of **5a**, the residual oil, 126 mg, which could not be crystallized, had the NMR spectrum of **2a**[4] [δ 1.90 (d, J = 1.5 Hz), 2.10 (s), 5.10 (d, J = 10 Hz), 5.88 (m), 5.92 (d, J = 10 Hz), 7.5–7.9 (m)] with only a trace of **5a**. A solution of this oil in 2 ml of *tert*-butyl alcohol was heated for 16 h at 70 °C and was then evaporated. Crystals formed slowly from ether. Repeated recrystallization from ether gave colorless needles of **9a** (R′ = *t*-Bu): mp 177–178 °C; δ 1.30 (s, *t*-Bu), 2.0 (d, J ~0.4 Hz, 3-CH_3), 2.11 (d, $COCH_3$), 4.80 (d, J = 9.5 Hz) and 5.05 (d, J = 9.5 Hz) [$-OCH_2N$], 6.1 and 6.9 (both apparent doublets, NH and H-5, 7.6 (s, C_6H_5).

Anal. Calcd for $C_{18}H_{24}N_2O_3$: C, 68.33; H, 7.65; N, 8.85. Found: C, 68.38; H, 7.66; N, 8.88.

Registry No.—**1a**, 5109-37-5; **1b**, 5109-45-5; **2a**, 36004-91-8; **2b**, 10137-20-9; **5a**, 36004-94-1; **8a** (R′ = *i*-Pr), 59729-10-1; **8b** (R′ = Et), 59729-11-2; **8b** (R′ = *i*-Pr), 59729-12-3; **9a** (R′ = *t*-Bu), 59729-13-4; **9b** (R′ = *i*-Pr), 59729-14-5; **9b** (R′ = *t*-Bu), 59729-15-6.

Supplementary Material Available. Table of atomic coordinates (5 pages). Ordering information is given on any current masthead page.

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A Symmetrical Diazaditwistane. 2,9-Dicyano-5,11-dimethyl-5,11-diazatetracyclo[6.2.2.0^{2,7}.0^{4,9}]dodecane

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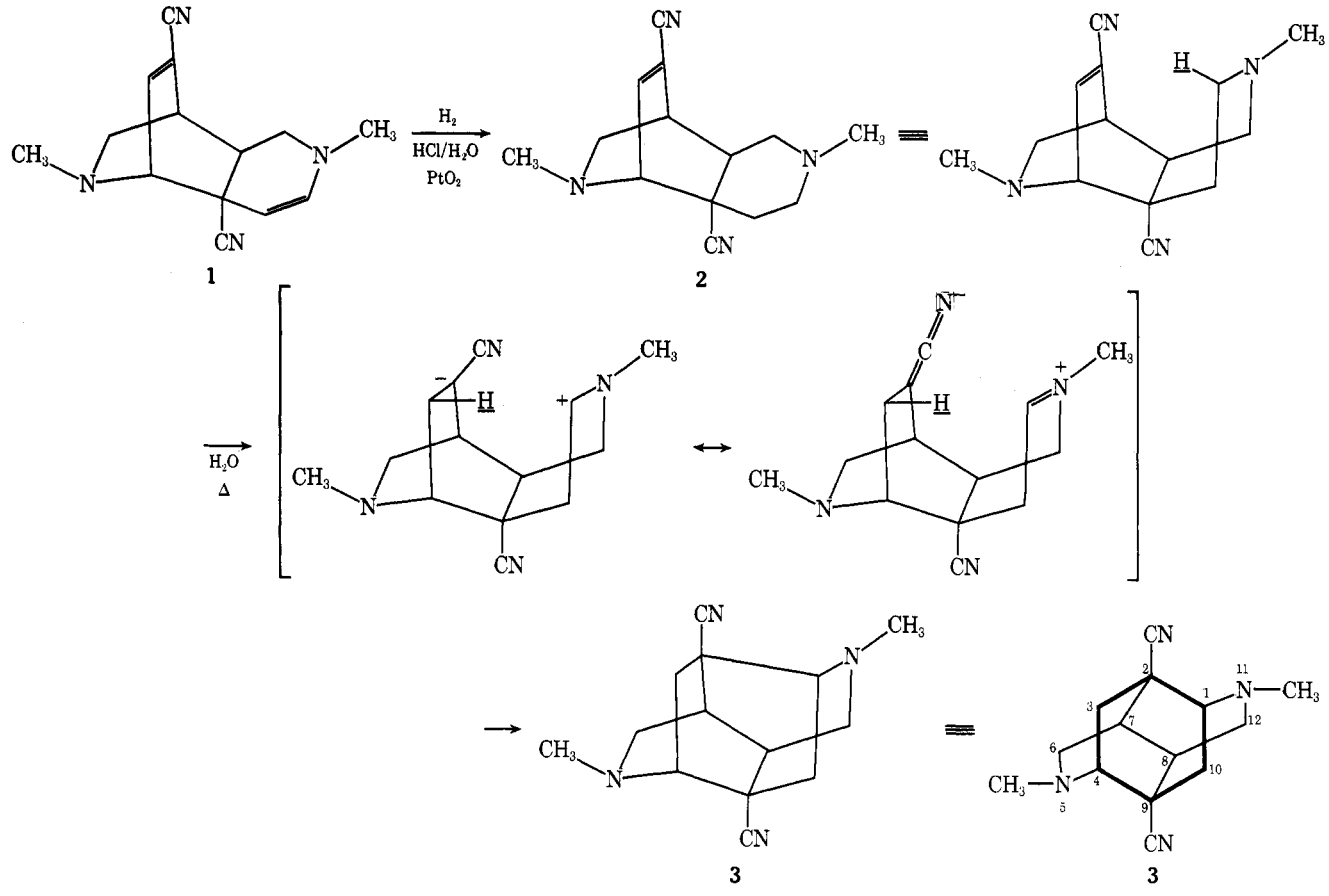
The facile synthesis of 2,9-dicyano-5,11-dimethyl-5,11-diazatetracyclo[6.2.2.0^{2,7}.0^{4,9}]dodecane (**3**), a unique and symmetric diazaditwistane, from *endo*-7,11-dicyano-4,9-dimethyl-4,9-diazatricyclo[6.2.2.0^{2,7}]dodeca-11-ene (**2**) via an intramolecular hydride transfer is reported. Spectral evidence and deuterium labeling studies confirming the structure of **3** and its mode of formation are presented.

In connection with studies directed toward the development of bioactive molecules with functional groups in unique and fixed three-dimensional relationships, an examination of the chemistry of Diels–Alder adduct **1** and its reduction product **2**, both of which have been recently prepared by Liberatore, Casini, and Carelli,[1] was begun. During the course of these studies, we have discovered that **2**, when heated in polar, protic solvents, undergoes a facile rearrangement to afford **3** (2,9-dicyano-5,11-dimethyl-5,11-diazatetracyclo[6.2.2.0^{2,7}.0^{4,9}]dodecane), which is a substituted, diaza analogue of the recently reported ditwistane system.[2] Formation of **3** was first noted when **2** was refluxed in water. It was isolated in 55% yield by filtration and shown to be isomeric with **2** by means of mass spectral and elemental analyses. Subsequent large-scale preparations of **3** in 81% yield have been carried out in methanol at 150 °C. The ir spectrum of **3** displayed one band at 2240 cm^{-1} ($CHCl_3$) indicative of saturated nitrile, and no double bond stretching absorptions were present in the spectrum. The ^1H and ^{13}C NMR spectra of **3** provided the basis for its structural assignment. In 1 N DCl the ^1H NMR spectrum revealed nine protons distributed in a ratio of 2:1:3:1:1:1, starting from high field, none of which occurred in the vinyl region. Since mass spectral and elemental analyses confirmed a molecular formula of $C_{14}H_{18}N_4$ for **3**, we concluded that it must be highly symmetrical in nature. The proton spectrum is summarized in Table I. The *N*-methyl resonance appeared as a singlet at 3.08 ppm, and the remainder of the proton spectrum could be interpreted by a first-order analysis, with second-order effects contributing to line broadening. The presence of the following groups was indicated: CH_3N, $NCHCH_2$, and NCH_2CH. The ^{13}C NMR spectrum, summarized in Table II, suggested the presence of seven types of carbon atoms. In addition to the five already indicated, a nitrile carbon and a carbon attached to four other carbons were detected. Assignments were confirmed by off-resonance decoupling experiments. The highly symmetrical nature was again indicated in this spectrum. Based on the accumulated data, structure **3** has been assigned to the new product. It contains a C_2 axis of symmetry and exists as an enantiomeric pair. Resolution of **3** has been achieved via its dibenzoyl-D-tartrate salt. Details of this procedure are reported in the Experimental Section.

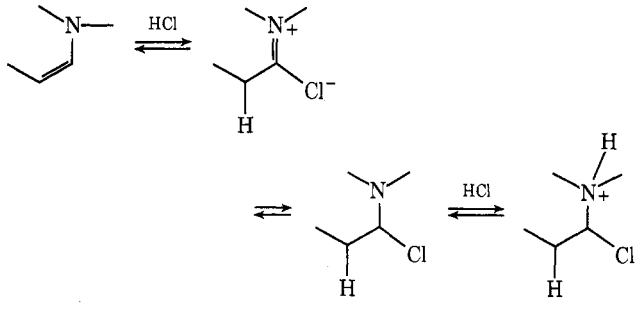
A reasonable reaction path for the formation of **3** involves an intramolecular hydride transfer in **2** as indicated, which proceeds through a dipolar transition state or through a discrete zwitterionic intermediate, which subsequently affords **3**. The proposed reaction path requires that the piperidine ring in **2** adopt a boatlike conformation prior to hydride transfer. Models suggest that this, the subsequent hydride transfer, and the final ring closure involve no severe distortions of the molecular framework. The latter two transformations occur over six-atom frameworks. This and the ability of the substituents to stabilize the developing charges in the intermediate or transition state account for facility of the reaction.

Consistent with the proposed intramolecular reaction path, no deuterium incorporation resulted when the reaction was run in D_2O. Also, it was noted that the reaction proceeded at comparable rates in water (100 °C), methanol (150 °C), and ethylene glycol (160 °C), much more slowly in 1-butanol (118 °C), hardly at all in *tert*-butyl alcohol (150 °C) and dimethyl sulfoxide (150 °C), and not at all in diglyme (125 °C) and xylene (140 °C). The requirement for a polar, protic solvent is consistent with the proposed ionic nature of the reaction path. In acetic acid (115 °C) and 50% aqueous acetic acid (105 °C) the reaction proceeded at one-quarter of its rate in water, suggesting that acid catalysis does not facilitate the reaction. Although we have not been able to find a direct analogy for this specific type of hydride-transfer reaction in the literature,



compound **2** contains all of the fundamental elements required for a hydride-transfer reaction as noted by Deno, Peterson, and Saines[4] in their review on this general class of reactions. The facilitation of intramolecular hydride-transfer reactions due to steric proximity in bridged, polycyclic systems has been noted by Prelog and Traynham in their review of transannular hydride shifts.[5]

To provide further support for the proposed reaction path for the formation of **3**, the sequence was reexamined in a deuterated series. Compound **1** was reduced in DCl/D_2O over PtO_2 using deuterium gas. It has been previously established that enamines in aqueous acid protonate at their β carbon and are in equilibrium with their iminium forms. This results in a net exchange of the β protons in deuterated media. It has also been shown that when the acids used have a nucleophilic anion, addition of that anion to the imine occurs.[6] Thus, the equilibria involved for an enamine in aqueous HCl, neglecting hydrolysis which is slow for cyclic enamines, can be represented as follows:



Given the complex nature of this series of equilibria, the a priori prediction of the resultant species upon reduction of **1** in a deuterated system is not possible. However, incorporation of three deuterium atoms in the product is expected: two at the β carbon via exchange and one at the α carbon via reduction. Examination of the mass spectrum of the reduction product of **1** in the deuterated system revealed 88% of d_3 species, 6% of d_2, 2% of d_1, and 4% of d_0. Support for these results was obtained by comparison of the ^{13}C spectra of **2** and its trideuterio analogue. In the ^{13}C spectrum of the trideuterio analogue the high-field resonance at 27.6 ppm due to a C–CH_2–C group was absent, having been replaced by a C–CD_2–C group. In addition the NCH_2– group at 49.0 ppm in **2** had become a triplet at 48.5 ppm since it was now a CHD group in the trideuterio analogue. Up to this point the stereochemistry at the α carbon in the trideuterio analogue has not been specified. This became possible by a comparison of the ^1H NMR spectra of the protio and deuterio compounds. The ^1H NMR spectrum of **2** shows a sextet corresponding to one proton at approximately 3.0 ppm ($CDCl_3$), due to a single proton in one of the NCH_2 groups. Only two other of the NCH protons in **2** are further downfield. Referring to structure **2a**, H_x, which is a methine geminal to nitrogen and also allylic, occurs as a doublet (δ 3.60 ppm, J = 6.0 Hz) and H_y, which is geminal to nitrogen and in the deshielding regions of the nitrogen lone pair and the cyano group,[1,7] occurs as a quartet (δ 3.42 ppm, J = 10, 2.0 Hz). The remainder of the protons on carbon adjacent to a nitrogen atom occur as a complex multiplet at 2.2–2.7 ppm. In the trideuterio analogue the sextet at 3.0 ppm has become a broadened singlet, and the high-field methylene on the β carbon in **2a**, which occurs as a multiplet at 1.7 ppm in **2**, is completely absent. Thus, the sextet at 3.0 ppm in **2** must be due to one of the protons on the α carbon of the original enamine group. The sum of the splittings in this pattern is observed to be 28 Hz. The magnitude of the geminal splitting should be on the order of 12 Hz,[3] leaving the sum of the vicinal couplings at approximately 16 Hz. This is consistent only with an essentially axial orientation of the methylenic proton exhibiting this multiplet.[8] Assuming that pseudochair conformations will be more stable for the flexible six-membered ring in **2** than the corresponding boat conformations, conformations **2a** and **2b** can be drawn for **2**, and the sextet observed in its spectrum could arise from H_a in either

Table I. ^{1}H NMR Spectrum of 3[a]

Chem shift,[b] mult	J, Hz	Area	Assignment
2.71, d	2.7	2	—CH_2CHN<
2.91, d	2.7	1	>$CHCH_2N$<
3.08, s		3	>NCH_3
3.67, d[c]	13.5	1	H, H
3.91, q[c]	13.5, 3.5	1	>N—C—CH<
4.38, t	2.9	1	>$NCHCH_2$—

[a] Spectrum taken in 1 N DCl/D_2O with DSS standard. [b] δ, ppm. [c] The multiplets at 3.67 and 3.91 ppm are in accord with a methylene attached to nitrogen coupled to a methine in which one dihedral angle approaches 90° giving a vanishingly small splitting and the other is such that a moderate splitting results.[3] This, based on molecular models, is in accord with **3**.

Table II. ^{13}C NMR Spectrum of 3[a]

Chem shift[b]	Multiplicity[c]	Assignment
22.5	t	OCH_2C
35.0	s	C, C, C, C
36.4	d	C, CCHC
41.6	q	>NCH_3
50.9	t	>NCH_2C
59.6	d	>NCH< C, C
122.9	s	—CN

[a] Spectrum taken in $CDCl_3$. [b] δ, ppm, Me_4Si internal reference. [c] Observed with off-resonance proton decoupling.

case. However, in conformation **2a** H_a would experience a deshielding effect because of its position relative to the cyano group, whereas in conformation **2b** H_a would experience a shielding effect because of its position relative to the π lobes of the double bond.[7] Since H_a is downfield relative to the bulk of protons similar to it in **2**, conformation **2a** must obtain. Returning to the trideuterio analogue, since the sextet in **2a** has become a broadened singlet attributed to the same proton, the structure and conformation for the trideuterio analogue must be represented by **4a**. Integration of this broadened singlet accounted for only 0.7 H. Since the mass spectral analysis confirmed the labeled reduction product as principally a trideuterio species and its ^{1}H and ^{13}C spectra showed only involvement of the α- and β-carbon atoms of the original enamine, the remaining 0.3 H in the labeled species must be represented by structure **4b**. H_e in **4b** was not specifically observed in the labeled product mixture since it occurs with the bulk of the protons on carbon bound to nitrogen. In summary, therefore, reduction of **1** in the deuterated system affords approximately a 7:3 mixture of trideuterio compounds **4a** and **4b**.

The labeled mixture **4a** and **4b** was rearranged in water as before. No loss of deuterium occurred during the rearrangement. Examination of the ^{1}H NMR spectrum of the rear-

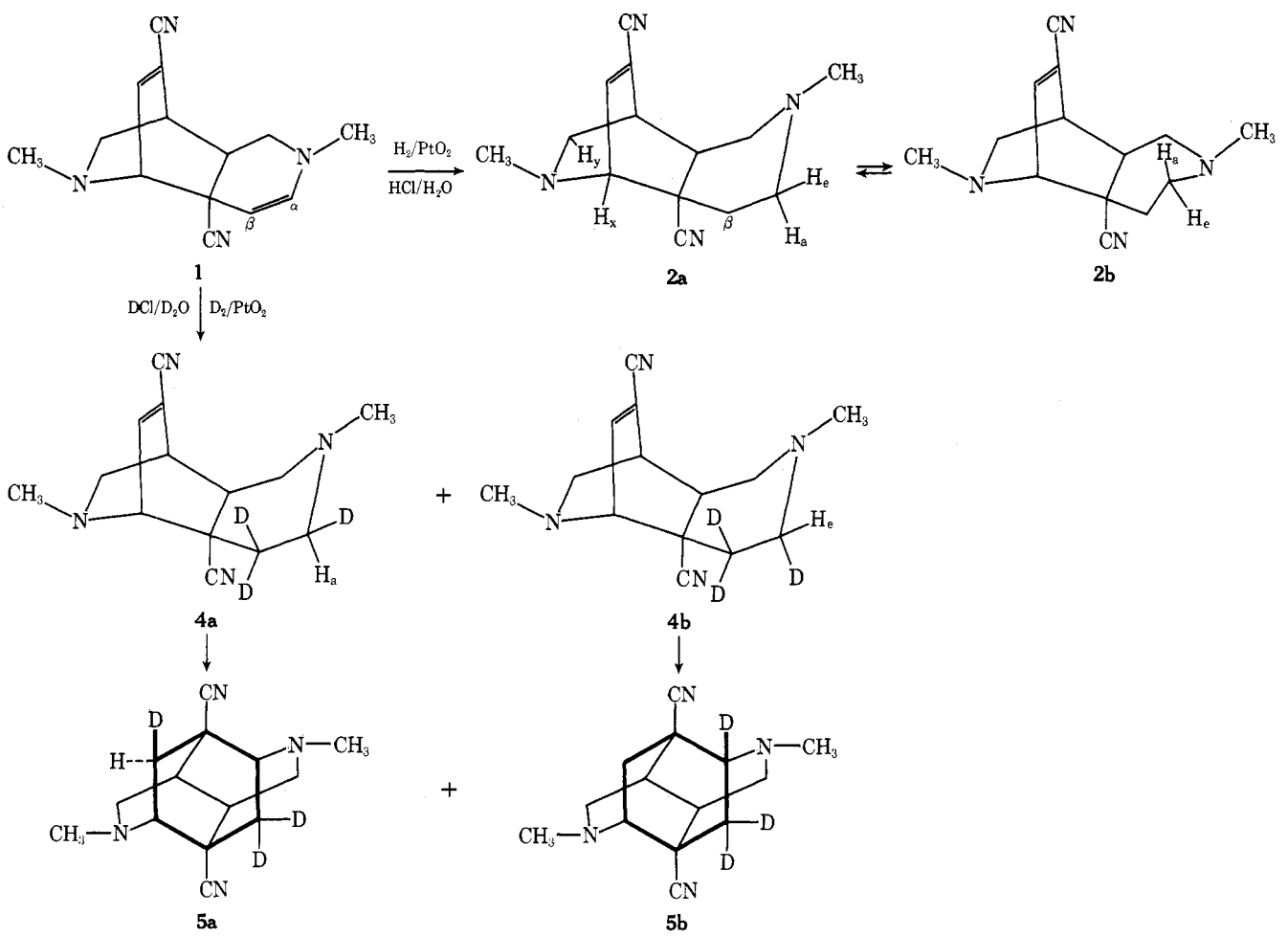


Table III. Proton Areas for the 5a–5b Mixture[a]

Group	NCH	NCH_2	NCH_3	CCH	CCH_2
Observed for **3**	2	4	6	2	4
Predicted for **5a–5b**	1.7	4	6	2	1.3
Observed for **5a–5b**	1.6	4	6	2	1.4

[a] Area measurement errors are estimated to be correct to ±0.1 H.

ranged product mixture (**5a** and **5b**) afforded relative areas for the various protons in accord with the proposed hydride transfer reaction path based on **4a** and **4b** being a 7:3 mixture. These results are summarized in Table III. Also, the ^{13}C NMR spectrum of the **5a–5b** mixture was in accord with the presence of the following groups: NCHCHD, $NCHCD_2$, $NCHCH_2$, and $NCDCD_2$.

In summary, we believe that sufficient evidence exists to establish diazaditwistane **3** as the product resulting from the rearrangement of **2** via an intramolecular hydride transfer and ring closure. To our knowledge this represents the first report of the synthesis of a symmetrical diazaditwistane.[9] In addition to being a symmetrical diaza analogue of a unique, rigid polycyclic system, diazaditwistane **3** has other unusual structural features. It can be viewed as a fusing of two piperidine rings. Because of the nature of the system, each nitrile exists simultaneously in a 1–3 and a 1–4 relationship to piperidine ring nitrogens.

Although **3** is a stable system, the functionality at positions 2, 5, 9, and 11 can be readily and extensively varied. Subsequent papers will present the chemistry which has been developed from **3**, and the biology which has resulted from that chemistry.[10]

Experimental Section

Melting points are uncorrected. Infrared spectra were taken with a Perkin-Elmer IR 257 spectrophotometer. ^1H NMR spectra were taken with a JEOL C60HL spectrometer and carbon-13 spectra were taken with a Varian CFT 20 spectrometer. Rotations were determined on a Zeiss photoelectric polarimeter using a 1-dm tube. We wish to thank Ms. Emily J. Maitheny, Mr. Robert A. Reamer, Mr. Jack L. Smith, Mr. Richard C. Zerfing, Mr. Richard N. Boos, and Mr. Jack P. Gilbert for assistance in obtaining the spectral and analytical data.

***endo*-7,11-Dicyano-4,9-dimethyl-4,9-diazatricyclo[6.2.2.-$0^{2,7}$]dodeca-5,11-diene (1).**[1,11] Under nitrogen 366 g (9.15 mol) of NaOH and 9.5 l. of CH_3OH were charged with stirring to a 12-l. flask. After 10 min the clear solution was cooled to 10 °C and 200 g (5.28 mol) of $NaBH_4$ was charged. Cooling was continued and at −18 °C 1326 g (5.39 mol) of 1-methyl-4-cyanopyridinium iodide[12] was charged over 15 min keeping the temperature between −15 and −20 °C. The mixture was stirred at −20 to 0 °C for 2.5 h. The precipitate was filtered, washed with 4 × 600 ml of cold CH_3OH, and dried at 40 °C (1 mm) overnight to yield 541 g (2.25 mol, 83%) of 1 as a yellow solid, mp 173–176 °C (lit.[1] 175 °C).

***endo*-7,11-Dicyano-4,9-dimethyl-4,9-diazatricyclo[6.2.2.-$0^{2,7}$]dodec-11-ene (2).** In 1.5 l. of 2.5 N HCl was dissolved 360 g (1.5 mol) of 1 and 1.50 g of PtO_2 catalyst was added. This was hydrogenated at an initial pressure of 40 psi and theoretical hydrogen uptake was complete in 2.5 h. Catalyst was removed by filtration through Supercel which was washed twice with 2 × 100 ml of 2.5 N HCl. Benzene (2.0 l.) was added to the filtrate followed by the addition of 165 g of NaOH in 500 ml of H_2O with stirring and cooling. After separation, the aqueous phase was extracted with 3 × 1 l. of benzene, and the combined benzene extracts were dried over Na_2SO_4, filtered, and vacuum concentrated to a crystalline mass. This was slurried with 1500 ml of ether and filtered, and the filtrate was washed with 2 × 300 ml of ether and dried under vacuum to afford 306 g (1.27 mol, 84%) of **2**, mp 139–143 °C. This material was of sufficient purity for subsequent preparative work. An analytical sample was prepared by recrystallization from 2-propanol: mp 145–147 °C (lit.[1] 148 °C); mass spectrum molecular ion at *m/e* 242.

Anal. Calcd for $C_{14}H_{18}N_4$: C, 69.39; H, 7.49; N, 23.12. Found: C, 69.19; H, 7.77; N, 22.91.

2,9-Dicyano-5,11-dimethyl-5,11-diazatetracyclo[6.2.2.$0^{2,7}$.-$0^{4,9}$]dodecane (3). Procedure A. A slurry of 242 g (1.0 mol) of **2** in 2.42 l. of water was refluxed for 3 h. During the course of the reaction much of the starting material went into solution; however, product crystallized before complete dissolution occurred. The resulting slurry was cooled to 5 °C, filtered, washed with 3 × 400 ml of water, and dried at 50 °C under vacuum to yield 134 g (0.55 mol, 55%) of **3**: mp 206–209 °C; TLC (98/2 $CHCl_3/CH_3OH$, silica gel) single spot at R_f 0.5; spectral data recorded in the text.

Anal. Calcd for $C_{14}H_{18}N_4$: C, 69.39; H, 7.49; N, 23.12. Found: C, 69.43; H, 7.34; N, 22.99.

Procedure B. In an autoclave 157 g (0.65 mol) of **2** in 1.57 l. of methanol was heated at 150 °C for 6 h. The resulting mixture was concentrated to remove 1.4 l. of methanol. The precipitate was then filtered, washed with 4 × 100 ml of 2-propanol, and dried at 50 °C under vacuum to afford 127 g (0.525 mol, 81%) of **3**, mp 205–209 °C. This material was identical with that previously prepared.

Resolutions. A solution of 12.12 g (50.0 mmol) of racemic **3** in 500 ml of refluxing methanol was treated with a hot solution of 18.7 g (52.5 mmol) of dibenzoyl-D-tartaric acid in 200 ml of methanol. On cooling granular crystals formed first and after 1 h flocculent crystals started to separate. The mixture was warmed to dissolve the latter and filtered, and the solid was washed with methanol and dried to yield 12.25 g of granular crystals of the monosalt of the (−) isomer of **3**. On aging for 24 h the filtrate yielded a flocculent crystal mass which was filtered, washed with methanol, and dried to yield 8.7 g of the monosalt of the (+) isomer. The granular salt of the (−) isomer was twice recrystallized from 40 volumes of methanol and converted to the free base by distribution between 60 ml of saturated $NaHCO_3$ solution and 150 ml of methylene chloride. After separation and evaporation of the methylene chloride there was obtained 3.40 g (56%) of the (−) isomer of **3**: mp 249–253 °C; $[\alpha]_{578}$ −220.8, $[\alpha]_{546}$ −250.6, $[\alpha]_{436}$ −426.0, $[\alpha]_{405}$ −509.0, $[\alpha]_{365}$ −660.2 (*c* 0.52, CH_2Cl_2). The flocculent salt of the (+) isomer was twice recrystallized from 30 volumes of methanol and converted to the free base as above to yield 2.06 g (36%) of the (+) isomer of **3**: mp 249–253 °C; $[\alpha]_{578}$ +223.1, $[\alpha]_{546}$ +254.1, $[\alpha]_{436}$ +431.6, $[\alpha]_{405}$ +517.1, $[\alpha]_{365}$ +666.3 (*c* 0.53, CH_2Cl_2).

4a and 4b. To a solution of 1.92 g (8.0 mmol) of 1 in 16 ml of 2.5 N DCl (97% D) was added 10 mg of PtO_2 and the mixture reduced with D_2 gas at 25 °C (40 psi) until 8.0 mmol of D_2 was taken up. The mixture was filtered, and the filtrate was adjusted to pH 12 with 2.5 N NaOH, resulting in some crystal formation. The mixture was extracted with 3 × 20 ml of benzene, which was dried over $MgSO_4$, filtered, and concentrated to dryness, and the residue was recrystallized from 7 ml of 2-propanol to afford 1.70 g (7.1 mmol, 88%) of **4a** and **4b**: mp 137–140 °C; 88% d_3, 6% d_2, 2% d_1, and 4% d_0 by mass spectral analysis.

Anal. Calcd for $C_{14}D_3H_{15}N_4$:[11] C, 68.53; H, 7.49; N, 22.83. Found: C, 68.81; H, 7.65; N, 22.65.

5a and 5b. A 1.0-g sample of the labeled **4a–4b** mixture was slurried in 10 ml of water and refluxed for 2.5 h. The resulting precipitate was filtered, washed with 2 × 1 ml of cold water, and dried at 64 °C (1 mm) to afford 0.47 g of the **5a–5b** trideuterio mixture: mp 206–208 °C; 87% d_3, 7% d_2, 2% d_1, and 4% d_0 by mass spectral analysis; spectral data recorded in text.

Anal. Calcd for $C_{14}D_3H_{15}N_4$:[13] C, 68.53; H, 7.49; N, 22.83. Found: C, 68.60; H, 7.42; N, 22.54.

Registry No.—**1**, 33422-84-3; **2**, 59711-05-6; (±)-**3**, 59711-06-7; (−)-**3**, 59711-07-8; (+)-**3**, 59711-08-9; **4a**, 59751-82-5; **4b**, 59751-83-6; **5a**, 59751-84-7; **5b**, 59711-09-0; 1-methyl-4-cyanopyridinium iodide, 1194-04-3; dibenzoyl-D-tartaric acid, 2743-38-6.

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Reaction of 2,4-Dinitrohalobenzenes with Imidazole in Nonpolar Aprotic Solvents[1]

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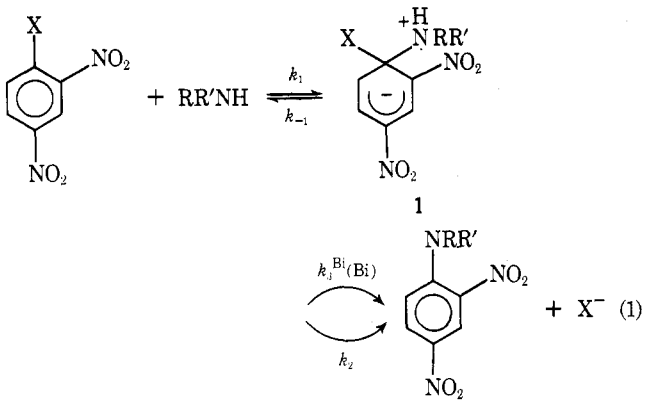
The reactions of 1-chloro-2,4-dinitrobenzene and 1-fluoro-2,4-dinitrobenzene with imidazole in benzene or chloroform were studied. It was found that the reaction of both substrates is general base catalyzed. For 1-chloro-2,4-dinitrobenzene the ratio of the catalyzed to the uncatalyzed rate coefficient (k_3^B/k_2) is 200 M^{-1} for the imidazole and 253 M^{-1} for Dabco in chloroform. The implication of base catalysis in this reaction is discussed.

The reaction of activated aromatic substrates with amines is often base catalyzed.[2] This observation has been rationalized in terms of the intermediate complex mechanism for which eq 1 is representative.



Base catalysis is experimentally observable when the product-forming steps k_2 and $k_3^{Bi}(Bi)$ are slower than the reversion of the intermediate **1** to reactants ($k_2 + \Sigma k_3^{Bi}(Bi) < k_{-1}$).

When the ratio $k_2/k_{-1} \ll 1$, base catalysis is usually observable;[2a] thus whether a given reaction is base catalyzed or not can be influenced by the factors which decrease k_2 and/or enhance k_{-1}.

With chloride as leaving group there are only a few examples where base catalysis has been unequivocally demonstrated and these are cases where the amine is weakly basic which tends to decrease the k_2/k_{-1} ratio by increasing k_{-1}. A case in point is the reaction of *p*-anisidine with 1-chloro-2,4-dinitrobenzene[3] in benzene solution.

Base catalysis in the reaction of 1-chloro-2,4-dinitrobenzene with piperidine and aniline in acetone was claimed by Hirst and Bankole,[4] but these results could not be reproduced in our hands.[5]

The reaction of imidazole with picryl chloride was shown to be catalyzed by imidazole and Dabco in chloroform.[6] Also Pietra[7] found that the reaction of 1-chloro-2,4-dinitrobenzene with imidazole is mildly accelerated by imidazole, but he did not regard this acceleration as base catalysis.

We became interested in the reaction of imidazole because we think that its behavior is important in regard to the mechanism of the k_2 step.

Base catalysis is usually recognized when a change to a better catalyst brings about stronger catalysis.[2a] Thus we investigated the reaction of 1-chloro-2,4-dinitrobenzene with imidazole in benzene and chloroform in the presence of Dabco and pyridine, in order to see whether the reactions are base catalyzed or not. We also report kinetic data on the reaction of 1-fluoro-2,4-dinitrobenzene with imidazole in chloroform catalyzed by imidazole and Dabco to compare these results with those of 1-chloro-2,4-dinitrobenzene.

Results and Discussion

1-Chloro-2,4-dinitrobenzene. In Table I the kinetic results for the reaction of the aforementioned substrate with imidazole with or without added other bases are displayed.

For the imidazole catalyzed reaction the three points at lower concentration compare well with those reported by Pietra[7] under the same experimental conditions, but the agreement is not as good at higher concentration. The ratio of the third- to the second-order rate constant is even lower in our case. The response of k_A to the base concentration is linear. For the reaction of imidazole with 1-chloro-2,4-dinitrobenzene in the presence of Dabco or pyridine the rate seems to level off at high base concentration (Table I).

The kinetic expression derived with reference to the mechanism depicted in eq 1, by means of the usual steady-state approximation, is represented in eq 2 where k_A is the observed second-order rate constant and the summation includes all the bases present in the solution including the nucleophile.

$$\frac{\text{rate}}{(\text{ArX})(\text{HNRR}')} = k_A = \frac{k_1\left[k_2 + \sum_i k_3^{Bi}(Bi)\right]}{k_{-1} + k_2 + \sum_i k_3^{Bi}(Bi)} \quad (2)$$

Linear dependence of the second-order rate constant k_A on the base concentration means that

$$k_2 + \sum_i k_3^{Bi}(Bi) \ll k_{-1}$$

which simplifies eq 2 to eq 3.

$$k_A = k_1\frac{k_2}{k_{-1}} + k_1\frac{\sum_i k_3^{Bi}(Bi)}{k_{-1}} \quad (3)$$