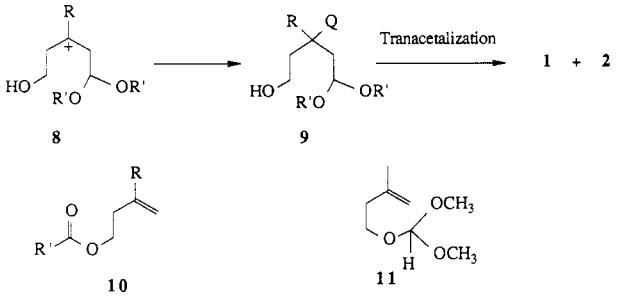
Scheme III



by control experiments in which the bismethoxy pyranosides (3 and its diastereomer) were individually resubjected to the reaction conditions; no isomerization or elimination of the tertiary ethers was observed.[13]

To rationalize the predominant product of one isomer when Sn(IV) is used and the absence of elimination products, we suggest that these cyclizations are preferentially occurring via the transition state A in which the dioxenium cation and the terminating group approach the olefin in a trans antiperiplanar fashion and in which the alkoxy group has adopted an axial orientation, thus maximizing any benefit derived from an "anomeric effect".[14] This mechanism presupposes that the reaction products are produced kinetically. When pure **1** or **2** (Q = Cl; R, R′ = CH_3) were resubjected to the reaction conditions, no equilibration to the opposite diastereomer occurred, supporting the idea that the reaction is kinetically controlled.

An alternate mechanism involving initial "Prins-like" addition of the dioxenium cation to the olefin to give 8 followed by transacetalization is possible (Scheme III). We have never detected intermediates such as **9**. However, in certain cases we have isolated esters of general structure **10**, presumably arising by hydration of the intermediate cation 6 upon workup. In addition, we have synthesized the presumed intermediate mixed ortho ester **11**[15] and found that cyclization to **1** (Q = Cl; R,R′ = CH_3) occurs when **11** is treated with $SnCl_4/CHCl_2$ at −20 °C. These data support the mechanism shown in Scheme II.

This methodology opens up possibilities for the construction of a variety of oxygenated heterocycles. Further investigation of this process and its application to natural product synthesis are currently in progress.

Acknowledgment is made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, for partial support of this research. F.P. thanks the Toyota Corporation for a graduate fellowship.

Registry No. 1 (R = R^1 = Me, Q = Cl), 109553-12-0; 1 (R = Me, R^1 = Et, Q = Br), 109553-13-1; 1 (R = R^1 = Me, Q = NHAc), 109553-14-2; 1 (R = OMe, R^1 = Q = Me), 109553-15-3; 1 (R = H, R^1 = Me, Q = Cl), 6559-36-0; 2 (R = R^1 = Me, Q = Cl), 109553-16-4; 2 (R = Me, R^1 = Et, Q = Br), 109553-17-5; 2 (R = OMe, R^1 = Q = Me), 109553-18-6; 11, 109553-19-7; CH_2=C(Me)$(CH_2)_2$OH, 763-32-6; CH_2=C(SPh)$(CH_2)_2$OH, 109553-20-0; CH_2=CH$(CH_2)_2$OH, 627-27-0; $CH(OMe)_3$, 149-73-5; $CH(OEt)_3$, 122-51-0; $^+CH(OMe)_2$, 23012-07-9; $^+CH(OEt)_2$, 44612-00-2; $SnCl_4$, 7646-78-8; $SnBr_4$, 7789-67-5; $ZnBr_2$, 7699-45-8; 4-chloro-2-methoxy-4-(phenylthio)tetrahydropyran, 109553-21-1; 2,4-dimethoxy-4-(phenylthio)tetrahydropyran, 109553-22-2; 3,6-dihydro-2 methoxy-4-methyl-2*H*-pyran, 31080-83-8.

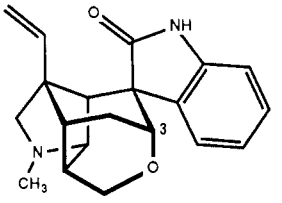
(13) We are grateful to a referee for suggesting these experiments.
(14) Although generally considered a ground-state phenomenon, the anomeric effect might be manifested in a reaction involving a late transition state (in this case a kinetic effect), such as one involving a highly stabilized cation. Deslongchamps, P. *Stereoelectronic Effects in Organic Chemistry*; Pergamon Press: New York, 1983.
(15) We have found that these mixed ortho esters can be synthesized in high yields by treating an alcohol in CH_2Cl_2 with an excess of trimethyl orthoformate using $MgCl_2$ to facilitate the exchange. These results will be described elsewhere.

Francoise Perron, Kim F. Albizati*
Department of Chemistry
Wayne State University
Detroit, Michigan 48202
Received March 16, 1987

Intramolecular Alkene Arylations for Rapid Assembly of Polycyclic Systems Containing Quaternary Centers. A New Synthesis of Spirooxindoles and Other Fused and Bridged Ring Systems

Summary: The preparation of a variety of tricyclic ring systems by palladium-catalyzed cyclizations of unsaturated aryl halides is described. These examples demonstrate (a) the ease with which quaternary centers can be formed by intramolecular Heck arylations, (b) that intramolecularity can overcome the usual reluctance of highly substituted alkenes to participate in palladium-catalyzed reactions, and (c) that the addition of silver salts dramatically reduces double-bond isomerizations of the cyclization products.

Sir: The palladium-catalyzed arylation of alkenes (Heck arylation) is a powerful method for the preparation of functionalized aromatics.[2] Intramolecular versions of this reaction have received some attention,[2] particularly in the area of heterocyclic synthesis,[3] since the pioneering early investigations by the Ban[4] and Heck[5] groups. As part of our ongoing studies pertaining to the total synthesis of the complex hexacyclic alkaloid gelsemine (1),[6] we recently



1

examined the use of intramolecular Heck arylations for the synthesis of 3-spiro-2-oxindoles.[7] These investigations have demonstrated the power of this reaction to solve formidable synthetic problems such as the elaboration of quaternary carbon centers, aspects of this chemistry not

(1) NIH NRSA Postdoctoral Fellow (GM-11332), 1986-1987.
(2) Heck, R. F. *Org. React. (N.Y.)* **1982**, *27*, 345.
(3) Recent publications, not reviewed in ref 2, include: (a) Odle, R.; Blevins, B.; Ratcliff, M.; Hegedus, L. S. *J. Org. Chem.* **1980**, *45*, 2709. (b) Iida, H.; Yuasa, Y.; Kibayashi, C. *J. Org. Chem.* **1980**, *45*, 2938. (c) Kasahara, A.; Izumi, T.; Murakami, S.; Yanai, H.; Takatori, M. *Bull. Chem. Soc. Jpn.* **1986**, *59*, 927. (d) Negishi, E.-I.; Tour, J. M. *J. Am. Chem. Soc.* **1985**, *107*, 8289.
(4) Mori, M.; Chiba, K.; Ban, Y. *Tetrahedron Lett.* **1977**, 1037.
(5) Terpko, M. O.; Heck, R. F. *J. Am. Chem. Soc.* **1979**, *101*, 5281.
(6) (a) Oh, T.; Overman, L. E. *Abstracts of Papers*, 193rd National Meeting of the American Chemical Society, Denver, CO, April, 1987; American Chemical Society: Washington, DC; Abstract ORGN 135. (b) See also; Joule, J. A. In *Indoles Part Four. The Monoterpene Indole Alkaloids*; Saxton, J. E., Ed.; John Wiley: New York, 1983; Chapter 5, pp 239-243.
(7) For a recent report of the synthesis of saturated 3-spiro-2-oxindoles by radical cyclization, see: Jones, K.; Thompson, M.; Wright, C. *J. Chem. Soc., Chem. Commun.* **1986**, 115. Leading citations to other syntheses of 3-spiro-2-oxindoles can be found in ref 3 of this paper.

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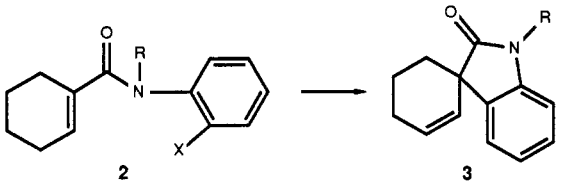
revealed by earlier studies.[2-5] We are prompted to report our investigations in preliminary form at this time as a result of the recent publication from Grigg's[8] laboratory on related palladium-catalyzed enamide cyclizations.

Our current gelsemine route requires the elaboration of a spirooxindole onto a tricyclic precursor in such a way that carbon-3 is left functionalized for subsequent closure of the tetrahydropyran ring. As a result, we examined initially the cyclization of several *N*-(2-bromophenyl)cyclohexenecarboxamides, see eq 1. Although the secondary



(eq 1)

2 **3**

a R=H **b** R=CH_3 **c** R=CH_2Ph **d** R=$CH_2OCH_2CH_2SiMe_3$

anilide **2a** could not be cyclized in satisfactory yield, treatment of the tertiary anilide **2b** (X = Br) with 3 mol% of $Pd(OAc)_2$, 12 mol% of Ph_3P, and 2 equiv of Et_3N in refluxing acetonitrile for 36 h provided cleanly the desired 3-spiro-2-oxindole **3b**,[9-11] as a colorless oil, in 85% yield. This conversion was considerably slower, and the yield of **3b** lower, if tri-*o*-tolylphosphine or tri-*p*-tolylphosphine was substituted for Ph_3P. Bromoanilides containing easily removed *N*-benzyl- or *N*-(2-(trimethylsilyl)ethoxy)methyl substituents were cyclized in a similar fashion[10] to provide **3c**[9] and **3d**[9] in yields of 68% and 70%, respectively. Spirooxindole **3c** could be prepared also with equal efficiency by using 2–3 mol % of $Pd(Ph_3P)_4$ as the catalyst. In all cases no trace was seen of products arising from cyclization to the β-carbon of vinyl amide **2**, which stands in marked contrast to bimolecular reactions of this type which typically occur at the least substituted alkene terminus.[2]

Cyclization of the aryl iodide **2b** (X = I) proceeded more rapidly than that of the corresponding bromide with less $Pd(OAc)_2$ catalyst (1 mol %, 3 h) but produced a 1:1 mixture of **3b** and its double-bond regioisomer.[12,13] Since alkene isomerization undoubtedly arises from readdition–elimination of Pd–H species,[2] we investigated the addition of agents known to trap hydrohalic acids.[14] These preliminary studies showed that silver carbonate or silver nitrate in the presence of Et_3N were the additives of choice. Thus, cyclization of **2b** (X = I) at *room temperature* in acetonitrile in the presence of 1 mol % of $Pd(OAc)_2$, 3 mol % of Ph_3P, 1 equiv of $AgNO_3$, and 2 equiv of Et_3N was complete after *3 h* and afforded a *26:1* mixture of **3b** and its alkene regioisomer in 70% yield. To our knowledge this represents the first report of the use of silver salts to suppress alkene isomerization in Heck arylations, although Hallberg[15] and co-workers have previously observed that added $AgNO_3$ suppresses desilylation and enhances the rate of palladium-catalyzed arylations of vinyl- and allylsilanes.

The scope of this new synthesis of 3-spiro-2-oxindoles is illustrated further by the conversions summarized in entries 1–5 of Table I.[9,10] Since increasing double-bond substitution dramatically reduces the yield of bimolecular palladium-catalyzed alkene arylations,[2] the success of the intramolecular cyclization with a substrate containing a tetrasubstituted double bond (entry 3) is striking. To our knowledge, this is the *first* example of palladium-catalyzed alkenylation of any organic halide with a tetrasubstituted alkene. The mixtures of stereoisomeric cyclohexenylspirooxindole products obtained in the conversions summarized in entries 1 and 2 imply that the migratory insertion step shows no strong equatorial or axial bias and that face selectivity is not effectively controlled by a small α'-substituent.

The more general scope of intramolecular alkene arylations is apparent in entries 6–13 of Table I.[9] Entry 6 merits particular note since it demonstrates that this chemistry is not limited to the preparation of heterocycles but should find application as well in the area of carbocyclic synthesis. The preparation of spirocyclic ethers is illustrated by the conversion reported in entry 7, while entries 6–13 demonstrate,[16] as expected,[2] that the alkene need not be electron-deficient. In general, aryl iodides react more rapidly than bromides; however, they lead to more isomerized alkenes (e.g., compare entries 8 and 9). As observed with **2b** (X = I), alkene isomerization is markedly reduced when the cyclization is conducted at room temperature in the presence of a silver salt. Using these conditions, aryl iodides can be cyclized in good yields to provide predominately the initially formed allylic alkene isomer (see entries 6, 7, and 10). Entries 10–13 illustrate the use of intramolecular Heck arylations for forming six- and seven-membered rings. In the conversion shown in entry 10, stereoselective cyclization in only the exocyclic sense to form *cis*-benzohydroisoquinoline **7**[9,18] was observed. The high yield formation of a seven-membered ring as observed in the conversion reported in entry 12[9,18] is apparently not general, since **10** was quite resistant to cyclization. Even when Bu_4NCl was used as a phase-transfer catalyst, as recommended by Jeffrey,[19] the cyclization of **10** → **11** proceeded in low yield only.[20]

(8) Grigg, R.; Sridharan, V.; Stevenson, P.; Worakan, T. *J. Chem. Soc., Chem. Commun.* **1986**, 1697.

(9) New compounds showed IR, ^1H NMR, ^{13}C NMR, and mass spectra in accord with their assigned structures. Molecular composition was determined by high resolution MS or elemental analysis. Copies of IR and ^1H NMR spectra for pure samples of all cyclization substrates and products were submitted to the editors for review and are available from L.E.O. upon request. ^1H NMR spectra of selected cyclization products (or their dihydro derivatives) are included in the supplementary material.

(10) The cyclization was conducted initially in the presence of 1 mol % of $Pd(OAc)_2$ and 3 mol % of Ph_3P. Two additional equal amounts of $Pd(OAc)_2$ and Ph_3P were added at 12 and 24 h. This procedure of sequential catalyst addition was utilized in most of the cyclizations reported in this manuscript.

(11) Characterization data for **3b**: IR (film) 1720, 1620 cm^{-1}; MS (70 eV) (relative intensity) 213 (M, 100), 212 (82), 184 (38), 159 (22); ^1H NMR (300 MHz, $CDCl_3$) δ 7.29 (dt, J = 1.1, 7.6 Hz, C-6'H), 7.24 (d, J = 8.1 Hz, C-4'H), 7.06 (app dt, J = 0.9, 7.6 Hz, C-5'H), 6.85 (d, J = 7.7 Hz, C-7'H), 6.14 (dt, J = 9.9, 3.7 Hz, CH_2CH=CH), 5.30 (dt, J = 9.9, 1.9 Hz, CH_2CH=C*H*), 3.22 (s, NCH_3), 2.3–2.1 (m, 3 H), 2.03 (ddd, J = 12.7, 9.3, 2.7 Hz, axial O=CCC*H*H), 1.8–1.94 (m, 1 H), 1.74 (ddd, J = 12.7, 7.8, 3.0 Hz, equatorial O=CCCH*H*); ^{13}C NMR (76 MHz, $CDCl_3$) 179.7 (C=O), 142.8 (C-7a'), 134.7 (C-3a'), 131.4, 127.8, 124.7, 123.7, 122.3, 107.8 (C-7'), 49.3 (spiro carbon), 32.1 (*C*C=C), 26.3 (NCH_3), 24.0 (O=C*C*C), 18.1 (*C*CC=C).

(12) It has been suggested[13] recently that different forms of palladium(0), specifically metallic palladium and palladium(0)–phosphine complexes, are involved in the Heck reaction of aryl iodides and aryl bromides, respectively.

(13) Andersson, C.-M.; Karabelas, K.; Hallberg, A.; Anderson, C. *J. Org. Chem.* **1985**, *50*, 3891.

(14) Agents screened included $Pb(NO_3)_2$, $CdCO_3$, $BaCO_3$, $CaCO_3$, Na_2CO_3, Li_2CO_3, K_2CO_3, Ag_2O, Ag_2SO_4, $AgOSO_2CF_3$.

(15) Karabelas, K.; Westerlund, C.; Hallberg, A. *J. Org. Chem.* **1985**, *50*, 3896. Karabelas, K.; Hallberg, A. *Ibid.* **1986**, *51*, 5286.

(16) Verification of the structure of the product formed in the cyclizations reported in entries 8 and 9 could be obtained by chemical correlation (H_2, Pd/C; excess MeLi) with 1',2'-dihydrospiro[cyclohexane-1,3'-(3*H*)indole]: mp 77–78 °C (*lit.*[17] mp 76–77 °C).

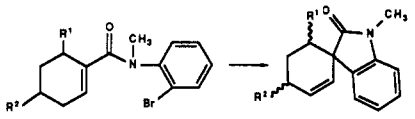
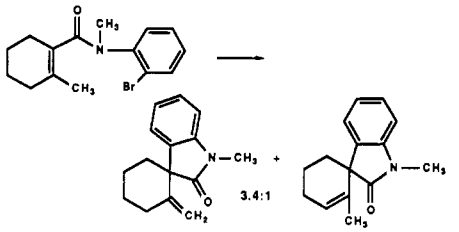
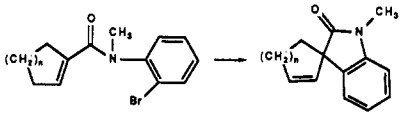
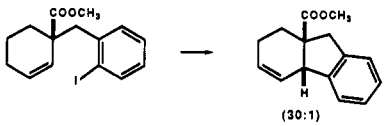
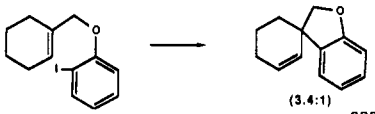
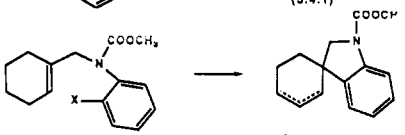
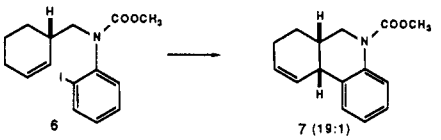
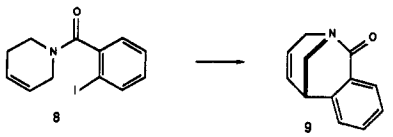
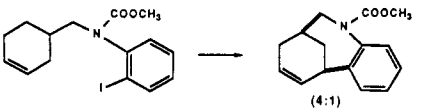
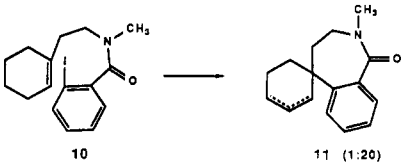
(17) Rodriguez, G.; Benito, Y.; Temprano, F. *Chem. Lett.* **1985**, 427.

(18) The structure of this material was established by extensive homonuclear ^1H NMR decoupling experiments at 500 MHz.

(19) Jeffrey, T. *J. Chem. Soc., Chem. Commun.* **1984**, 1287. Jeffrey, T. *Tetrahedron Lett.* **1985**, *26*, 2667.

(20) Deiodinated **10** and the biaryl resulting from homocoupling of **10** are produced also in yields of 20% and 10%, respectively.

Table I. Palladium-Catalyzed Intramolecular Alkene Arylations

entry	conversion	conditions[a]				
		$Pd(OAc)_2$, %	Ph_3P, %	time, h	temp, °C	yield,[b,c] %
1	 R^1=H, R^2=Bu^t	3	12	36	82	75[d]
2	R^1=CH_3, R^2=H	2	8	24	82	89[e]
3	 3.4:1	5	20	56	82	58 (69)
4	 n=1	1	4	18	82	91
5	n=3 (13:1)	3	12	36	82	90
6	 (30:1)	5	15	30	23	86[f]
7	 (3.4:1)	8	24	48	23	71[f]
8	 4 a X=I, 5 (1:1.6)	1	4	10	82	82
9	b X=Br (8:1)	5	20	56	82	52 (74)
10	 6, 7 (19:1)	5	15	30	23	74[f,g]
11	 8, 9	3	12	36	82	78[g]
12	 (4:1)	1	4	4	82	83[g]
13	 10, 11 (1:20)	10[h]	20	24	82	29

[a] Reactions were conducted in acetonitrile (100 mg substrate/3 mL) in the presence of 2 equiv of Et_3N. Small differences in the weight of catalyst employed are not believed significant in light of the errors involved in weighing small amounts of $Pd(OAc)_2$. [b] All yields refer to chromatographically purified products. Yields in parentheses are based on consumed starting material. [c] When mixtures of double-bond isomers were produced, catalytic hydrogenation provided a single saturated product. Regioisomer ratios are reported in parentheses with the allylic isomer on the left. [d] A 1.1:1 mixture of isomers. This reaction also produced 10% of a structural isomer. [e] A mixture of stereo and double-bond isomers. A 2.3:1 mixture of stereoisomers is produced upon catalytic hydrogenation. The major stereoisomer is tentatively assigned to the isomer with the Me and Ph groups cis on the basis of ^1H NMR spectra. [f] This reaction was conducted in the presence of 2 equiv of Ag_2CO_3 in the absence of Et_3N. [g] See ref 18. [h] A mixture of $Pd(OAc)_2$, Ph_3P, K_2CO_3 (2 equiv), and NBu_4Cl (1 equiv) in acetonitrile at 82 °C was employed, see ref 19.

In summary, our results as well as those of other workers[2-5,8] demonstrate that a wide variety of spiro, bridged, and fused polycyclic systems can be assembled by intramolecular palladium-catalyzed alkene arylations. The studies reported here specifically illustrate the ease with which quaternary centers can be formed by intramolecular Heck reactions and demonstrate that intramolecularity can overcome the usual reluctance of highly substituted alkenes to participate in palladium-catalyzed reactions. Our results also show that competing palladium-catalyzed isomerization of the alkene product can be greatly reduced by conducting the cyclization at room temperature in the presence of a silver salt. Since the cyclization substrates are typically available in just a few steps from commercial materials, we anticipate that intramolecular alkene arylations will prove useful for preparing a variety of complex aromatic heterocyclic as well as carbocyclic natural products. Studies in these areas are currently underway in our laboratories.

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Registry No. **1**, 509-15-9; **2b** (X = Br), 102804-51-3; **2b** (X = I), 109686-67-1; **2c** (X = Br), 109686-65-9; **2d** (X = Br), 109686-66-0; **3b**, 109686-68-2; **3b** (regioisomer), 109686-71-7; **3c**, 109686-69-3; **3d**, 109686-70-6; **4a**, 109686-42-2; **4b**, 109686-43-3; **5** (regioisomer 1), 109686-57-9; **5** (regioisomer 2), 109686-58-0; **6**, 109686-44-4; **7** (regioisomer 1), 109719-20-2; **7** (regioisomer 2), 109719-21-3; **8**, 109270-63-5; **9**, 109241-05-6; **10**, 109686-45-5; **10** (deiodinated), 109686-61-5; **11** (regioisomer 1), 109686-63-7; **11** (regioisomer 2), 109686-62-6; 1′,2′-dihydrospiro[cyclohexane-1,3′-(3*H*)indole], 4740-63-0; 2,2′-bis[[2-(1-cyclohexenyl)ethyl]-methylaminocarbonyl]-1,1′-biphenyl, 109686-64-8; 1-bromo-2-[(4-*tert*-butyl-1-cyclohexenylcarbonyl)methylamino]benzene, 109686-35-3; 1-bromo-2-[(6-methyl-1-cyclohexenylcarbonyl)-methylamino]benzene, 109686-36-4; 1-bromo-2-[(2-methyl-1-cyclohexenylcarbonylmethyl amino]benzene, 109686-37-5; 2-bromo-*N*-(1-cyclopentenylcarbonyl)-*N*-methylaniline, 109686-38-6; 2-bromo-*N*-(1-cycloheptenylcarbonyl)-*N*-methylaniline, 109686-39-7; 1-(2-iodobenzyl)-1-(methoxycarbonyl)-2-hexene, 109686-40-0; 1-iodo-2-(1-cyclohexenylmethyloxy)benzene, 109686-41-1; 1-iodo-*N*-(1-cyclohexen-4-ylmethyl)-*N*-(methoxycarbonyl)aniline, 109719-18-8; *cis*-1′,2′-dihydro-1′-methyl-2′-oxo-4-*tert*-butylspiro-[cyclohex-2-ene-1,3′-[3*H*]indole], 109686-46-6; *trans*-1′,2′-dihydro-1′-methyl-2′-oxo-4-*tert*-butylspiro[cyclohex-2-ene-1,3′-[3*H*]indole], 109686-47-7; 1′,2′-dihydro-1′,2-dimethyl-2′-oxospiro[cyclohex-2-ene-1,3′-[3*H*]indole, 109686-48-8; 1′,2′-dihydro-1′,2-dimethyl-2′-oxospiro[cyclohex-3-ene-1,3′-[3*H*]indole, 109686-49-9; 1′,2′-dihydro-1′-methyl-2-methylenyl-2′-oxospiro-[cyclohexane-1,3′-[3*H*]indole, 109686-50-2; 1′,2′-dihydro-1′,2-dimethyl-2′-oxospiro[cyclohex-2-ene-1,3′-[3*H*]indole, 109719-19-9; 1′,2′-dihydro-1′-methyl-2′-oxospiro[cyclopent-2-ene-1,3′-[3*H*]-indole], 109686-51-3; 1′,2′-dihydro-1′-methyl-2′-oxospiro[cyclopent-3-ene-1,3′-[3*H*]indole), 109686-52-4; *cis*-2,4a,9,9a-tetrahydro-9a-(methoxycarbonyl)-1*H*-fluorene, 109686-53-5; *cis*-4,4a,9,9a-tetrahydro-9a-(methoxycarbonyl)-1*H*-fluorene, 109686-54-6; spiro[benzofuran-3(2*H*),1′-cyclohex-2-ene], 109686-55-7; spiro[benzofuran-3(2*H*),1′-cyclohex-3-ene], 109686-56-8; 5,8,9,10,11a-pentahydro-11-(methoxycarbonyl)-11-aza-5,9-methanobenzocyclononene, 109686-59-1; 5,6,9,10,11a-pentahydro-11-(methoxycarbonyl)-11-aza-5,9-methanobenzocyclononene, 109686-60-4; *cis*-1′,2′-dihydro-1′,2-dimethyl-2′-oxospiro-[cyclohex-2-ene-1,3′-[3*H*]indole], 109719-12-2; *trans*-1′,2′-dihydro-1′,2-dimethyl-2′-oxospiro[cyclohex-2-ene-1,3′-[3*H*]indole], 109686-72-8; 1′,2′-dihydro-1′-methyl-2′-oxospiro[cyclohept-2-ene-1,3′-[3*H*]indole], 109686-73-9; 1′,2′-dihydro-1′-methyl-2′-oxospiro[cyclohept-3-ene-1,3′-[3*H*]indole], 109686-74-0.

Supplementary Material Available: Copies of the ^{1}H NMR spectra for **3c**, **3d**, and the cyclization products reported in Table I, entries 3, 4, 5, 6 (dihydro), 7 (dihydro), 10, 11, and 13 (12 pages). Ordering information is given on any current masthead page.

Matthew M. Abelman,[1] Taeboem Oh
Larry E. Overman*
Department of Chemistry
University of California
Irvine, California 92717
Received March 12, 1987

Lewis Acid Induced Nucleophilic Substitution Reactions of β-Nitro Sulfides via Episulfonium Ions[1]

Summary: The nitro group of β-nitro sulfides is replaced by a cyano or allyl group via episulfonium intermediates on treatment with Me_3SiY (Y = CN or allyl) in the presence of an appropriate Lewis acid.

Sir: Recently nucleophilic substitution reactions of aliphatic nitro compounds have drawn much attention as a new synthetic method, for the nitro group serves as an excellent activating group for carbon–carbon bond-forming reactions. The following nucleophilic substitution reactions of aliphatic nitro compounds have been documented; nucleophilic substitution reaction via one-electron-transfer processes,[2] palladium-catalyzed substitution reactions of allylic nitro compounds,[3] palladium-uncatalyzed substitution reactions of allylic nitro compounds,[4] and Lewis acid induced substitution reactions of tertiary, benzylic, or allylic nitro compounds.[5] Thus, nitro groups can be replaced by nucleophiles in all of these reactions. However, primary or secondary nitro groups are not replaced by nucleophiles except for benzylic or allylic cases. Here we report a new type of nucleophilic substitution reaction of nitro compounds, namely, the replacement of the nitro group of β-nitro sulfides by nucleophiles in the presence of an appropriate Lewis acid.

β-Nitro sulfides are readily prepared by the condensation reaction of aldehydes or ketones with nitro compounds followed by the Michael addition of thiols. This two-step reaction can also be done in a one-pot procedure by mixing carbonyl compounds, nitro compounds, and thiols in the presence of amines.[6] Treatment of thus obtained β-nitro sulfides **1** with Me_3SiY (Y = CN, $CH_2CH{=}CH_2$) in the presence of an appropriate Lewis acid gave the substitution product (**2** and **3**), where the nitro group was cleanly replaced by CN or $CH_2CH{=}CH_2$, respectively: the results are summarized in Table I. This is the first general case of replacement of primary or secondary nitro groups by nucleophiles. Assistance by the β-phenylthio function is crucial for the present Lewis acid induced substitution

(1) This paper is dedicated to the late professor Ryozo Goto, Kyoto University.

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