J. M. *J. Am. Chem. Soc.* **1987**, *109*, 7213. (c) Erker, G.; Czisch, P.; Schlund, R.; Angermund, K.; Kruger, C. *Angew. Chem.* **1986**, *98*, 356. (d) Erker, G.; Dorf, U.; Czisch, P.; Petersen, J. L. *Organometallics* **1986**, *5*, 668. (e) Waymouth, R. M.; Clauser, K. R.; Grubbs, R. H. *J. Am. Chem. Soc.* **1986**, *108*, 6385. (f) Martin, B. D.; Matchett, S. A.; Norton, J. R.; Anderson, O. P. *Ibid.* **1985**, *107*, 7952. (g) Kropp, K.; Skibbe, V.; Erker, G. *Ibid.* **1983**, *105*, 3353. (h) Erker, G.; Kropp, K.; Kruger, C.; Chiang, A.-P. *Chem. Ber.* **1982**, *115*, 2447. (i) Erker, G.; Rosenfeldt, F. *J. Organomet. Chem.* **1982**, *224*, 29. (j) Wood, C. D.; Schrock, R. R. *J. Am. Chem. Soc.* **1979**, *101*, 5421.

(13) Manzer, L. E. *Inorg. Synth.* **1982**, *21*, 135.

(14) In situ generation of **1** entails dissolving $VCl_3(THF)_3$ in dichloromethane (ca. 0.5 M) and adding 0.6 equiv of zinc dust (20% excess). The reagent is ready for use when the solution color changes from red to green (ca. 15 min). No filtration is necessary.

(15) To our knowledge this reagent has not been previously used in organic synthesis.

(16) Aldehydes and ketones capable of forming chelates with early metals often exhibit accelerated rates of alkylation: (a) Reetz, M. T.; Maus, S. *Tetrahedron* **1987**, *43*, 101. (b) Reetz, M. T. *Top. Curr. Chem.* **1982**, *106*, 1. Chelation also appears to be necessary in the deoxygenation of α-oxygenated esters by SmI_2/HMPA. (c) Kusuda, K.; Inanaga, J.; Yamaguchi, M. *Tetrahedron Lett.* **1989**, *30*, 2945.

(17) Functionalized aldehydes capable of forming a five-membered chelate ring with a vanadium center in some cases also exhibit accelerated coupling. However, in these cases the inductive effect of the α-heteroatom undoubtedly contributes to increased reactivity, and the separation of these factors in these cross coupling reactions has not yet been investigated.

(18) These were one of our better class of substrates in the homocoupling experiments. However, other types of CA aldehydes are effective in this general reaction. Details will be reported in the future.

Magnesium Amide Bases and Amido-Grignards. 1. Ortho Magnesiation

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Received April 17, 1989

Hauser bases (R_2NMgBr) and magnesium diamides [$(R_2N)_2Mg$] are known,[1,2] but their uses in organic synthesis have barely been explored.[3,4] With this communication we introduce the first of our work with these bases and demonstrate their exceptional utility and bright future.

Ortho lithiation of substituted aromatics has been developed elegantly into one of the major tools of organic synthesis.[5] It

(1) (a) Hauser, C. R.; Walker, H. G. *J. Am. Chem. Soc.* **1947**, *69*, 295. (b) Hauser, C. R.; Frostick, F. C. *Ibid.* **1949**, *71*, 1350.

(2) (a) Ashby, E. C.; Lin, J. J.; Goel, A. B. *J. Org. Chem.* **1978**, *43*, 1564. (b) Ashby, E. C.; Goel, A. B. *J. Inorg. Chem.* **1978**, *17*, 1862. (c) Ashby, E. C.; Willard, G. F. *J. Org. Chem.* **1978**, *43*, 4750.

(3) (a) Stille, J. K.; Scott, W. J.; Crisp, G. T. *J. Am. Chem. Soc.* **1984**, *106*, 7500. (b) Stille, J. K.; Scott, W. J. *Ibid.* **1986**, *108*, 3033. (c) Holton, R. A.; Krafft, M. E. *Tetrahedron Lett.* **1983**, *24*, 1345. (d) Solladie, G.; Mioskowski, C. *Ibid.* **1975**, 3341. (e) Adams, R.; Blatt, A. H.; Boekelheide, V.; Cairns, T. L.; House, H. O.; Cram, D. J. *Org. React. (N.Y.)* **1968**, *16*, 1. (f) Corey, E. J.; Marfat, A.; Falck, J. R.; Albright, J. O. *J. Am. Chem. Soc.* **1980**, *102*, 1433.

(4) (a) Sanchez, R.; Scott, W. *Tetrahedron Lett.* **1988**, *29*, 139. (b) Rathman, T. L. Chemspec USA '88 Symposium, Boston, MA, Sept, 1988.

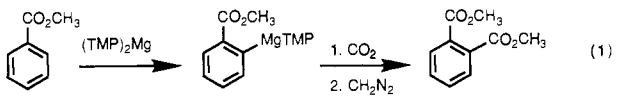
0002-7863/89/1511-8016$01.50/0

has been extended to include lithiation of activated vinyl,[6] allylic,[7] and strained "saturated" systems,[8] amongst others, and its utility broadened by the introduction of transmetalation processes in which other metals, e.g., mercury,[9] magnesium,[10] and zinc,[11] can be substituted for lithium after the initial lithiation step. To our knowledge, it has always been assumed that the initial metalation depended crucially, if not exactly explicably, on the properties of lithium. To the contrary, as we show here, direct "ortho magnesiation" can be accomplished readily.

2,2,6,6-Tetramethylpiperidine (TMPH) on reaction in refluxing tetrahydrofuran with 1 equiv of ethylmagnesium bromide (Aldrich, 3.0 M in diethyl ether) or with 0.5 equiv of dibutylmagnesium (Alfa, 0.9 M in heptane) gave, respectively, clear solutions of 2,2,6,6-tetramethylpiperidinomagnesium bromide, TMPMgBr, or bis(2,2,6,6-tetramethylpiperidino)magnesium, $(TMP)_2Mg$.[12] For our purposes we prepared half-molar solutions. The reactions were complete within a few hours, as judged by the complete lack of propanoic acid or pentanoic acid in aliquots quenched with carbon dioxide followed by aqueous acid. Solutions of the corresponding diisopropylamine (DAH) derivatives, DAMgBr and $(DA)_2Mg$,[4] were obtained similarly. Diisopropylamido- and tetramethylpiperidinomagnesium amide bases so prepared *are stable in refluxing tetrahydrofuran for hours and, in this way, differ markedly from the corresponding lithium amides* which rapidly decompose at this temperature. (LiTMP is unstable above 0 °C in THF.[11]) The ability to employ these magnesium amide bases in refluxing THF is important, particularly in reactions with materials of otherwise low solubility or low reactivity.

Reaction of *N,N*-diethylbenzamide at room temperature for several hours in THF with an excess[13] of either $(TMP)_2Mg$ or $(DA)_2Mg$ followed by quenching with carbon dioxide, acidification, and diazomethane esterification gave *o*-carbomethoxy-*N,N*-diethylbenzamide in 90% isolated yield. DAMgBr and TMPMgBr were also effective but required higher temperature (reflux) to obtain reasonable rates. Qualitatively at least, the reactions of TMPMgBr proceeded similarly whether or not this reagent was prepared as just described or from reaction of LiTMP with 1 equiv of magnesium bromide. $(TMP)_2Mg$ obtained from "lithium-free" dibutylmagnesium derived[14] from 99.99% magnesium chips behaved like that prepared from the reaction of LiTMP with 0.5 equiv of $MgBr_2$. There were no obvious differences traceable to the presence or absence of lithium ions. Thus, the metalation reactions are taken to commence with ortho magnesiation rather than (trace) ortho lithiation followed by transmetalation.

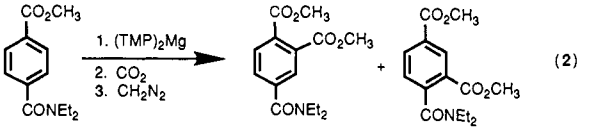
In classic ortho lithiation reactions, esters are not usually suitable substrates as the ester group is too labile to nucleophilic attack.[15] We find that esters are similarly sensitive in ortho magnesiations conducted with TMPMgBr. Probably, the intermediate magnesiated species, most easily formulated as the Grignard R′MgBr, condenses with the ester group in standard fashion. On the other hand, we find that even methyl and ethyl esters are quite appropriate substrates in ortho magnesiations using $(TMP)_2Mg$. For example, reaction of methyl benzoate for 45 min with excess $(TMP)_2Mg$ in THF at room temperature followed by quenching with carbon dioxide, acidification, and esterification gave dimethyl *o*-phthalate in 81% isolated yield (eq 1). Ap-



(1)

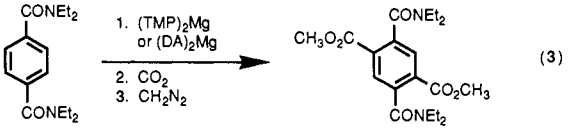
parently, the intermediate organometallic, formulated (without regard to aggregation or complexation) as R′MgTMP, is not very reactive; an ester group can coexist with it for some time. We call such $R'MgNR_2$ species "amido-Grignards". The amine substituent moderates the Grignard reactivity of such compounds by decreasing nucleophilicity and/or lessening ability to complex with substrate. Electronic and/or steric reasons can be invoked. We are undertaking a complete study of this class of Grignard reagents and the applications of such amido-Grignards in synthesis.[16]

We have not yet studied the relative ability of various functional groups to activate for ortho magnesiation, but it is already clear that ester activation is superior to amide activation. Reaction of *p*-carbomethoxy-*N,N*-diethylbenzamide with $(TMP)_2Mg$ followed by carboxylation and esterification gave primarily (3:1) reaction ortho to the carbomethoxy group rather than ortho to the amide group (eq 2).[17] The use of esters rather than amides as activating groups in ortho metalation eases the frustrating problem of how to convert an amide, subsequent to its use as an activator, to a group more amenable to transformation.



(2)

Ortho lithiation twice over on a doubly activated aromatic ring has not been achieved without resorting to halogen–metal exchange reactions[18] or reverse transmetalation processes.[9] Presumably, the change of one C–H bond to a very polar C–Li bond deactivates the remaining C–H bonds toward lithiation. Carbon–magnesium bonds are not as polarized. Indeed, reaction of *N,N*-diethyl terephthalamide with excess $(TMP)_2Mg$ in refluxing THF for 2 h resulted in double substitution and, after carboxylation and esterification, the pyromellitic acid derivative in 87% isolated yield (eq 3). When we started with the diester dimethylterephthalate



(3)

(5) For reviews, see: (a) Gschwend, H. W.; Rodriguez, H. R. *Org. React. (N.Y.)* **1979**, *26*, 1. (b) Snieckus, V. *Heterocycles* **1980**, *14*, 1649. (c) Beak, P.; Snieckus, V. *Acc. Chem. Res.* **1982**, *15*, 306. (d) Narasimhan, N. S.; Mali, R. S. *Synthesis* **1983**, 957. (e) Beak, P.; Meyers, A. I. *Acc. Chem. Res.* **1986**, *19*, 356.

(6) For example: (a) McDougal, P. G.; Rico, J. G. *Tetrahedron Lett.* **1984**, *25*, 5977. (b) Beak, P.; Kempf, D. J.; Wilson, K. D. *J. Am. Chem. Soc.* **1985**, *107*, 4745.

(7) Beak, P.; Hunter, J. E.; Jun, Y. M.; Wallin, A. P. *J. Am. Chem. Soc.* **1987**, *109*, 5403.

(8) (a) Eaton, P. E.; Castaldi, G. *J. Am. Chem. Soc.* **1985**, *107*, 724. (b) Eaton, P. E.; Daniels, R. G.; Casucci, D.; Cunkel, G. T. *J. Org. Chem.* **1987**, *52*, 2100.

(9) Eaton, P. E.; Martin, R. M. *J. Org. Chem.* **1988**, *53*, 2728.

(10) For example: (a) Seebach, D.; Hassel, T. *Angew. Chem., Int. Ed. Engl.* **1979**, *31*, 391. (b) Courtoid, G.; Miginiac, L. *J. Organomet. Chem.* **1974**, *69*, 1. (c) Seebach, D.; Geiss, K.-H. *J. Organomet. Chem. Library 1*, **1976**, 1. (d) Seebach, D.; Geiss, K.-H. *Angew. Chem., Int. Ed. Engl.* **1976**, *88*, 449. (e) Sibi, M. P.; Chattopashyay, J. W.; Dankwardt, J. W.; Snieckus, V. *J. Am. Chem. Soc.* **1985**, *107*, 6312.

(11) Eaton, P. E.; Higuchi, H.; Millikan, R. *Tetrahedron Lett.* **1987**, *28*, 1055.

(12) For the present, these structures are given on the assumption of metathesis reactions. No consideration of complexation, aggregation, or other complication is included.

(13) We usually used a 6-fold excess for completeness, but this is probably at least twice what is needed for excellent conversions. The equilibrium constant for anion formation from *N,N*-diisopropylbenzamide and $(DA)_2Mg$ is approximately 3. Optimization studies are underway.

(14) Strohmeier, W.; Seifert, F. *Chem. Ber.* **1961**, *94*, 2356.

(15) See, for example: Beak, P.; Upton, C. J. *J. Org. Chem.* **1975**, *40*, 1094.

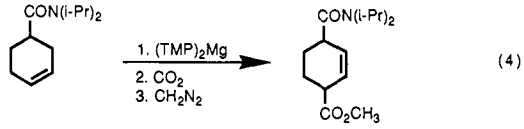
(16) For earlier relevant work, see: (a) Mosset, P.; Manna, S.; Viala, J.; Falck, J. R. *Tetrahedron Lett.* **1986**, *27*, 299. (b) Moustakis, C. A.; Weerasinghe, D. K.; Mosset, P.; Falck, J. R. *Tetrahedron Lett.* **1986**, *27*, 303. (c) We suspect in addition that at least some of the reactions previously reported for reagents composed of mixtures of ordinary Grignards and lithium amides are in fact reactions of amido-Grignards and do not depend on the presence of lithium ion. See, for possibilities: (a) Fehr, C.; Galindo, J. *Helv. Chim. Acta* **1986**, *69*, 228. (b) Fehr, C.; Galindo, J.; Perret, R. *Ibid.* **1987**, *70*, 1745. (c) Sternbach, D. D.; Rossana, D. M.; Onan, K. D. *J. Org. Chem.* **1984**, *49*, 3427. (d) Fehr, C.; Galindo, J. *J. Am. Chem. Soc.* **1988**, *110*, 6909. Commercial LDA (Lithium Corporation of America) is stabilized with $(DA)_2Mg$. Some of the reactions of this LDA may instead be reactions of $(DA)_2Mg$.

(17) The use of $(DA)_2Mg$ leads to conversion of the ester to the corresponding diisopropylamide. This reaction, usually a nuisance, can be suppressed entirely by using $(TMP)_2Mg$, whose amine component is too bulky to be an effective amidation reagent.

(18) Snieckus, V.; Mills, R. J.; Horvath, R. F.; Sibi, M. P. *Tetrahedron Lett.* **1985**, *26*, 1145.

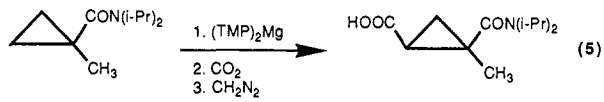
rather than the terephthalamide, we could even obtain some tetramethylpyromellitate (25%). However, in boiling THF some condensation between ester and intermediate amido-Grignard does occur, and this limits the yield of monomeric product.[19]

Ortho magnesiation is not restricted to aromatic systems. Similar to Beak's demonstration of remote lithiation,[7] we found that reaction of (*N*,*N*-diisopropylcarboxamido)cyclohex-3-ene with $(TMP)_2Mg$ gave, after carboxylation and esterification, the 4-carbomethoxy-2-ene in good yield (eq 4).



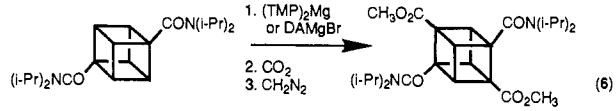
(4)

Following upon our earlier discoveries that ortho lithiation of amide-activated strained systems which have s-rich, acidity-enhanced C–H bonds,[8] we examined the behavior of cubane and cyclopropane derivatives toward amidomagnesium bases. This has been very successful. Reaction of 1-methyl-(*N*,*N*-diisopropylcarboxamido)cyclopropane with excess $(TMP)_2Mg$ followed by carboxylation and esterification gave the *cis*-2-carbomethoxy derivative in 85% yield, free of trans isomer (eq 5). Similar treatment of (*N*,*N*-diisopropylcarboxamido)cyclopropane, in which there is an acidic hydrogen α to the carbonyl group, gave both α- and β-carboxylation and some bis-carboxylation as well.



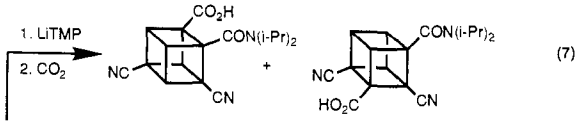
(5)

The cubane system behaves very well under magnesiation conditions. Reaction of 1,4-bis(*N*,*N*-diisopropylcarboxamido)-cubane with excess $(TMP)_2Mg$ in refluxing THF, followed by carboxylation and esterification, gave directly the 1,4-diamide-2,7-diester derivative in better than 80% isolated yield (eq 6). DAMgBr worked as well in refluxing THF; at room temperature its reaction was controlled easily to give just monometalation and thus monocarboxylation.

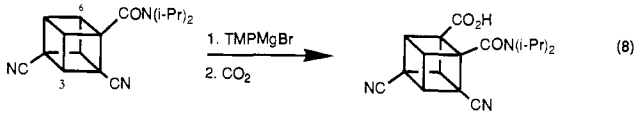


(6)

Ortho magnesiation and ortho lithiation reactions can complement one another neatly. Thus, for example, reaction of 2,4-dicyano-(*N*,*N*-diisopropylcarboxamido)cubane with excess LiTMP gave, after carboxylation, a 1:1 mixture of the corresponding 3- and 6-carboxy derivatives as shown in eq 7. Obviously, the cyano groups together activate the doubly-ortho C–H groups toward lithiation about as well as one amide group activates its ortho C–H groups. On the other hand, reaction with TMPMgBr and carboxylation gave only the 6-carboxy derivative (eq 8).



(7)



(8)

We are continuing our investigation of magnesium amide bases and will report soon on their structures and their utility for metalation in a variety of circumstances, on the uses of polymer bound magnesium amides, on optical induction from magnesium amides derived from chiral amines, etc. Similarly, we are expanding our work on amido-Grignard reagents.

(19) This establishes that amido-Grignards under correct conditions are sufficiently nucleophilic to react with esters.

Acknowledgment. We thank the National Institutes of Health (GM-36436), the Office of Naval Research, and the Technology Commercialization Center at The University of Chicago for support of this work. The National Science Foundation and the NIH, the latter through the University of Chicago Cancer Center (CA 14599), contributed significantly to the departmental instrument facility.

Registry No. $(TMP)_2Mg$, 117973-78-1; $(DA)_2Mg$, 23293-23-4; DAMgBr, 50715-01-0; TMPMgBr, 122357-95-3; TMP, 768-66-1; LiTMP, 38227-87-1; EtMgBr, 925-90-6; $PhCO_2Me$, 93-58-3; *p*-$MeO_2CC_6H_4CONEt_2$, 122357-96-4; *o*-$MeO_2CC_6H_4CO_2Me$, 131-11-3; 3,4-$(MeO_2C)_2C_6H_3CONEt_2$, 122357-99-7; 2,4-$(MeO_2C)_2C_6H_3CONEt_2$, 122382-43-8; dibutylmagnesium, 1191-47-5; diisopropylamine, 108-18-9; dimethyl terephthalate, 120-61-6; (*N*,*N*-diisopropylcarboxamido)cyclohex-3-ene, 87115-25-1; 1-methyl-1-(*N*,*N*-diisopropylcarboamido)cyclopropane, 106711-45-9; 1,4-bis-(*N*,*N*-diisopropylcarboxamido)cubane, 94161-36-1; 2,4-dicyano-1-(*N*,*N*-diisopropylcarboxamido)cubane, 122357-97-5; *N*,*N*-diethylbenzamide, 1696-17-9; *N*,*N*-diethylterephthalamide, 15394-30-6; 3,6-dicarboxy-*N*,*N*-diethylterephthalamide, 21761-77-3; 3,6-dicarbomethoxy-*N*,*N*-diethylterephthalamide, 122357-98-6; tetramethylpyromellitate, 635-10-9; 4-carbomethoxy-1-(*N*,*N*-diisopropylcarboxamido)cyclohex-2-ene, 122382-44-9; *cis*-2-carboxy-1-methyl-1-(*N*,*N*-diisopropylcarboxamido)cyclopropane, 122358-00-3; 2,7-dicarboxy-1,4-bis(*N*,*N*-diisopropylcarboxamido)cubane, 106711-44-8; 6-carboxy-2,4-dicyano-1-(*N*,*N*-diisopropylcarboxamido)cubane, 122358-01-4; 3-carboxy-2,4-dicyano-1-(*N*,*N*-diisopropylcarboxamido)cubane, 122358-02-5; 2,7-dicarbomethoxy-1,4-bis(*N*,*N*-diisopropylcarboxamido)cubane, 122358-03-6; *o*-carboxy-*N*,*N*-diethylbenzamide, 4166-52-3; *o*-carbomethoxy-*N*,*N*-diethylbenzamide, 26593-44-2; *o*-carboxymethylbenzoate, 4376-18-5.

Supplementary Material Available: Representative experimental procedures and spectral data (^1H NMR, ^{13}C NMR) (3 pages). Ordering information is given on any current masthead page.

Carbonylative Cyclization via Intramolecular Trapping of Acylmetal Derivatives by Carbon Nucleophiles Catalyzed by Late Transition Metals[1]

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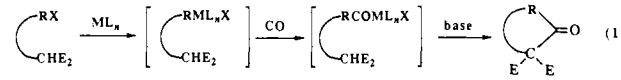
Received June 5, 1989

We wish to report a potentially general carbonylative cyclization methodology involving the use of catalytic amounts of late transition-metal complexes, in particular those of Cu, Ni, and Pd. The generalized scheme for the method is shown in eq 1.



(1)

E = anion-stabilizing C and/or S groups; R = C group; X = halogen, e.g., I; ML_n = late transition metal complex.

Specifically, the dimethyl and diethyl esters of *o*-iodobenzylmalonic acids (**1a** and **1b**, respectively) were chosen as test substrates, and the feasibility of their carboxylative cyclization was examined, by using CO (600 psi), NEt_3 (1.0–2.0 equiv), and catalytic amounts of late transition-metal complexes containing Fe, Co, Ni, Cu, Ru, Rh, and Pd at the reaction temperature of 90–100 °C. As indicated by the results summarized in Table I, Li_2CuCl_4, $NiBr_2$, $NiBr_2$ treated in situ with *n*-BuLi (2 equiv) in the presence of 2 equiv of cyclooctadiene (COD), $Pd(PPh_3)_4$, and $Cl_2Pd(PPh_3)_2$ induced the desired carbonylative cyclization of **1** to produce **2** in high yields. Under comparable conditions, the use of $CpCo(CO)_2$ led only to a 40% yield of **2**, and the reactions

(1) Metal-Promoted Cyclization. 29. Part 28. Swanson, D. R.; Rousset, C. J.; Negishi, E.; Takahashi, T.; Seki, T.; Saburi, M.; Uchida, Y. *J. Org. Chem.* **1989**, *54*, 3521.

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