NOE's on the phenyl ring protons. Differential NOE's of different protons of the same ring were paralleled by differences in broadening of their resonances. These results unequivocally establish the relationship of the negative NOE to the binding process.

Negative NOE's[7] observed at δ 1.9 and 3.1 ppm cannot be identified with specific alkyl groups on the protein; however, the effect at δ 6.86 ppm can be unambiguously assigned to the ortho protons of the single protein tyrosine residue.[8] These results demonstrate that the protein tyrosine is adjacent to the aromatic ring at position 2 of the peptide, in the complex. This conclusion is supported by preliminary experiments using a neurophysin derivative,[9] in which the single tyrosine is mononitrated. An intensity decrease in the phenyl protons of B in a 14:1 mixture of B and nitro NP-II was observed when the single proton ortho to the nitrotyrosine hydroxyl was saturated ($\delta \sim 6.88$ ppm; pH 6.1). No appreciable effects could be detected on irradiating the proton ortho to the nitro group (δ 7.93 ppm). It should be noted that the chemical shifts of the nitrotyrosine protons are strongly pH dependent in the pH range 6–8 due to the lowered pK_a of the hydroxyl group in the nitrated derivative.

In separate observations of the *protein* tyrosine protons, it was observed that the ortho proton signals became narrower and moved downfield ($\Delta_{\Delta\nu} = 6$ Hz; $\Delta\delta \approx 20$ Hz) on addition of saturating concentrations of B, indicating that the protein tyrosine is less restricted in the complex than in the free protein. This result suggests that either the protein tyrosine is displaced from an intramolecular binding interaction by the entering peptide, or that it is freed from motional constraints by a local conformational change attendant to binding. In either event the proximity, in the complex, of the aromatic ring at position 2 of the peptide and the protein tyrosine residue, is indicated by the NOE data.

Acknowledgment. This work was performed with the support of National Institutes of Health Grant No. GM-17528 to Cornell University Medical College, New York, and used the NMR Facility for Biomedical Research supported by National Institutes of Health Grant No. RR-00292 to the MPC Corporation, Pittsburgh.

---

[7] P. Balaram, A. A. Bothner-By, and J. Dadok, **94**, 4015 (1972).

[8] R. Walter, D. H. Schlesinger, I. L. Schwartz, and J. D. Capra, *Biochem. Biophys. Res. Commun.*, **44**, 293 (1971).

[9] A. J. Furth and D. B. Hope, *Biochem. J.*, **116**, 545 (1970).

P. Balaram, A. A. Bothner-By*
Department of Chemistry, Carnegie-Mellon University
Pittsburgh, Pennsylvania 15213
E. Breslow
Department of Biochemistry, Cornell University Medical College
New York, New York 10021

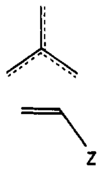
Received March 16, 1972

Nickel(0)-Catalyzed Reaction of Methylenecyclopropane with Olefins. Orientation and Stereochemistry[1]

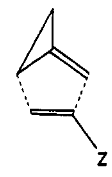
Sir:

Bis(acrylonitrile)nickel(0) ($Ni(AN)_2$) catalyzes the cycloaddition of methylenecyclopropane (**1**) and methyl acrylate yielding 3-carbomethoxymethylenecyclopentane.[2] The new coupling reaction between three- and two-carbon units provides an example of reactions which are *formally* envisaged as thermally forbidden [2 + 2] processes, but which can be realized through metal catalysis. This communication discloses the detailed features of a reaction involving the cleavage of strained carbon–carbon σ bond.

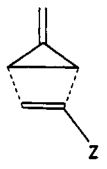
As to the mode of the combination of the two components, four possibilities A–D could be considered *a priori* (Z = $COOCH_3$).



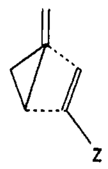
A



B

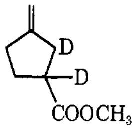


C



D

Path A which proceeds *via* trimethylenemethane species (either free or complexed) and path B[3] have been previously eliminated,[2] leaving modes C and D which involve the reaction at the allylic and vinylic bonds of **1**, respectively. The actual orientation of mode D was demonstrated by an examination of the reaction product employing a deuterium-labeled substrate. Reaction of **1** (6 mmol) and methyl acrylate-α,β-d_2[4] (25 mmol) in the presence of $Ni(AN)_2$ (0.2 mmol) under a nitrogen atmosphere (60°, 48 hr) afforded the 1:1 adduct **2** in 70% yield.[5] The structure was determined by nmr analysis (Figure 1). The spectrum of undeuterated 3-carbomethoxymethylenecyclopentane exhibited three-proton, overlapping multiplets at δ 2.4–2.8 arising from methylene protons of C-2 and $CHCOOCH_3$, while the nmr of **2** showed only a one-proton broad signal at the same region.[6] The cycloaddition *via* path D could reasonably be explained by assuming the intermediacy of the organonickel **3** (L = $CH_2 = CHZ$) produced by the oxidative addition of the strained carbon–carbon σ bond to the d_{10} Ni(0) atom.[1,7]



2

3

The efficiency of the catalyst and the course of the reaction are subtly influenced by the olefinic substrates which act as the metal ligands. Firstly, in the absence of olefins, treatment of **1** with $Ni(AN)_2$ in benzene solution resulted in the recovery of the starting material.[5] Secondly, unlike methyl acrylate which undergoes cyclo-

---

[1] Nickel-Catalyzed Reactions Involving Strained σ Bonds. IV. Part III: R. Noyori, T. Suzuki, and H. Takaya, *J. Amer. Chem. Soc.*, **93**, 5896 (1971).

[2] R. Noyori, T. Odagi, and H. Takaya, *ibid.*, **92**, 5780 (1970).

[3] For the uncatalyzed $[_{\sigma}2 + _{\pi}2 + _{\pi}2]$-type reaction of methylenecyclopropanes and tetracyanoethylene, see R. Noyori, N. Hayashi, and M. Katô, *ibid.*, **93**, 4948 (1971).

[4] A mixture of cis and trans isomers (87:13 by nmr) prepared by the method of T. Yoshino, J. Komiyama, and M. Shinomiya (*ibid.*, **86**, 4482 (1964)) was used.

[5] A trace amount of 3-cyanomethylenecyclopentane[2] and some butadiene (<5%) were formed.

[6] We thank Dr. T. Nishida of Nippon Electrical Varian, Ltd., for recording the spectra.

[7] J. Halpern, *Accounts Chem. Res.*, **3**, 386 (1970), and references cited therein.

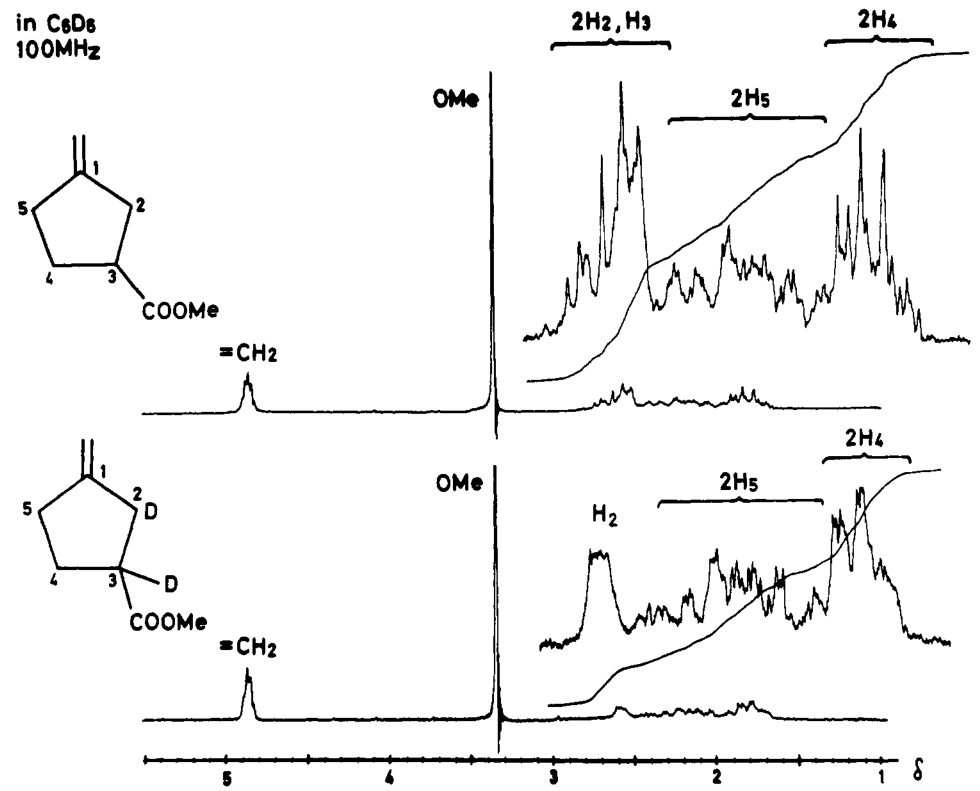
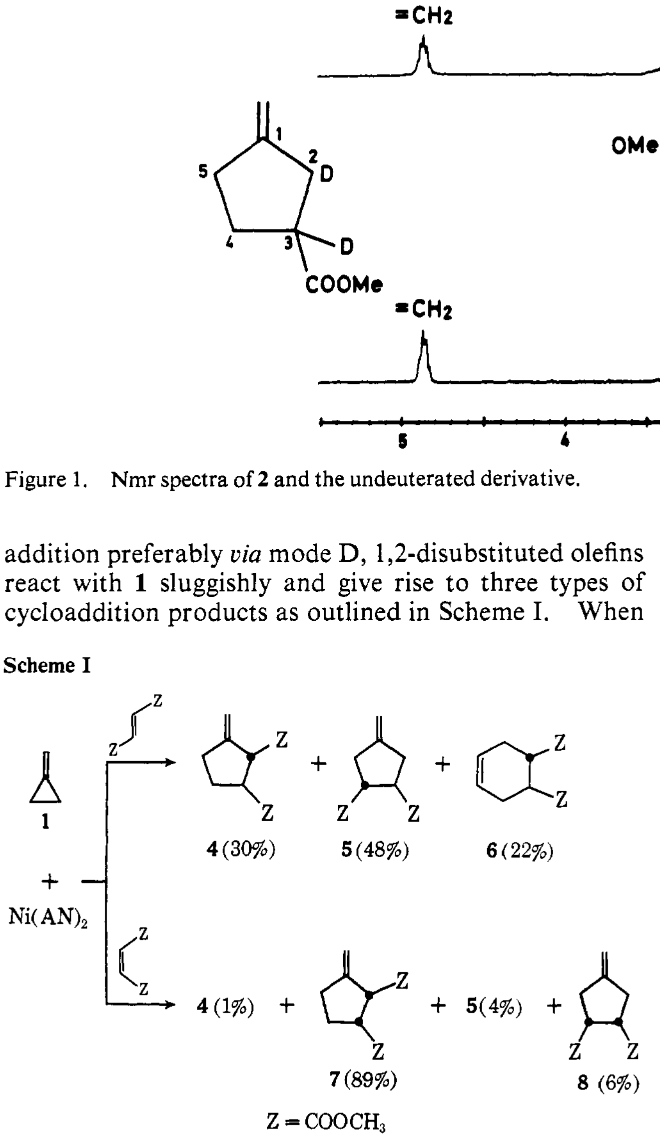


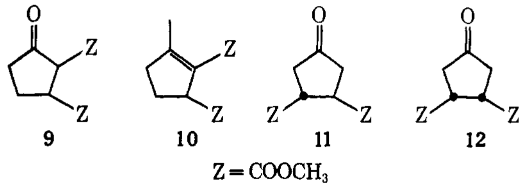
Figure 1. Nmr spectra of **2** and the undeuterated derivative.

addition preferably *via* mode D, 1,2-disubstituted olefins react with **1** sluggishly and give rise to three types of cycloaddition products as outlined in Scheme I. When

Scheme I



a mixture of **1** (7 mmol), dimethyl fumarate (28 mmol), and Ni(AN)$_2$ (0.4 mmol) in benzene (5 ml) was heated at 60° for 48 hr, a mixture of 1:1 adducts, **4**, **5**, and **6** (30:48:22 ratio), was obtained in 27% combined yield.[5,8] It is likely that the cyclohexene derivative **6** arises from Diels–Alder reaction of fumarate and butadiene produced during the reaction.[9] The use of dimethyl maleate under comparable conditions gave an isomeric mixture of **4**, **5**, **7**, and **8** (1:4:89:6 ratio) in 20% yield.[5,8,10] None of the six-membered adduct was detected in the reaction mixture. The spectral data of the products were fully in accord with the assigned structures.[11] Ozonolysis of **4** and **7** gave the known cyclopentanone derivative **9**.[12] The *cis*-diester **7** upon exposure to 0.05 *M* CH$_3$ONa in CH$_3$OH at 20° for 5 min was readily converted to the cyclopentene derivative **10**,[13] whereas the isomerization of **4** having trans stereochemistry required heating at 55° for 2 hr. Compounds **5** and **8** were transformed by ozonolysis to the known cyclopentanones, **11** and **12**, respectively.[14]



It is worthwhile pointing out that the major catalytic reactions of disubstituted olefins proceed in a highly, if

---

(8) The product composition was determined by glpc analysis, either directly or after ozonolysis. Unless otherwise stated, all new compounds gave correct elemental analyses and molecular peaks in mass spectra.

(9) Heating of a mixture of butadiene (0.7 mmol) and dimethyl fumarate (28 mmol) in benzene (5 ml) at 60° for 10 hr gave **6** in 30% yield, while the reaction with maleate afforded only a trace, if any, of the corresponding cyclohexene derivative. No effects of Ni(AN)$_2$ were observed.

(10) During the reaction, dimethyl maleate isomerized slightly, and the recovered esters contained *ca.* 1.5% of fumarate.

(11) All ir and nmr (60 MHz) spectra were taken in CCl$_4$ solution: **4**, ir 1736 (C=O), 1655 (C=C), and 891 cm^{-1} (=CH$_2$); nmr δ 3.67, 3.71 (s, 3 H each, OCH$_3$), 4.98, and 5.07 (m, 1 H each, =CH$_2$); **5**, ir 1737 (C=O), 1660 (C=C), and 880 cm^{-1} (=CH$_2$); nmr δ 3.62 (s, 6 H, OCH$_3$) and 4.85 (m, 2 H, =CH$_2$); **7**, ir 1740 (C=O), 1651 (C=C), and 888 cm^{-1} (=CH$_2$); nmr δ 3.60 (s, 6 H, OCH$_3$), 4.95, and 5.08 (m, 1 H each, =CH$_2$). The product **8** could not be isolated in a pure state, but the structure was confirmed after ozonolysis.

(12) F. W. Kay and W. H. Perkin, Jr., *J. Chem. Soc.*, **89**, 1640 (1906). Nmr and uv spectra indicated that the keto ester **9** is 20–25% enolic in CCl$_4$ or cyclohexane solution.

(13) Ir 1737, 1717 (C=O), and 1647 cm^{-1} (C=C); nmr δ 2.16 (br s, 3 H, =CCH$_3$), 3.63, and 3.68 (s, 3 H each, OCH$_3$); uv (C$_2$H$_5$OH) 231 nm (log ε 3.96).

(14) K. Auwers, *Ber. Deut. Chem. Ges.*, **26**, 364 (1893).

not completely, stereospecific manner and with retention of configuration of the olefins. Apparently, however, dual mechanisms are operating in these cases, and the full account is open to studies in the future.[15] Methylenecyclobutane, a higher homolog of **1**, has proved to be stable under the same catalytic conditions.

[15] Methylenecyclopropane substrates appropriate for the elucidation of the mechanism are not at hand. Attempted reactions of 2,2-dimethylmethylenecyclopropane or isopropylidenecyclopropane with dimethyl fumarate or maleate have failed.

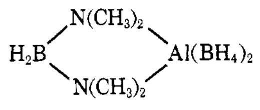
R. Noyori,* Y. Kumagai, I. Umeda, H. Takaya
Department of Chemistry, Nagoya University
Chikusa, Nagoya, Japan
Received January 10, 1972

Reaction of Diborane with Tris(dimethylamino)alane. Isolation of a New B–N–Al Heterocycle and a New Compound with a B–N–B–N–B Skeleton

Sir:

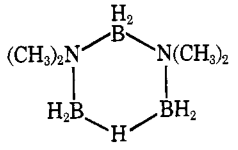
Tris(dimethylamino)alane reacts with excess diborane in diethyl ether at room temperature to form $[(CH_3)_2NBH_2]_2$, μ-$(CH_3)_2NB_2H_5$, $[(CH_3)_2NAl(BH_4)_2]_2$, and two new compounds which we formulate to be $H_2B[N(CH_3)_2]_2Al(BH_4)_2$ and $H_2BN(CH_3)_2BH_2N(CH_3)_2BH_3$.

The first, a colorless crystalline solid produced in 75% yield, passes 0° and stops at −17° under trap-to-trap vacuum line separation. *Anal.* Calcd for $[(CH_3)_2N]_2AlB_3H_{10}$: Al, 17.1; B, 20.9; H (hydrolytic), 6.33; $(CH_3)_2N$, 55.7. Found: Al, 17.5; B, 20.2; H (hydrolytic), 6.20; $(CH_3)_2N$, 55.7. The mass spectrum contains no peaks higher than the monomer parent ion at *m/e* 158. The infrared spectrum shows strong bands at 2510, 2420, and 2340, and at 2120 cm^{-1} (B–H, and Al–H–B stretching, respectively). No absorption characteristic of Al–H stretching is present. The boron-11 nmr spectrum[1] shows a 1:2:1 triplet at −1.6 ppm (J_{BH} = 115 Hz) and a 1:4:6:4:1 quintet at 37.6 ppm (J_{BH} = 89 Hz); the sharp well-resolved signals are in the integrated intensity ratio of 1:2, respectively. The proton nmr spectrum (toluene-d_8) shows a strong relatively sharp N–CH_3 singlet and a weaker broad 1:1:1:1 quartet assigned to the BH_2 protons. No proton signal arising from the borohydride groups bonded to aluminum could be detected, probably owing to extreme broadening by interaction with the aluminum-27 quadrupole moment. The cyclic structure shown below is consistent with this information.



This material, although very sensitive to air, moisture, and hydroxylic solvents, only decomposes slowly at room temperature when kept in clean evacuated vessels.

The second compound, a colorless liquid formed in 5–10% yield, passes −17° and stops at −30°. *Anal.* Calcd for $[(CH_3)_2N]_2B_3H_7$: B, 25.4; H (hydrolytic), 5.49; $(CH_3)_2N$, 69.0. Found: B, 25.1; H (hydrolytic), 5.46; $(CH_3)_2N$, 68.7. The mass spectrum is qualitatively similar to that of $[(CH_3)_2NBH_2]_2$ with the exceptions of an envelope associated with the parent ion $[(CH_3)_2N]_2B_3H_7^+$ starting at *m/e* 128 and a peak assigned to $(CH_3)_2NB_2H_5^+$ at *m/e* 71. The boron-11 nmr spectrum of a toluene solution at 30° consists of a sharp 1:2:1 triplet at −6.7 ppm (J_{BH} = 109 Hz) overlapping a very broad triplet centered at 1.6 ppm having twice the intensity of the low-field signal. The broad signal exhibits a temperature dependence characteristic of a H_2B–H–BH_2 group,[2,3] resolving into a triplet of doublets at −30° and into a symmetrical 1:5:10:10:5:1 sextet at 60°. The sharp triplet does not change in this temperature range. The proton nmr spectrum at −20° in toluene-d_8 shows a sharp single N–CH_3 resonance, two overlapping 1:1:1:1 BH quartets in approximate 1:2 intensity ratio, and a broad B–H–B bridge proton signal at highest field. These data suggest the hydrogen-bridged cyclic structure.



At 75° the compound decomposes to μ-$(CH_3)_2NB_2H_5$ and $[(CH_3)_2NBH_2]_2$ according to

$$H_2BN(CH_3)_2BH_2N(CH_3)_2BH_3 \longrightarrow \mu\text{-}(CH_3)_2NB_2H_5 + {}^1/_2[(CH_3)_2NBH_2]_2$$

The chemistry of both new materials and the reactions of diborane with other aminoalane derivatives are under investigation in this laboratory and will be reported more fully at a later date.

Acknowledgment. Support for this work by the National Science Foundation is gratefully acknowledged.

---

[1] Boron-11 and proton nmr spectra were obtained using a Varian HA-100 spectrometer equipped with standard accessories. Boron-11 chemical shifts are in parts per million (ppm) relative to diethyl ether–boron trifluoride.

[2] D. F. Gaines and R. Schaeffer, *J. Amer. Chem. Soc.*, **86**, 1505 (1964).

[3] R. F. Schirmer, J. H. Noggle, and D. F. Gaines, *ibid.*, **91**, 6240 (1969).

Philip C. Keller
Department of Chemistry, University of Arizona
Tucson, Arizona 85721
Received February 2, 1972

A Fair Test for Competitive Cycloadditions. Duality of Mechanism in the Cyclization of 5-Allylcyclohexa-1,3-diene

Sir:

In studies of the intramolecular Diels–Alder reaction, Doering and Krantz[1] have noted that heating 5-allylcyclohexa-1,3-diene (**1**) at 225° leads to tricyclo-[3.3.1.0^{2,7}]non-3-ene (**2**), benzene (**3**), 1-allylcyclohexa-1,3-diene (**4**), 2-allylcyclohexa-1,3-diene (**5**), and recovered starting material. This communication deals with the stereochemical fate of the deuterium label in cyclized α,α-dideuterio-5-allylcyclohexa-1,3-diene (**6**) as a convenient probe of mechanism in the range of 184–203°. At 203° equilibrium between **1** and **2** was established by heating either isomer for 48 hr.[2]

---

[1] (a) W. von E. Doering and A. Krantz, unpublished results; (b) A. Krantz, Ph.D. thesis, Yale University, New Haven, Conn., 1967; (c) cited by A. Krantz and C. Y. Lin, *Chem. Commun.*, 1287 (1971).