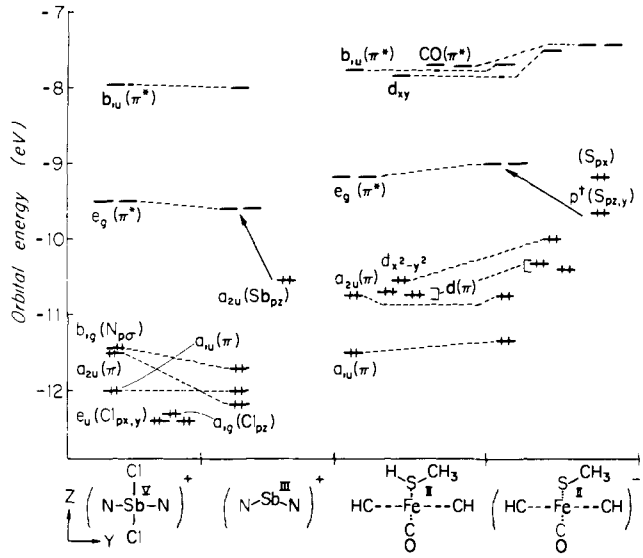


**Figure 3.** Orbital energy levels for Sb(V) (normal type), Sb(III) (hyper type), Fe(II) CO mercaptan (normal type), and Fe(II) CO mercaptide (hyper type) porphines by iterative extended Huckel (IEH) method. Arrows indicate charge transfer transitions. Porphine geometries in the $y$–$z$ plane are illustrated: $y$ axes through either the pyrrole nitrogens (Sb) or the methine carbons (Fe) are equivalent and related by a 45° rotation. Detailed bond lengths and angles will be given in ref 19 and 21. Both antimony compounds form stable cations and their anions were not included in the calculation. The iron $d_{z^2}$ orbitals, which occur at energies higher than −7 eV, are not shown.

bitals among its valence orbitals, eliminating the possibility of a $p^\dagger \rightarrow e_g(\pi^*)$ transition.

Our orbital mechanism for the origin of *hyper* spectra in CO-P-450 and in the CO model compounds leads to the prediction that other low spin ferrous porphyrin mercaptide complexes could exhibit *hyper* spectra. Indeed, Chang and Dolphin have synthesized $O_2$ mercaptide heme complexes which also clearly exhibit *hyper* absorption spectra.[4b] IEH calculations on $O_2$–mercaptide and $O_2$–mercaptan complexes give results similar to the CO complexes.[21] There is considerable mixing of mercaptide, but not mercaptan, sulfur orbitals with the porphyrin $\pi$ system, indicating a similar mechanism for the *hyper* spectra observed in the $O_2$ mercaptide complex.

The possibility exists that "CO-P-450 type" spectra can occur in the absence of a mercaptide ligand. Chaing et al.[23] find that CO-chloroperoxidase has a spectrum very similar to CO-P-450, yet they report that the protein contains no cysteines. Our orbital mechanism specifically requires, however, that both CO-P-450 and CO-chloroperoxidase have electron donating ligands which can play the same role in causing *hyper* spectra as the mercaptide sulfur in the model compounds.

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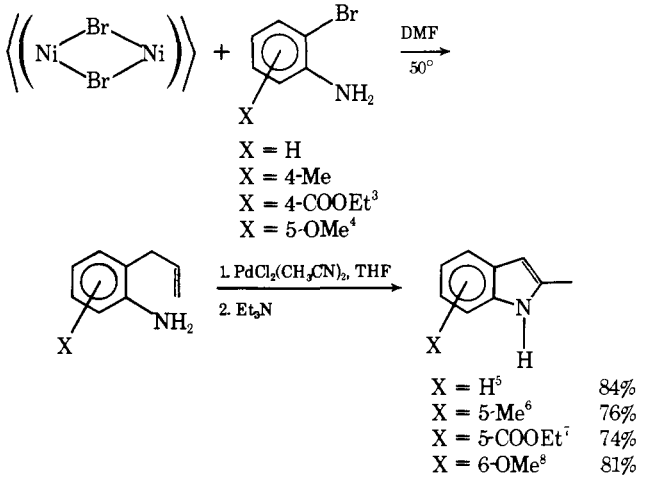
## Palladium Assisted Intramolecular Amination of Olefins. A New Synthesis of Indoles

*Sir:*

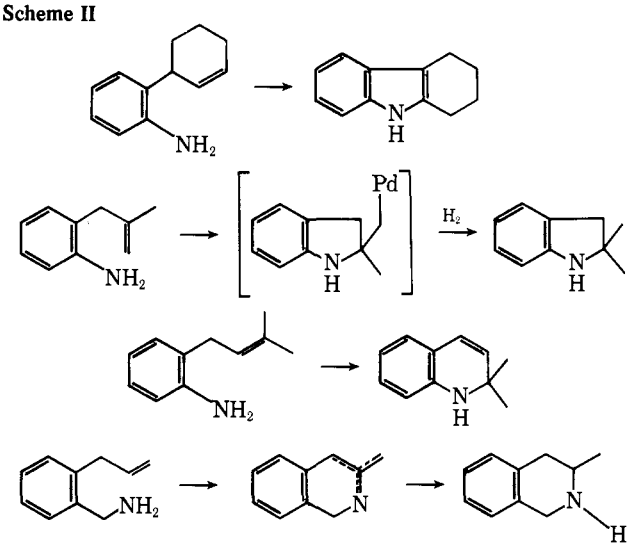
We recently reported the palladium assisted amination of simple monoolefins by secondary amines to produce tertiary amines. We report herein the development of an *intra*molecular version of this reaction for the cyclization of *o*-allylanilines to 2-methylindoles in high yield under remarkably mild conditions. The synthetic approach is outlined in Scheme I. The requisite *o*-allylanilines were prepared in high yield by the reaction of *o*-bromoanilines with $\pi$-allylnickel bromide,[2] a reaction which proceeds under mild conditions, tolerates a wide range of functionality, and allows the facile preparation of a variety of differently substituted *o*-allylanilines.

Addition of the *o*-allylaniline to a THF solution of $PdCl_2(CH_3CN)_2$ produced a yellow-brown precipitate. Upon addition of triethylamine the solid dissolved and the resulting cherry red solution began to deposit metallic palladium. After deposition was complete (~2 h), the solution was filtered and evaporated to dryness. The crude material was essentially the

**Scheme I**




**Scheme II**

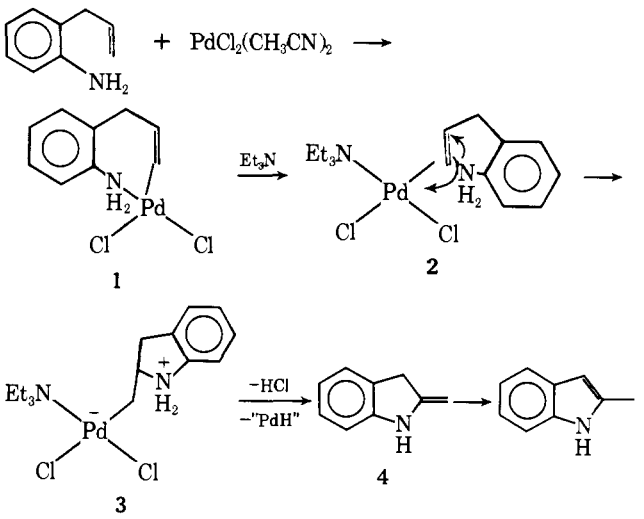



desired 2-methylindole contaminated with small amounts of $Et_3N{\cdot}HCl$. The yields reported for the reaction in Scheme I are for isolated pure products obtained by preparative layer chromatography on silica gel or by crystallization from heptane.

Not only is this reaction compatible with a wide range of functional groups on the benzene ring but the cyclization is also successful with compounds having alkyl substitution at the 2 or the 3 position of the allyl side chain. Thus *o*-(2-cyclohexenyl) aniline is converted to tetrahydrocarbazole,[9] *o*-(2-methallyl)aniline to 2,2-dimethylindoline,[10] and *o*-(3,3-dimethylallyl)aniline to 2,2-dimethyl-1,2-dihydroquinoline.[11] Finally, *o*-allylbenzylamine[12] cyclizes to 3-methyl-1,2,3,4-tetrahydroisoquinoline (after reduction of the mixture of dihydroisoquinolines[13]), indicating that the cyclization is not restricted to the very weakly basic anilines ($pK_a$ = 4.6) but proceeds well with the considerably more basic benzylamines ($pK_a$ = 9.4) (Scheme II).

The probable course of the cyclization reaction is outlined in Scheme III. The *o*-allylaniline reacts with $PdCl_2$ to produce complex **1**, in which both the amino group and the olefinic group are coordinated in a chelating fashion.[15] Since the amino group is coordinated, it cannot attack the olefin. Addition of triethylamine leads to displacement of the weakly basic aromatic amine, generating complex **2**, in which the aromatic amine can achieve the trans stereochemistry required for amination of the coordinated olefin.[16] Attack of the coordinated olefin by the aromatic amine results in the $\sigma$-alkylpalladium complex **3**, which upon elimination of HCl and $\beta$-

**Scheme III**[14]




elimination of "Pd-H" gives compound **4**, which spontaneously rearranges to the observed 2-methylindole.

With the methyl substituted allylanilines ring closure occurs at the *most* substituted terminus of the double bond, allowing palladium to occupy the *less* substituted position, as evidenced by exclusive production of 2,2-dimethylindoline rather than 3-methylquinoline from methallylaniline, and 2,2-dimethyl-1,2-dihydroquinoline rather than 2-isopropylindole from *o*-(3,3-dimethylallyl)aniline. This regioselectivity, as well as the proposed mechanism of this cyclization detailed in Scheme III, is analogous to those of palladium assisted amination of simple monoolefins.[1] Experimental verification of this proposed mechanism is in progress.

This cyclization is remarkable in several respects. Our previous studies[1] showed that primary amines and weakly basic amines such as aniline failed to aminate simple monoolefins. In contrast, the intramolecular amination reported herein proceeded readily and in high yield with anilines. With simple monoolefins the olefin-palladium complex had to be preformed in the absence of amine, and amine addition conducted at −50° to avoid displacement of olefin from the metal by the amine. Again, this intramolecular version did not suffer these problems, even with the strongly basic benzylamine. Of the simple monoolefins, cyclohexene and 2-methylbutene could *not* be aminated in the intermolecular reaction, while the *intra*molecular amination reported in this paper proceeded readily. Finally, this palladium assisted cyclization was not restricted to nitrogen nucleophiles. Treatment of *o*-allylbenzoic acid with palladium chloride and sodium carbonate in THF produced 3-methylisocoumarin in good yield.[17,18]

Investigations of the application of this cyclization reaction to the synthesis of other ring systems are continuing.

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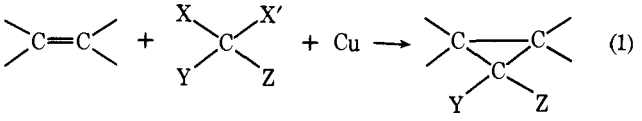
## A Novel Synthetic Route to Cyclopropane Derivatives from Olefins

*Sir:*

We wish to report a new, versatile, and convenient method for the synthesis of cyclopropane derivatives by the reaction of olefins with organic *gem*-dihalides and copper.[1] The reaction



(1)

(X, X′ = halogen)

is usually free from serious side reactions, and appears to be applicable to wide ranges of olefins and organic *gem*-dihalides. The reaction proceeds smoothly at moderate temperature and gives cyclopropane derivatives often in good yields. An aromatic hydrocarbon is the most suitable solvent for the reaction. Reactions were carried out in a flask fitted with a reflux condenser and a magnetic stirrer.[3] Some experimental results are given in Table I. All products were identified by comparison of their $^1H$ NMR and ir spectra with those of authentic samples, or showed satisfactory analytical data and expected spectra.

Reaction 1 with dihalomethanes gives cyclopropane derivatives in good yields as the corresponding Simmons-Smith reaction.[7] Reaction 1 with trihalomethanes is useful in the synthesis of monohalocyclopropane derivatives from olefins, and shows syn stereoselectivity.[9] The reaction with dibromoacetic esters shows syn selectivity when steric repulsion between the alkoxycarbonyl group and the substituents of the olefin is not significant, contrary to the reaction of diazoacetic esters with olefins.[10] The cis isomer is obtained predominantly from terminal olefins such as 1-hexene, 1-octene, and styrene. Although the exo isomer predominated over the endo isomer in the reaction with cyclic olefins, the anti selectivity is much lower than that of the corresponding reaction of ethyl diazoacetate.[11]

Except for the case with cyclohexene and methyl dibromoacetate,[12] isomeric olefins, which would be expected from the insertion of the corresponding free carbenes into C-H bonds, were not detected in the reaction mixture. Reaction 1 seems to proceed via organocopper intermediates rather than free carbenes.

The reaction of pure *trans*-stilbene with diiodomethane and copper in ethylbenzene gave *trans*-1,2-diphenylcyclopropane.[13] *cis*-1,2-Diphenylcyclopropane and *cis*-stilbene were not detected in the reaction mixture. On the other hand, the corresponding reaction with pure *cis*-stilbene gave a 97.1:2.9 mixture of *cis*- and *trans*-1,2-diphenylcyclopropane.[13] The recovered stilbene was also a 98.1:1.9 mixture of cis and trans isomers. These experimental results show that reaction 1 loses the stereospecificity to some extent probably by the action of copper(I) halide.

**Table I.** Synthesis of Cyclopropane Derivatives from Olefins, Organic *gem*-Dihalides, and Copper[a]

| Olefin | Halide | Temp (°C) | Time (h) | Product | Yield (%)[b] | Isomer ratio |
|---|---|---|---|---|---|---|
| Cyclohexene | $CH_2I_2$ | 70 | 50 | Bicyclo[4.1.0]heptane[c] | 85-87 | — |
| Cyclohexene | $CH_2BrI$ | 70 | 50 | Bicyclo[4.1.0]heptane[c] | 69 | — |
| Cyclohexene | $CHCII_2$ | 70 | 25 | *endo/exo*-7-Chlorobicyclo[4.1.0]heptane[d] | 48 | 2.1 |
| Cyclohexene | $CHCl_2I$ | 70 | 50 | *endo/exo*-7-Chlorobicyclo[4.1.0]heptane[d] | 14 | 2.2 |
| Cyclohexene | $Br_2CHCOOCH_3$ | 55 | 50 | *exo/endo*-7-Methoxycarbonylbicyclo[4.1.0]-heptane[e] | 31 | 2.4 |
| 1-Hexene | $Br_2CHCOOCH_3$ | 60 | 98 | *cis/trans*-1-Butyl-2-methoxycarbonylcyclo-propane[e] | 25 | 2.7 |
| Cycloheptene | $Br_2CHCOOCH_3$ | 80 | 50 | *exo/endo*-8-Methoxycarbonylbicyclo[5.1.0]-octane[e] | 46 | 1.9 |
| *cis*-Cyclooctene | $CH_2I_2$ | 100[f] | 50 | *cis*-Bicyclo[6.1.0]nonane[c] | 77 | |
| *cis*-Cyclooctene | $Br_2CHCOOCH_3$ | 55 | 50 | *exo/endo*-9-Methoxycarbonyl-*cis*-bicyclo-[6.1.0]nonane[e] | 71 | 1.3 |
| 1-Octene | $CH_2I_2$ | 70 | 47 | Hexylcyclopropane[c] | 86 | — |
| 1-Octene | $Br_2CHCOOCH_3$ | 70 | 50 | *cis/trans*-1-Hexyl-2-methoxycarbonylcyclo-propane[e] | 21 | 2.7 |
| Styrene | $CH_2I_2$ | 70 | 92 | Phenylcyclopropane[c] | 90 | — |
| Styrene | $Br_2CHCOOCH_3$ | 100[f] | 48 | *cis/trans*-1-Methoxycarbonyl-2-phenylcyclo-propane[e] | 22 | 1.6 |
| *trans*-Stilbene | $CH_2I_2$ | 125[g] | 50 | *trans*-1,2-Diphenylcyclopropane[c] | 27 | — |
| *cis*-Stilbene | $CH_2I_2$ | 125[g] | 50 | *cis/trans*-1,2-Diphenylcyclopropane[c,e] | 22 | 33 |

[a] Reactions were carried out with 4.0 mmol of olefin, 8.0 mmol of organic *gem*-dihalide, 18.0 mmol of copper, and 0.2 mmol of iodine in 3.0 ml of benzene. [b] Based on the olefin. [c] Authentic samples were prepared by the Simmons-Smith reaction.[7] [d] Authentic samples were prepared by the reaction of lithium carbenoid.[8] [e] Complete spectral and elementary analyses of these compounds are included in the supplementary material. [f] Toluene was used instead of benzene. [g] Ethylbenzene was used instead of benzene.