gave 5.56 g of product, mp 129.5–131.0° (lit.[2] mp 155–157°). We cannot account for the difference in the melting points, but all of our physical data confirm the structure of **2c**.

Anal. Calcd for $C_{10}H_7N_3O_4$: C, 51.51; H, 3.03; N, 18.02. Found: C, 51.28; H, 3.07; N, 18.09.

Aminomaleimides (3).—The aminomaleimides were prepared according to methods reported in the literature for the preparation of pyridazinones, except for the dimethyl derivative, which was reported as the aminomaleimide, 1-acetylaminomaleimide,[9] 1,1-dimethylaminomaleimide,[1] 1-benzenesulfonylaminomaleimide,[9] and 1-(2,4-dinitrophenyl)aminomaleimide.[10]

1-(2-Nitrophenyl)aminomaleimide (3c).—Glacial acetic acid (100 ml) was added to 4.0 g of 1-(2-nitrophenyl)-2-(3-carboxyacryloyl)hydrazine. The resulting dark red solution was refluxed for 3 hr and the solvent was removed *in vacuo* to give a red-orange solid. Recrystallization from 95% ethanol produced 0.64 g of the aminomaleimide, mp 136.0–137.5°.

Anal. Calcd for $C_{10}H_7N_3O_4$: C, 51.51; H, 3.03; N, 18.02. Found: C, 51.47; H, 3.08; N, 17.94.

1-(4-Nitrophenyl)aminomaleimide (3e).—The experiment was performed as described for the preparation of **3c**. 1-(4-Nitrophenyl)-2-(3-carboxyacryloyl)hydrazine gave 1.3 g of dark orange **3e**, mp 179.0–180.5° (EtOH).

Anal. Calcd for $C_{10}H_7N_3O_4$: C, 51.51; H, 3.03; N, 18.02. Found: 51.69; H, 3.22; N, 17.74.

Rearrangement of Aminoisomaleimides (2). A. In Acetic Acid.—Glacial acetic acid was added to 0.006 mol of the aminoisomaleimide and the mixture was refluxed for the time indicated with each compound. The solvent was removed *in vacuo* and the product was purified by recrystallization: 1-acetylaminoisomaleimide, 5 hr; 1,1-dimethylaminoisomaleimide, 2 hr; 1-benzenesulfonylaminoisomaleimide, 6 hr; 1-(2,4-dinitrophenyl)-aminoisomaleimide, 4 days; 1-(2-nitrophenyl)aminoisomaleimide, 18 hr; 1-(3-nitrophenyl)aminoisomaleimide, 6 days; and 1-(4-nitrophenyl)aminoisomaleimide, 2 days (no transformation took place).

In all but one case, the product formed was found to be identical with the corresponding aminomaleimide. The exception was the 3-nitrophenyl derivative, which rearranged to the pyridazinone.

B. In Sulfuric Acid.—The various nitrophenylaminoisomaleimides **2c–f** were treated with sulfuric acid according to the methods described by Baloniak.[2] **2d** and **2e** formed the corresponding pyridazinones **4d** and **4e** and **2c** gave the aminomaleimide **3c**. The 2,4-dinitrophenyl derivative **2f** was converted to a mixture consisting of the aminomaleimide **3f** and 3-carboxyacryloylhydrazine **1f**. The nmr spectrum of this mixture was identical with the spectrum of a 1:1 mixture of authentic **3f** and **1f**.

Reaction of 3-Carboxyacryloylhydrazines with Sulfuric Acid or Sulfuric–Acetic Acid Mixture.—The various nitrophenyl 3-carboxyacryloylhydrazines were treated according to methods reported by Baloniak.[2] The 3-nitrophenyl- and 4-nitrophenyl-substituted hydrazines **1d** and **1e** formed the corresponding pyridazinones **4d** and **4e**. The 2-nitrophenyl and 2,4-dinitrophenyl derivatives **1c** and **1f** gave the corresponding aminomaleimides **3c** and **3f**.

In the case of **1d** treatment with refluxing acetic acid also produced the corresponding pyridazinone **4d**.

Attempted Rearrangement of Aminomaleimides with Sulfuric Acid or Sulfuric–Acetic Acid. A. Sulfuric Acid.—A 0.5-g sample of the 2-nitro- and a 0.42-g sample of the 4-nitrophenylaminomaleimides were dissolved in 2.5 and 2 ml of concentrated sulfuric acid, respectively. The solutions obtained were added to 10 and 8 ml of distilled water to produce 0.46 and 0.40 g of recovered starting material.

B. Sulfuric–Acetic Acid.—Glacial acetic acid (50 ml) was added to 50 ml of concentrated sulfuric acid and the resulting solution was cooled to room temperature. A 1.64-g sample of 1-(2,4-dinitrophenyl)aminomaleimide was dissolved in the acid mixture and the mixture was stirred for 24 hr. On addition of water a solid (1.30 g) precipitated which was identified as starting material.

Registry No.—**1c**, 39704-29-5; **1d**, 39704-30-8; **1e**, 39704-31-9; **1f**, 31413-88-4; **2a**, 6903-87-3; **2b**, 30986-27-7; **2c**, 39704-35-3; **2d**, 39838-39-6; **2e**, 39704-36-4; **2f**, 31413-91-9; **3c**, 14938-99-9; **3e**, 20970-39-2; **3f**, 20970-35-8; **4d**, 39704-40-0; **4e**, 39704-41-1.

Acknowledgment.—We are indebted to Mr. Michael Wuerthele of Scott Graphics Inc., Holyoke, Mass., for the microanalyses.

Rates of Intramolecular Diels–Alder Reactions of Pentadienylacrylamides

HEINZ W. GSCHWEND* AND AVELINA O. LEE

Research Department, Pharmaceuticals Division, CIBA-GEIGY Corporation, Summit, New Jersey 07901

HANS-PETER MEIER

Pharma Division, Production Department, CIBA-GEIGY A. G., 4000 Basel, Switzerland

Received February 26, 1973

Among the substrates derived from 4,5-diphenylpentadienylamines **4**, prepared for a study of the intramolecular Diels–Alder reaction, the highly reactive N–CH_3 amide of fumaric acid ethyl ester **7a** directly produces the endo cycloadduct **8a** at 0°, whereas the *N*-demethyl derivative **7b** is far less reactive. The N–CH_3 cinnamamide **9** and *N*-allylamine **11** give predominantly the cycloadducts *trans*-**10** at 90° and *cis*-**12** at 140°, respectively, while the acrylamide **13a** produces an equal mixture of *trans*-*cis*-**14a**. The structures and relative configurations of the cycloadducts are discussed and elaborated. The kinetic parameters for the intramolecular cycloadditions of **13a–d** reveal that $\Delta G^{\ddagger}$ decreases from 28.7 kcal/mol for **13a** by increments of $\Delta\Delta G^{\ddagger} \cong 1.2$ kcal/mol for the homologs **13b** and **13c** to 25.3 kcal/mol for **13d**. This phenomenon is discussed in terms of a conformational equilibrium on part of the substrate, as evinced by nmr studies.

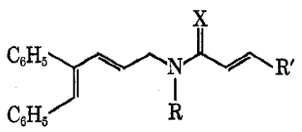
The marked rate-increasing or -decreasing effects of alkyl substituents in the [4 + 2] cycloaddition of dienes with dienophiles has been observed in numerous cases and is well documented.[1–3] The reactivity of a diene increases if appropriate alkyl substituents, such as in the 2 and 3 positions of butadiene, move the conformational equilibrium to the s-cis form, the prerequisite diene conformation for the Diels–Alder reaction. Conversely, bulky substituents at the dienophile generally have a rate-decreasing effect. The present study of the intramolecular Diels–Alder reaction with amides of α,β-unsaturated acids reveals still another phenomenon: the rate-accelerating influence of a bulky substituent attached neither to the diene nor to the dienophile component but to an atom linking the two together.

(1) S. Seltzer in "Advances in Alicyclic Chemistry," Vol. 2, Academic Press, New York, N. Y., 1968, pp 17–32.

(2) R. Huisgen, R. Grashey, and J. Sauer in "The Chemistry of Alkenes," S. Patai, Ed., Wiley-Interscience, New York, N. Y., 1964, pp 878–929.

(3) J. G. Martin and R. K. Hill, *Chem. Rev.*, **61**, 537 (1961).

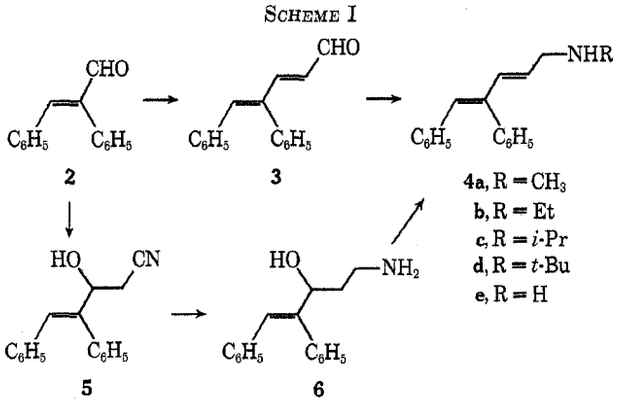
Synthesis of Substrates.—For various reasons the acrylamides **1** were chosen as substrates for this study



1

of the intramolecular [4 + 2] cycloaddition. The initial goal then was the preparation of the parent 4,5-diphenyl-2,4-pentadienylamines in which the size of R would be varied from H to *t*-Bu. The synthesis of these amines **4** is outlined in Scheme I.

SCHEME I



4a, R = CH_3
b, R = Et
c, R = *i*-Pr
d, R = *t*-Bu
e, R = H

2 **3** **5** **6**

α-Phenylcinnamaldehyde (**2**) was readily obtained according to methods described previously.[4] The cis arrangement of the two phenyl groups was confirmed by the uv data of the known[5] α-phenylcinnamyl alcohol obtained by $LiAlH_4$ reduction of **2**. Homologization to the aldehyde **3** is most cleanly accomplished *via* the directed aldol condensation[6a,b] of **2** with the lithiated cyclohexylimine of acetaldehyde and subsequent hydrolysis and dehydration. The trans stereochemistry of the newly introduced double bond is secured by the nmr data: the vinylic proton next to the aldehyde function, appearing at δ 5.78 ppm, exhibits the large trans coupling constant of 15.5 Hz in addition to the 8-Hz coupling with the aldehydic proton. Formation of the appropriate imines[7] and subsequent reduction with $NaBH_4$ gave access to the desired amines **4**, which were characterized as their hydrochloride salts. Their uv spectra are most characteristic and show absorption maxima at 206 nm (log ε 4.38), 224 (4.13), 232 (4.08), 288 (4.49), and 308 (4.26). In order to confirm the assumption that the cis relationship of the two phenyl groups was retained during the steps **2** → **4**, one of which involved the intermediacy of an allylic carbonium ion, the disubstituted double bond of **4c** was cleanly and selectively reduced with $(Ph_3P)_3RhCl$–H_2. The uv data of the dihydro product [257 nm (log ε 4.03)] are clearly in good agreement with the *cis*-stilbene chromophore. The primary amine **4e** was accessible *via* the alternate route outlined in Scheme I. Condensation of **2** with α-lithioacetonitrile[8] afforded a good yield of the hydroxy nitrile **5**, which after $LiAlH_4$ reduction and acid-catalyzed dehydration of the crystalline amino alcohol **6** produced the well-identified primary amine **4e**.

The next step toward a substrate **1** consisted in linking the amines **4** with an appropriate dienophile moiety. We were in fact looking for a substrate **1** which would meet the following criteria for a kinetic study: (a) solubility in a nonpolar solvent suitable for uv measurements; (b) crystalline, easily purified compounds; (c) undergo the intramolecular [4 + 2] cycloaddition in a practical temperature range, such as 25–150°. Scheme II outlines the substrates actually prepared by acylation or alkylation of the corresponding amines **4**.

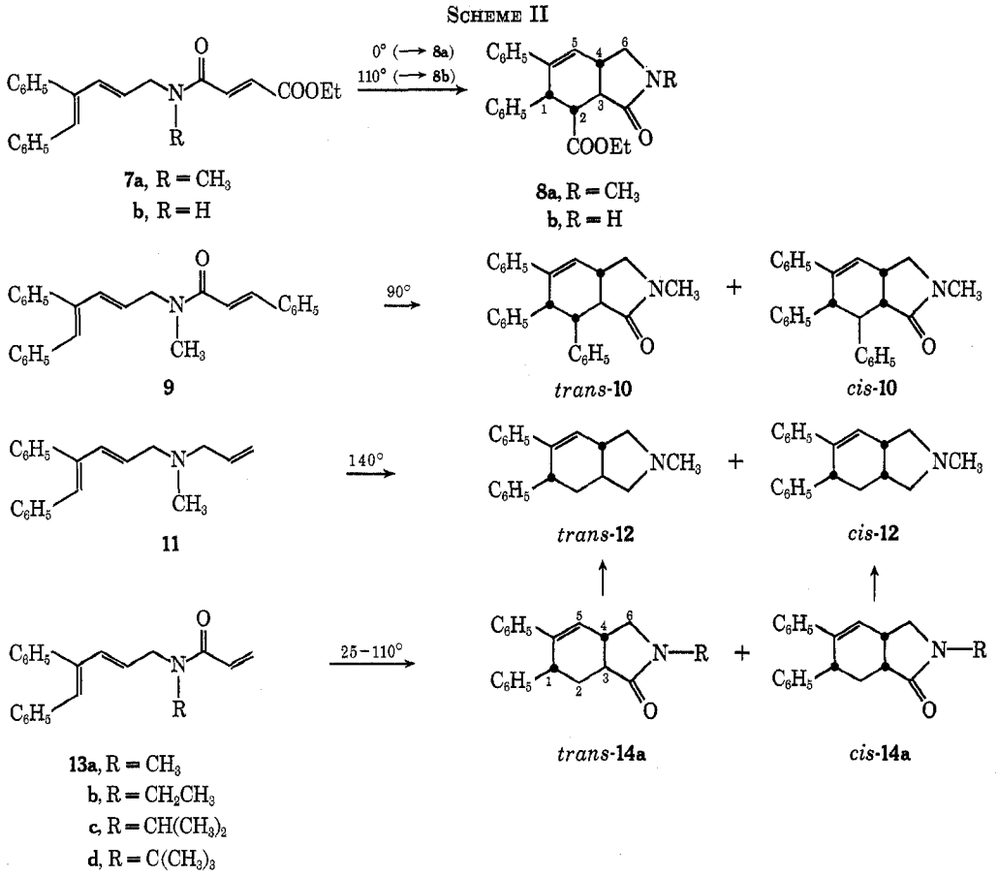
As we have experienced with other examples,[9,10] the intermediate amide **7a** of fumaric acid ethyl ester was far too reactive and could not be isolated. Instead, the product of an endo addition **8a** was isolated directly in 63% yield. In sharp contrast to **7a**, which undergoes the cycloaddition at 0° or below, the demethylamide **7b** could be isolated without difficulty. Intramolecular cycloaddition occurs only above 100° to produce **8b** in 58% yield. The respective structures and the relative configurational relationships of the four asymmetric centers of these two adducts are firmly supported by the analytical and spectral data. Both cycloadducts **8a** and **8b** exhibit the styrene chromophore at 242 nm (log ε 4.06). The ir carbonyl frequencies for ester and γ-lactam are at 1718 and 1686 (**8a**) and at 1713 and 1664 cm^{-1} (**8b**), respectively. A 100-MHz nmr spectrum with double-resonance experiments permitted the assignment of all the important protons in **8a**. With the cis arrangement of phenyl and carboethoxy group, the ester protons are heavily shielded by the aromatic ring current and appear at 0.90 and 3.75 ppm (ABX_3 system owing to hindered rotation). The benzylic hydrogen at 4.57 ppm is coupled to H_2 (3.22 ppm) with J = 7 Hz. The latter, forming nearly a 180° angle with H_3 (2.8 ppm), exhibits the large trans-diaxial coupling of 13 Hz. The N–CH_3 group appears normal at 2.9 ppm and the adjacent CH_2 protons (H_6) as a multiplet at 3.4 ppm. The vinylic proton H_5 at δ 6.26 forms approximately a 90° angle with H_4 (2.82 ppm) and is virtually uncoupled. The signal does sharpen somewhat by irradiating at the frequency of the benzylic proton (H_1).

The cinnamamide **9**, incorporating a less powerful dienophile, was isolated in crystalline form and with an approximate half-life of 2 hr underwent cycloaddition at 90° to a 8:1 mixture of the endo and exo adducts **10** separable by preparative tlc.

The isolated and unactivated double bond, representing the least reactive dienophile available, was tested by preparing the *N*-allylamine **11**. The free base, isolated and characterized as its hydrochloride salt, was in fact amenable to a [4 + 2] cycloaddition under relatively mild conditions. After 12 hr at 140° the product mixture consisted, according to nmr and glc analysis, of 84% *cis*-**12** and 16% *trans*-**12** identical

(4) K. Alder, J. Haydn, K. Heimbach, and K. Neufang, *Justus Liebigs Ann. Chem.*, **586**, 128 (1954).
(5) J. H. Brewster and H. O. Baya, *J. Org. Chem.*, **29**, 105 (1964).
(6) (a) G. Wittig and H. Reiff, *Angew. Chem.*, **80**, 8 (1968); (b) G. Wittig and P. Suchanek, *Tetrahedron, Suppl. 8*, Part I, 347 (1966).
(7) E. M. Kosower and T. S. Sorensen, *J. Org. Chem.*, **28**, 692 (1963).
(8) E. M. Kaiser and C. R. Hauser, *J. Org. Chem.*, **33**, 3402 (1968).
(9) H. W. Gschwend and H. P. Meier, *Angew. Chem., Int. Ed. Engl.*, **11**, 294 (1972).
(10) H. W. Gschwend, *Helv. Chim. Acta*, in preparation.

SCHEME II



spectroscopically with the reduction products obtained from *cis–trans*-**14** (see below).

The most convenient substrates, meeting all our criteria for a kinetic study, were found to be the acrylamides **13**. The amides **13a–d** were all obtained in crystalline form *via* standard procedures. The intramolecular cycloaddition was carried out preparatively in the case of **13a**. Upon refluxing a solution of the amide for 8 hr in toluene and subsequent separation of the product mixture, 42% *trans*-**14a**, 40% *cis*-**14**, and 8% unreacted starting material were isolated. The assignment of the relative configurations at C_3–C_4 is based partly on the observation that base-catalyzed isomerization of a 1:1 mixture of *cis–trans*-**14a** leads to an enrichment of the cis component, which is considered to be the thermodynamically more stable isomer. More significant, however, are the nmr data. In *cis*-**14a** the coupling constant of 5.5 Hz between H_1 and both methylene protons at C_2 suggests an axial position of the phenyl group at C_1. An axial phenyl ring would be expected to exert a shielding effect on the N–CH_3 group, which indeed appears shifted by 0.2 ppm to higher field in comparison to *trans*-**14a** the trans fused lactam. Additionally, the coupling constant of 4 Hz between H_5 and H_4 reflects a dihedral angle of 20–30°, whereas in *trans*-**14a** the angle is closer to 90° and the coupling very small (1.5 Hz). The spectrum of *trans*-**14a** is very similar to the one of **8a**, also assigned the trans ring fusion (*cf.* Figure 1).

Kinetics.—The characteristic uv spectra of the substrates **13a–d** with a maximal extinction coefficient in the 290-nm area, an absorption which is absent in the products, made it possible to monitor the course of the cycloaddition by uv spectroscopic measurements of the concentration of the starting material. Another feasible, though less accurate, method was the nmr spectroscopic following of the reaction, which, however, was used only for a rough determination of the most convenient reaction temperature as well as for an estimation of the trans:cis product ratio. All kinetic measurements were carried out at uv concentrations in decahydronaphthalene (6×10^{-5} *M*, approximately corresponding to infinite dilution) and the samples (7–13 per run) were analyzed without further dilution. The data points which were collected up to 80% conversion were analyzed by a simple linear regression computer program for the determination of first-order rate constants.[11] The calculated standard deviations of the slope were used as the limits of error for the rate constants. The first-order rate constants k determined by this method clearly include both k_{trans} and k_{cis}, since both possible products *trans–cis*-**14a–d** were formed during the cycloaddition. As determined by nmr integration of the product mixture, k_{trans} was nearly equal to k_{cis} for all four substrates **13a–d**. The activation parameters were determined by the least-squares method using standard computer programs.[12] The limits of error include both the maximal deviations in the rate constants and temperature. Table I records the data.

Discussion

A qualitative comparison of the results of the intramolecular [4 + 2] cycloaddition of the substrates **7a**

(11) A. A. Frost and R. G. Pearson, "Kinetics and Mechanism," 2nd ed, Wiley, New York, N. Y., 1961.

(12) ACTENG, written by D. F. deTar, Department of Chemistry, Florida State University.

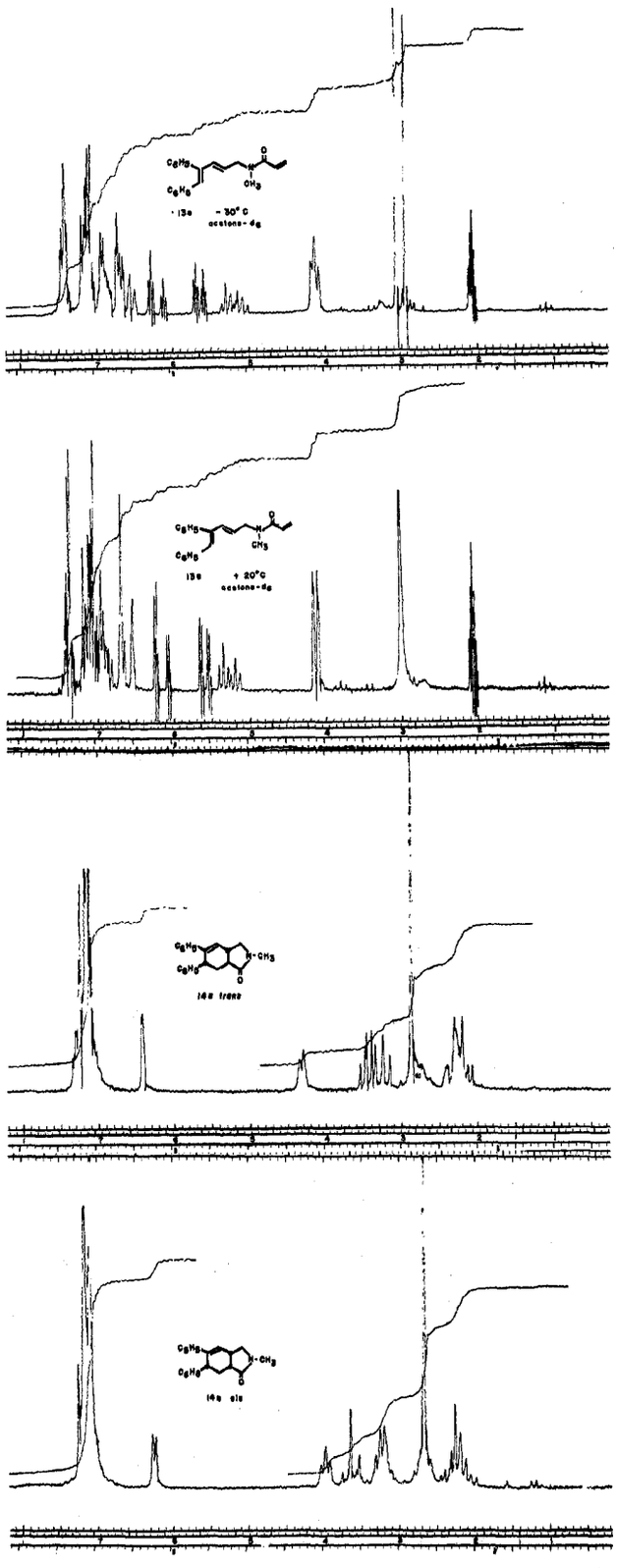


Figure 1.—Nmr spectra (100 MHz) of **13a** in acetone-d_6 and of *trans*-**14a** and *cis*-**14a** in $CDCl_3$.

and **9** with those described earlier[9,10] reveals surprisingly that the additional phenyl substituent in the 4 position of the pentadienylamine moiety did not affect the rate of the reaction in any dramatic way. A quite remarkable effect, however, on the rate of cycloaddition is noticed by replacing the N–CH_3 group with a hydrogen. Aside from the influence on the gross conformational equilibrium of the substrate exerted by size of the N substituent, as outlined below, intermolecular hydrogen bonding in nonpolar solvents in the case of **7b** would, relative to **7a**, not only alter the electronic properties of the dienophile part of the molecule but most certainly also change the conformational situation *via* bimolecular interactions. The possibility of intermolecular H bonding in **7b** is thus considered to be the dominant factor for its markedly decreased reactivity as compared to **7a**. It would be expected that the cycloaddition would be considerably accelerated in a polar solvent, such as DMF.

Intramolecular Diels–Alder reactions, in which isolated nonactivated double bonds add to the highly reactive, substituted cyclopentadienes and *o*-quinodimethanes, have been reported previously.[13,14] More recently it was observed[15] that *N*-allylamines undergo an intramolecular cycloaddition to an endocyclic cis–cis butadiene system, although the temperatures required were rather high (180°) and the yields of cycloadducts low. It was therefore surprising and remarkable that the cycloaddition of the *N*-allylamine **11**, in which the diene moiety has a trans–trans geometry and is not particularly activated, proceeds under relatively mild conditions. It is also of interest to note that in the absence of a terminal π system, which otherwise stabilizes a transition state leading to the trans-fused cycloadducts, such as in **7a** or **9**, the cis-fused product is favored by a respectable margin, namely, 84:16. This observation parallels the results of Oppolzer in the cycloadditions of *o*-quinodimethanes.[14a,b] The transition from an *N*-allyl to an *N*-acryloyl system (**13a–d**) leads only to a modest increase in reactivity. This is rationalized by the fact that in the transition state of **13a** → **14a** the terminal double bond can no longer assume coplanarity with the amide carbonyl, thus losing some of the reactivity of an α,β-unsaturated double bond system. Again, in the absence of a terminal π system the trans-fused product is not favored and the cis:trans ratio remains through all the products **14a–d** virtually the same, namely, approximately unity. The kinetic measurements for the cycloadditions of **13a–d** (Table I) clearly indicate that the free energy of activation ($\Delta G^{\ddagger}$) decreases with increasing size of the N substituent. In the four examples studied, namely, methyl, ethyl, isopropyl, and *tert*-butyl, the average decrease in $\Delta G^{\ddagger}$ ($\Delta\Delta G^{\ddagger}$) is 1.2 kcal/mol. Although the size of the respective $\Delta\Delta G^{\ddagger}$'s is not very large, it is nevertheless significant, but quite definitely of a different order of magnitude than the probable, yet not actually determined, $\Delta\Delta G^{\ddagger}$ between **7a** and **7b** (N–CH_3 *vs.* N–H). The values of approximately 1.2 kcal/mol happen to be very close to the differences in the inversion barriers of N-substituted aziridines (N–CH_3 to N–Et, $\Delta\Delta G^{\ddagger}$ = 1.4 kcal/mol).[16]

(13) (a) G. Brieger, *J. Amer. Chem. Soc.*, **85**, 3783 (1963); (b) E. T. McBee, J. O. Stoffer, and H. P. Braendlin, *J. Amer. Chem. Soc.*, **84**, 4540 (1962).

(14) (a) W. Oppolzer, *J. Amer. Chem. Soc.*, **93**, 3833, 3834, 3836 (1971); (b) W. Oppolzer, 13th Medicinal Chemistry Symposium, Iowa City, Iowa, June 18–22, 1972.

(15) A. L. Johnson and H. E. Simmons, *J. Org. Chem.*, **34**, 1140 (1969).

(16) (a) J. B. Lambert and W. L. Oliver, *J. Amer. Chem. Soc.*, **91**, 7774 (1969); (b) J. M. Lehn and J. Wagner, *Chem. Commun.*, 148 (1968); (c) A. Loewenstein, J. F. Neumer, and J. D. Roberts, *J. Amer. Chem. Soc.*, **82**, 3599 (1960); (d) A. T. Bottini and J. D. Roberts, *ibid.*, **90**, 5203 (1968); (e) S. L. Brois, *ibid.*, **89**, 4242 (1967).

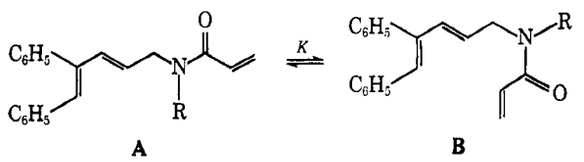
TABLE I
KINETIC DATA FOR THE INTRAMOLECULAR CYCLOADDITIONS

13a–d ⟶ *cis-trans*-**14a–d**

Compd	Temp, °C (±0.1)	Rate constant $K = k_{trans} + k_{cis} \times 10^{-5}$, sec^{-1}	Activation parameters $\Delta H^{\ddagger}$, kcal/mol	$\Delta S^{\ddagger}$, cal/°K mol	$\Delta G^{\ddagger}_{298}$, kcal/mol
	90.2	1.2275 ± 0.0147			
13a	96.9	2.3797 ± 0.0141	24.7 ± 0.3	−13.4 ± 0.7	28.7 ± 0.5
	101.6	3.5570 ± 0.0211			
	109.4	7.3025 ± 0.0857			
	90.0	2.1003 ± 0.0147			
13b	96.9	3.8192 ± 0.0264	22.2 ± 0.6	−19.2 ± 1.5	27.9 ± 1.0
	101.6	5.4197 ± 0.0672			
	109.4	10.9470 ± 0.2551			
	69.4	1.7056 ± 0.0142			
13c	76.0	3.1147 ± 0.0090	20.4 ± 0.4	−21.2 ± 1.0	26.7 ± 0.7
	82.3	5.2758 ± 0.0670			
	90.0	9.8378 ± 0.1781			
	34.0	0.5233 ± 0.0051			
13d	45.2	1.8986 ± 0.0127	21.0 ± 0.1	−14.4 ± 0.3	25.3 ± 0.2
	52.0	3.8217 ± 0.0248			
	60.7	8.9581 ± 0.0636			

It seems appealing to explain this phenomenon in terms of the conformational differences among the four substrates **13a–d**. Since both diene and dienophile moieties are part of the same substrate undergoing an intramolecular Diels–Alder reaction, a new conformational equilibrium becomes a codeterminant factor. In addition to the prerequisite s-cis conformation of the diene part, the rate of cycloaddition depends upon the population of the one conformer in which the spatial relationship of the four reaction centers starts to resemble the geometry of the transition state. Thus, the conformational equilibrium of the least reactive N–CH_3 amide **13a** would appear to be almost exclusively on the side of the "stretched" or linear conformer A (Scheme III), whereas the reactive **13d**, the other extreme, would virtually be frozen as the bent conformer B.

SCHEME III



A B

Nmr spectroscopy provides a practical tool to determine conformational equilibria, which in this particular case seem to be determined essentially by the energy barrier to rotation around the amide bond. However, the known dependence of such measurements upon concentration and in particular the solvent[17] made it rather difficult if not impossible to correlate the kinetic data (infinite dilution, in decahydronaphthalene) with any nmr data. A series of nmr studies (in acetone-d_6) revealed that **13d** was exclusively one conformer (B) between −30 and 20° (at higher temperatures cycloaddition occurs). At −30° the other three substrates (**13a–c**) exhibited the sharp and distinctly different signals of two conformers in the ratios of 1:1 (**13a**) (see Figure 1), 3:2 (**13b**), and 1:2 (**13c**). Between 0 and 10° the signals coalesce and appear sharp at 20°. The established presence of such a conformation equilibrium makes the meaning of the calculated activation parameters somewhat questionable. The first-order rate constants for the formation of the products may actually be composite: $dP/dt = k'R$ with $k' = kK(1 + K)$.[18] The conformational equilibrium between forms A and B is described by the constant K, and k' would be the rate constant for the disappearance of the reactive conformer B. Thus, only with extreme K values (very small or large) would a standard transition-state theory plot produce accurate activation parameters. Since **13d** appears to exist almost exclusively as the reactive conformer B (K large) as evinced in the nmr studies, the rather crude (solvent difference) correlation of this fact with the measurements of the rate constants seems to indicate that the activation parameters for **13d** are probably the most meaningful ones. The calculated values for the entropies and enthalpies of activation for the other congeners, in particular though for **13b** and **13c**, are likely to be less reliable.

(17) (a) J. V. Hatton and W. G. Schneider, *Can. J. Chem.*, **40**, 1285 (1963); M. L. Blanchard, A. Chevallier, and G. J. Martin, *Tetrahedron Lett.*, 5057 (1967). (c) R. C. Newmann, Jr., and L. B. Young, *J. Phys. Chem.*, **69**, 2570 (1965).

Experimental Section

The physical data were obtained as follows: melting points in a Thomas-Hoover melting point apparatus (uncorrected); ir spectra on a Perkin-Elmer 521; uv curves on a Cary Model 14; mass spectra on a AEI MS 902 by direct insertion; nmr spectra on either a Varian A-60 or a XL-100 using tetramethylsilane as internal standard. The following abbreviations are used: b, broad; w, weak; sh, shoulder; ex, exchangeable with D_2O; s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet.

4,5-Diphenyl-2,4-pentadienal (3).—To a solution of 36.5 ml of diisopropylamine in 260 ml of dry ether was added 162 ml 1.6 *M* BuLi–hexane, the temperature being kept below −10°. Then 32.4 g (259 mmol) of cyclohexylacetaldimine in 260 ml of ether was added dropwise. After 15 min the temperature was lowered to −70° and a solution of the aldehyde **2** (45 g, 216 mmol) in 1.2 l. of ether was added dropwise. After the addition the temperature was raised to 20°, then again lowered to −10°, and 450 ml of water was added. The ethereal layer was then separated and stirred for 16 hr vigorously with 300 ml of benzene, 108 ml of AcOH, and 270 ml of H_2O. The organic layer was again separated and washed with dilute H_2SO_4, ice water, dilute NaOH, and finally brine. After drying the sol-

(18) Suggestion of a referee of this paper.

vent and evaporation, the residue (49 g) was crystallized from EtOH to give 32.2 g of **3**, mp 92–94°, and a second and third crop of 9.4 g, mp 85–92° (83%): ir (Nujol) 1675, 760, 710, 690 cm^{-1}; uv (CH_3OH) 228 mμ (ε 10,500), 236 (10,900), 326 (39,400); nmr ($CDCl_3$) δ 5.78 (q, J = 15.5 and 8 Hz, 1 H), 6.7–7.6 (m, 12 H), 9.65 (d, J = 8 Hz, 1 H).

Anal. Calcd for $C_{17}H_{14}O$: C, 87.15; H, 6.02. Found: C, 87.12; H, 6.21.

***N*-(4,5-Diphenyl-2,4-pentadienyl)-*N*-methylamine (4a).**—The aldehyde **3**, 23.1 g (99 mmol), was stirred together with 53 g of Na_2SO_4 in 230 ml of 1.73 N CH_3NH_2–benzene for 4 hr at room temperature. The heterogenous mixture was then filtered and the benzene was evaporated to give 25 g of crude methylimine. This imine was dissolved in 415 ml of ethanol and cooled to 0° and 5.8 g of $NaBH_4$ was added. After an additional 1 hr at room temperature, the ethanol was evaporated *in vacuo*, the residue was made acidic with 5 N aqueous HCl, then made basic with 30% NaOH, and the amine was extracted into CH_2Cl_2. After drying over Na_2SO_4 and removal of the solvent, 25.9 g of crude product was obtained. This was dissolved in ethanol and 1 molar equiv of ethereal HCl was added. A total of 19.7 g of hydrochloride was thus collected: mp 154–158° (70%); ir (Nujol) 760, 700 cm^{-1} (broad); uv (CH_3OH) 207 mμ (ε 19,300), 224 (12,300), 232 (11,900), 288 (27,800); on free base nmr ($CDCl_3$) δ 1.08 (s, ex, 1 H), 2.37 (s, 3 H), 3.24 (d, J = 6.5 Hz, 2 H), 5.4 (td, J = 6.5, 16 Hz, 1 H), 6.56 (s, 1 H), 6.58 (d, J = 16 Hz, 1 H), 6.7–7.5 (m, 10 H).

Anal. Calcd for $C_{18}H_{19}N \cdot HCl$: C, 75.64; H, 7.05; N, 4.90. Found: C, 75.48; H, 7.13; N, 5.20.

***N*-(4,5-Diphenyl-2,4-pentadienyl)-*N*-ethylamine (4b).**—From 2 g of aldehyde **3** was obtained 2.28 g of imine by following the above procedure. This was reduced as described for **4a** to give 2.2 g of crude amine. From ethanol a total of 2.1 g of hydrochloride salt was collected: mp 154–156° (80%); ir (Nujol) 980, 760, 700, 690 cm^{-1}; uv (CH_3OH) 207 mμ (ε 23,400), 233 (12,100), 288 (30,800), 308 (18,000).

Anal. Calcd for $C_{19}H_{21}N \cdot HCl$: C, 76.11; H, 7.40; N, 4.67. Found: C, 76.33; H, 7.64; N, 4.66.

***N*-(4,5-Diphenyl-2,4-pentadienyl)-*N*-isopropylamine (4c).**—From 2 g (8.6 mmol) of aldehyde **3** and 19.2 ml of 1.8 N isopropylamine in benzene one obtained, after a reaction of 20 hr at room temperature, 2.4 g of crude imine. Reduction with $NaBH_4$ for 2 hr and work-up as outlined for **4a** produced 2.3 g of crude amine. From ethanol a total of 2.17 g of hydrochloride salt was collected: mp 192–193° (80%); ir (Nujol) 980, 750, 700, 680 cm^{-1}; uv (CH_3OH) 232 mμ (ε 13,000), 288 (31,360), 308 (18,200).

Anal. Calcd for $C_{20}H_{23}N \cdot HCl$: C, 76.53; H, 7.70; N, 4.46. Found: C, 76.57; H, 7.63; N, 4.50.

***N*-tert-Butyl-*N*-4,5-diphenyl-2,4-pentadienylamine (4d).**—The aldehyde **3** (2.0 g, 8.6 mmol) was stirred with 29 ml of 1.8 M *t*-$BuNH_2$–benzene for 44 hr. The crude product, 2.5 g, was reduced as described above to give 2.5 g of crude amine. From hexane, 1.1 g of crystalline **4a** was obtained, mp 98°. To the mother liquor in ethanol was added ethereal HCl and an additional 1.16 g of hydrochloride salt was collected, mp 196–198° (total yield 78%). The analytical data were obtained on the free base: ir (Nujol) 970, 750, 700, 688 cm^{-1}; uv (CH_3OH) 206 mμ (ε 24,970), 224 (13,400), 232 (12,100), 288 (31,200), 308 (18,000).

Anal. Calcd for $C_{21}H_{25}N$: C, 86.55; H, 8.65; N, 4.81. Found: C, 86.78; H, 8.85; N, 4.67.

4,5-Diphenyl-2,4-pentadienylamine (4e) (2 → 5 → 6 → 4e).—In a three-necked flask 16.5 ml of 1.6 M BuLi in hexane was cooled to −75° under a N_2 atmosphere. Then 16.5 ml of dry THF was added all at once and immediately thereafter a solution of 980 mg of CH_3CN in 24 ml of THF over 5 min. Stirring was continued for 1 hr at −70° and then a solution of 5 g (24 mmol) of aldehyde **2** was added. The cold bath was removed, stirring was continued for 1 hr and then ice and dilute HCl were added. The organic layer was diluted with ether. After drying the organic part over Na_2SO_4 and removal of the solvent, a solid residue of 6 g was obtained (**5**). This material was dissolved in 350 ml of ether and carefully added to a cold suspension of 1.5 g of $LiAlH_4$ in 90 ml of ether. After stirring at room temperature for 16 hr, excess hydride was destroyed by the addition of 1.5 ml of H_2O, 1.5 ml of 15% NaOH, and 4.5 ml of H_2O. The mixture was filtered and the filtrate was evaporated to give a residue of 5.6 g. Crystallization from ether gave a total of 3.6 g of hydroxyamine **6**: mp 114–116° (60% overall); ir (Nujol) 3350, 3290, 700, 690 cm^{-1}; uv (CH_3OH) 217–224 mμ (ε 15,400), 255 (13,500).

Anal. Calcd for $C_{17}H_{19}NO$: C, 80.57; H, 7.56; N, 5.53. Found: C, 80.20; H, 7.68; N, 5.65.

The hydroxy amine **6** (15.5 g, 61.3 mmol) was refluxed in 150 ml of dioxane and 460 ml of 2 N H_2SO_4 for 5 hr. The mixture was cooled, made basic with 30% NaOH, and extracted into $CHCl_3$. After drying over Na_2SO_4 and removal of the solvent, the residue weighed 14.8 g. From ethanol and an equivalent amount of ethereal HCl 11.4 g of the hydrochloride salt of **4e** was obtained: mp 212°; ir (Nujol) 1610, 1660, 1510, 790, 705, 690 cm^{-1}; uv (CH_3OH) 224 mμ (ε 12,400), 232 (11,240), 287 (28,000), 308 (17,000).

Anal. Calcd for $C_{17}H_{17}N \cdot HCl$: C, 75.13; H, 6.68; N, 5.15. Found: C, 75.22; H, 6.89; N, 4.95.

Ethyl 5,6-Diphenyl-2-methyl-3-oxo-4,5,3a,7a-tetrahydroisoindoline-4-carboxylate [4a → (7a) → 8a].—A solution of 11.1 g (44.7 mmol) of **4a** (free base) in 450 ml of CH_2Cl_2 was stirred in an ice bath. Then 4.4 ml of pyridine and a solution of 7.7 g of fumaric acid chloride ethyl ester in 90 ml of CH_2Cl_2 were added. The mixture was stirred at 25° overnight. The dark solution was subsequently washed with a cold Na_2CO_3 solution and dried over Na_2SO_4. After evaporation of the solvent, the residue of 17 g was crystallized from benzene to give a first crop of 7.9 g of **8a**, mp 247–251°, and a second crop of 2.5 g, mp 230–240° (63% yield): ir (Nujol) 1718, 1686 cm^{-1}; uv (CH_3OH) 242 mμ (ε 11,450); nmr ($CDCl_3$, 100 MHz) δ 0.86 (t, J = 7 Hz, 3 H), 2.82 (m, 2 H), 2.85 (s, 3 H), 3.22 (J = 12 and 7 Hz, 1 H), 3.0–4.0 (m, 3 H), 4.57 (d, J = 7 Hz, 1 H), 6.26 (s, 1 H), 7.0–7.3 (m, 10 H).

Anal. Calcd for $C_{24}H_{25}NO_3$: C, 76.77; H, 6.71; N, 3.73. Found: C, 76.90; H, 6.72; N, 3.84.

Ethyl *N*-(4,5-diphenyl-2,4-pentadienyl)fumaramate (7b).—From 9.7 g (41.3 mmol) of amine **4e** was obtained, in the same manner as outlined for **7a**, 14.7 g of crude amide **7b**. This crude material (700 mg) was crystallized from ether to give 200 mg: mp 87–89°; ir (Nujol) 1713, 1664, 1644, 1632, 1556 cm^{-1}; uv (CH_3OH) 208 mμ (ε 38,300), 224 (27,100), 288 (36,000), 308 (21,600); nmr ($CDCl_3$) δ 1.23 (t, J = 7 Hz, 3 H), 4.2 (q, J = 7 Hz, 2 H), 4.0 (dd, $J \cong$ Hz, 2 H), 5.25 (t d, J = 6, 16 Hz, 1 H), 6.52 (s, 1 H), 6.55 (d, J = 16 Hz, 1 H), 6.7–7.5 (11 H).

Anal. Calcd for $C_{23}H_{23}NO_3$: C, 76.43; H, 6.41; N, 3.88. Found: C, 76.81; H, 6.54; N, 4.17.

Ethyl 5,6-Diphenyl-3-oxo-4,5,3a,7a-tetrahydroisoindoline-4-carboxylate (8b).—The crude amide **7b** (14.5 g) was refluxed in 700 ml of benzene for 5 hr. After cooling, the precipitated product was filtered off (8.5 g, 58%): mp 200–207°; ir (Nujol) 3200, 3100, 1725, 1700 cm^{-1}; uv (CH_3OH) 242 mμ (ε 11,300).

Anal. Calcd for $C_{23}H_{23}NO_3$: C, 76.43; H, 6.41; N, 3.88. Found: C, 76.45; H, 6.46; N, 3.82.

***N*-(4,5-Diphenyl-2,4-pentadienyl)-*N*-methylcinnamamide (9).**—To an ice-cold solution of 1.1 g (4.4 mmol) of amine **4a** and 0.44 ml of pyridine in 50 ml of CH_2Cl_2 was added a solution of 0.78 g of cinnamoyl chloride in 10 ml of CH_2Cl_2. After 2 hr the mixture was washed with cold dilute HCl and dilute Na_2CO_3 and dried. After evaporation of the solvent the residue (1.8 g) was crystallized from ether to give 1.1 g of **9**, mp 118°, and a second crop of 400 mg, mp 105–115° (84%): ir (Nujol) 1638, 1598 cm^{-1}; uv (CH_3OH) 213 mμ (ε 27,100), 223 (24,200), 290 (47,900); nmr ($CDCl_3$) δ 3.05 (s, 3 H), 4.13 (d, broad, J = 5.5 Hz 2 H), 5.3 (six lines, J = 5.5 and 15.5 Hz, 1 H), 6.4–7.6 (m, 18 H), 7.75 (d, J = 15.5 Hz, 1 H).

Anal. Calcd for $C_{27}H_{25}NO$: C, 85.45; H, 6.64; N, 3.69. Found: C, 85.65; H, 6.88; N, 3.63.

***N*-Allyl-*N*-methyl-4,5-diphenyl-2,4-pentadienylamine (11).**—A solution of 2.38 g (9.5 mmol) of amine **4a** in 100 ml of dry ether was cooled to −40° and (under N_2) 7.16 ml of BuLi–hexane was added, followed by 1.5 g (12.4 mmol) of allyl bromide in 20 ml of ether. The mixture was warmed to 25° and stirred at that temperature for 16 hr. Water was added, and the ether was separated, dried over Na_2SO_4, and evaporated. The residue of 2.47 g, containing, according to nmr, some starting material, was acylated with AcCl under Schotten–Baumann conditions. The basic material was then extracted into dilute HCl, the aqueous layer was separated, and the pH was adjusted to 11. Extraction with ether gave a residue of 1.5 g. From acetone 1.1 g of hydrochloride salt was obtained: mp 138–141° [recrystallization from acetone raised the melting point to 149–151° (300 mg)]: uv (CH_3OH) 222 mμ (ε 14,100), 232 (13,000), 289 (32,300), 306 (21,000).

Anal. Calcd for $C_{21}H_{23}N \cdot HCl$: C, 77.40; H, 7.42; N, 4.30. Found: C, 77.66; H, 7.54; N, 4.41.

Intramolecular Cycloaddition of 11 → *trans*-12 + *cis*-12.—A solution of 170 mg of **11** (free base) in 0.37 ml of C_6D_6 was heated in a sealed nmr tube at 140–142° and the reaction was monitored nmr spectroscopically. Rough estimates indicated that after 3 hr 60–70% and after 12 hr more than 95% of products **12** were formed. Glc analysis revealed a ratio of 84% *cis*-**12** and 16% *trans*-**12**. The characteristics of the pure compounds **12** are given below.

Preparation of Acrylamides 13a–d.—Generally a solution of the amine (**4a–d**) (2.75 mmol) and 260 mg of pyridine in 12 ml of CH_2Cl_2 was added at 0° to a solution of 300 mg (3.3 mmol) of acryloyl chloride in 40 ml of CH_2Cl_2. After 16 hr at 0–20° (0° for **13c** and **13d**) the CH_2Cl_2 was evaporated, and the residue was taken up in ether and washed with cold dilute HCl, then with Na_2CO_3 solution, and finally with brine. Drying over Na_2SO_4 and removal of the solvent *in vacuo* (temperature <30° for **13c** and **13d**) produced the crude amides, which were recrystallized.

13a had mp 98–101° (from ether); ir (Nujol) 1642, 1606 cm^{-1}; uv (CH_3OH) 224–236 mμ (ϵ 14,900), 288 (32,300), 307 (18,800); nmr, see Figure 1.

Anal. Calcd for $C_{21}H_{21}NO$: C, 83.13; H, 6.98; N, 4.62. Found: C, 83.14; H, 7.20; N, 4.46.

13b had mp 84–86° (from ether); ir (Nujol) 1643, 1609 cm^{-1}; uv (CH_3OH) 224 mμ (ϵ 15,500), 234 (15,200), 289 (32,100), 308 (18,500).

Anal. Calcd for $C_{22}H_{23}NO$: C, 83.24; H, 7.30; N, 4.41. Found: C, 83.06; H, 6.96; N, 4.58.

13c had mp 112–114° (from ether); ir (Nujol) 1650, 1609 cm^{-1}; uv (CH_3OH) 226 mμ (ϵ 15,700), 234 (15,600), 289 (32,000), 308 (19,200).

Anal. Calcd for $C_{23}H_{25}NO$: C, 83.34; H, 7.60; N, 4.23. Found: C, 83.38; H, 7.34; N, 4.31.

13d had mp 118–119° (from ether); ir (Nujol) 1648, 1607 cm^{-1}; uv (CH_3OH) 224 mμ (ϵ 14,200), 234 (14,100), 289 (30,400), 307 (18,800).

Anal. Calcd for $C_{24}H_{27}NO$: C, 83.44; H, 7.88; N, 4.05. Found: C, 83.74; H, 8.11; N, 3.91.

Intramolecular Cycloaddition of 13a → *trans*-14a + *cis*-14a.—A solution of 470 mg of amide **13a** in 20 ml of toluene was refluxed for 8 hr. Removal of the solvent and preparative tlc separation of the residue (silica gel, AcOEt/$CHCl_3$ 1:4) gave 198 mg of *trans*-**14a** (R_f 0.2, 42%) and 189 mg of *cis*-**14a** (R_f 0.4, 40%) besides 37 mg of starting material (8%) and 70 mg of material remaining at the origin. Crystallization of the main fractions from ether gave 120 mg of *trans*-**14a** and 100 mg of *cis*-**14a** crystalline material.

trans-**14a** had mp 131–133°; ir (Nujol) 1680 cm^{-1} (sh at 1685); uv (CH_3OH) 245 mμ (ϵ 12,100); nmr ($CDCl_3$, 100 MHz) δ 2.0–2.5 (m, 3 H), 2.6–3.0 (m, 1 H), 2.88 (s, 3 H), 3.15–3.6 (m, 2 H), 4.32 (d, J = 5 Hz, 1 H), 6.42 (d, $J \cong 1.5$ Hz, 1 H), 6.9–7.4 (m, 10 H).

Anal. Calcd for $C_{21}H_{21}NO$: C, 83.13; H, 6.98; N, 4.62. Found: C, 81.71; H, 6.95; N, 4.58 (crystallized with $^1/_3$ mol of ether).

cis-**14a** had mp 127–129°; ir (Nujol) 1672 cm^{-1} (sh at 1677); uv (CH_3OH) 243 mμ (ϵ 12,700); nmr ($CDCl_3$, 100 MHz) δ 2.25 (m, 2 H), 2.68 (s, 3 H), 2.7 (m, 1 H), 3.0–3.8 (m, 2 H), 3.21 (m, 1 H), 3.98 (dd, J = 5.5, 5.5 Hz, 1 H), 6.13 (d, J = 4 Hz, 1 H), 6.9–7.3 (m, 10 H).

Anal. Calcd for $C_{21}H_{21}NO$: C, 83.13; H, 6.98; N, 4.62. Found: C, 83.41; H, 7.22; N, 4.41.

Reduction of *cis*-14a to *cis*-12.—A solution of 350 mg of lactam *cis*-**14a** in 40 ml of ether was refluxed for 4 hr with 90 mg of $LiAlH_4$. Excess reagent was destroyed with 0.09 ml of H_2O, 0.09 ml of 15% NaOH, and 0.27 ml of H_2O. Filtration from the inorganic material and removal of the ether gave a residue of 350 mg which was dissolved in 3 ml of acetone. Upon addition of an equimolar amount of ethereal HCl, 270 mg of the hydrochloride salt, mp 255° (72%), was collected: ir (Nujol) 1490, 777, 755, 700, 690 cm^{-1}; uv (CH_3OH) 241 mμ (ϵ 12,300); nmr ($CDCl_3$) on free base δ 1.4–3.7 (m, 8 H), 2.33 (s, 3 H), 3.95 (m, 1 H), 6.17 (dd, J = 4, 2 Hz, 1 H), 6.9–7.5 (m, 10 H).

Anal. Calcd for $C_{21}H_{23}N \cdot HCl$: C, 77.40; H, 7.42; N, 4.30. Found: C, 77.34; H, 7.46; N, 4.39.

Reduction of *trans*-14a to *trans*-12.—The reduction was carried out analogously to *cis*-**14a** → *cis*-**12**. The product *trans*-**12** was isolated in 53% yield (250 mg from 300 mg of *trans*-**14a**) as the cyclohexylsulfamate salt: mp >115° dec; ir (Nujol) 1490, 760, 745, 695 cm^{-1}; uv (CH_3OH) 243 mμ (ϵ 10,000); nmr ($CDCl_3$) on free base δ 1.7–3.2 (m, 8 H), 2.45 (s, 3 H), 4.27 (m, 1 H), 6.48 (s, W_H = 3 Hz, 1 H), 6.9–7.5 (m, 10 H).

Anal. Calcd for $C_{21}H_{23}N \cdot C_6H_{13}NO_3S$: C, 69.19; H, 7.74; N, 5.97. Found: C, 68.95; H, 7.64; N, 5.67.

Reduction of 4c.—A solution of 310 mg of **4c** (hydrochloride salt) and 20 mg of $(Ph_3P)_3RhCl$ in 5 ml of ethanol was hydrogenated at atmospheric pressure until 1 mmol of H_2 was taken up. After filtration and removal of the solvent, the dihydro derivative was crystallized from ethanol–ether to give 90 mg: mp 154–156°; uv (CH_3OH) 218 mμ (ϵ 14,900), 257 (10,700), 260 (3100); mass spectrum m/e 279 (M^+), 264, 205, 178, 98.

Intramolecular Cycloaddition 9 → 10.—A solution of 67 mg of **9** in 0.42 ml of C_6D_6 was sealed in a nmr tube and heated in an oil bath of 91–92°. The reaction was completed after 6 hr and the product mixture consisted of eight parts trans and one part cis adduct, according to the nmr integrations.

A solution of 800 mg of **9** in 50 ml of toluene was heated in an oil bath at 91° for 9 hr. After removal of the solvent *in vacuo* the solid residue was separated by preparative tlc (silica, $CHCl_3$:AcOEt 4:1) to give 650 mg of *trans*-**10** (81%) and 85 mg of *cis*-**10** (10.6%).

The two compounds were recrystallized for analytical purposes.

trans-**10** (from CH_2Cl_2–ether) had mp 217–219°; ir (Nujol) 1693 cm^{-1}; nmr ($CDCl_3$, 100 MHz) δ 2.80 (s, 3 H), 2.75–3.5 (m, 4 H), 3.62 (dd, J = 6 and 11 Hz, 1 H), 4.25 (d, J = 6 Hz, 1 H), 6.4 (s, 1 H), 6.7 (m, 4 H), 6.8–7.3 (m, 11 H).

Anal. Calcd for $C_{27}H_{25}NO$: C, 85.45; H, 6.64; N, 3.69. Found: C, 85.08; H, 6.84; N, 3.69.

cis-**10** (from CH_2Cl_2–hexane) had mp 168–169°; ir (Nujol) 1703 cm^{-1}; nmr ($CDCl_3$, 100 MHz) δ 2.62 (s, 3 H), 2.81 (d broad, J = 9 Hz, 1 H), 3.3 (m, 2 H), 3.67 (t, J = 9 Hz, 1 H), 3.93 (t, J = 2.5 Hz, 1 H), 4.2 (s broad, 1 H) 6.45 (d, J = 4 Hz, 1 H), 7.0–7.4 (m, 15 H).

Anal. Calcd for $C_{27}H_{25}NO$: C, 85.45; H, 6.64; N, 3.69. Found: C, 85.10; H, 6.77; N, 3.65.

Registry No.—**2**, 1755-47-1; **3**, 39549-82-1; **4a**, 39549-83-2; **4a** HCl, 39549-84-3; **4b**, 39549-85-4; **4b** HCl, 39549-86-5; **4c**, 39549-87-6; **4c** HCl, 39549-88-7; **4c** dihydro derivative, 39549-89-8; **4d**, 39549-90-1; **4d** HCl, 39549-91-2; **4e**, 39549-92-3; **4e** HCl, 39549-93-4; **5**, 39549-94-5; **6**, 39549-95-6; **7b**, 39549-96-7; **8a**, 39549-97-8; **8b**, 39549-98-9; **9**, 39549-99-0; *cis*-**10**, 39550-00-0; *trans*-**10**, 39550-01-1; **11**, 39550-02-0; **11** HCl, 39550-03-3; *cis*-**12** HCl, 39550-04-4; *trans*-**12** cyclohexylsulfamate salt, 39550-05-5; **13a**, 39550-06-6; **13b**, 39550-07-7; **13c**, 39550-08-8; **13d**, 39550-09-9; *trans*-**14a**, 39550-10-2; *cis*-**14a**, 39550-11-3; lithiated cyclohexylimine of acetaldehyde, 39550-12-4; methylamine, 74-89-5; ethylamine, 75-04-7; isopropylamine, 75-31-0; *tert*-butylamine, 75-64-9; acetonitrile, 75-05-8; fumaric acid chloride ethyl ester, 26367-48-6; *trans*-cinnamoyl chloride, 17082-09-6; acryloyl chloride, 814-68-6.

Acknowledgment.—The authors would like to thank Dr. Neville Finch and Mr. L. Dorfman for their support and encouragement of this investigation. We also express our thanks to the staff of the Physical Sciences Division for the collection of the analytical data, to Mr. R. Grulich for his nmr studies, and to Mr. W. Woythaler of the Applied Mathematics Section for his assistance in the computer analyses.