Table II[a]

		k_a/k_b[b]	I[b]	k_a/k_b[c]	I[c]	k_c/k_d[d]	I[d]
Electron impact	70 eV	1.56 ± 0.1	1.0	1.58 ± 0.15	1.2 ± 0.2	1.74 ± 0.1	1.82 ± 0.1
	15 eV	1.50 ± 0.1	1.0	1.44 ± 0.05	0.8 ± 0.3	1.78 ± 0.1	1.78 ± 0.1
Pyrolysis[e]				1.86	1.6	12	2.7

[a] Refer to Chart I. [b] Derived from Table I with I assumed to be 1.0 (see text). [c] Calculated by directly comparing the peak intensities between **1** and **2** on the same scale as discussed in the text. [d] Derived from Table I using Curtin's analysis.[6] [e] Data from ref 5 and 6.

applied to obtain the desired ratio of k_c/k_d by utilizing the ion intensities at M − HOAc and M − DOAc (Table I).[11] Further, the isotope effect (I) may be calculated[6] by simply inverting one of the ion ratios. The results of these calculations are given in Table II.

The presence of other rate constants k_i for loss from the methyl groups from **1** and **2** disallows Curtin's kinetic analysis for the *sec*-butyl system. Nevertheless the necessary rate ratios may be obtained in another manner. The ratio of M − DOAc/(M − DOAc + M − HOAc) is equal to $Ik_a/(Ik_a + k_b + k_i)$ in **1** and $Ik_b/(Ik_b + k_a + k_i)$ in **2**. If I were 1, the quotient of these ratios from **1** and **2** would yield k_a/k_b. This assumption has been made to obtain the values of k_a/k_b in Table II (first column). As demonstrated below this ratio of k_a/k_b is correct.

If one could measure the ion intensities for M − DOAc in **1** and **2** on the same scale (*i.e.*, from the same number of molecular ions) the value obtained would be simply Ik_a/Ik_b or k_a/k_b.[10] Further, the difference between the M − DOAc ion intensities is equal to $I(k_a - k_b)$ while the difference between the M − HOAc intensities (all on the same scale) yields $k_a - k_b$. In this manner both I and k_a/k_b could be obtained. This procedure can be executed in the case of **1** and **2** since all the ions of higher *m/e* than M − H(D)OAc exhibit a nearly constant relationship between the spectra of **1** and **2**. This constant relationship is indeed a factor which allows the two spectra to be placed on an equivalent sensitivity scale. This procedure (various runs and scale factors) yielded the results shown in Table II, which also includes the pyrolytic data. A similar attempt for **3** and **4** was less satisfactory since the various ions other than M − H(D)OAc were not related by a constant factor.[12]

The observation of metastable peaks for loss of acetic acid in both series,[13] the low temperature of the ion source (*ca.* 50°),[14] and previous comparative observations of acetic acid loss by electron impact and cold photoionization[15] strongly support the electron impact induced nature of these fragmentations.

The only reasonable interpretation of the electron impact induced k_a/k_b and k_c/k_d ratios (Table II) is that loss of acetic acid occurs by a *cis* process[16] with preference for an *anti* relationship between the methyl groups in **1** and **2** and the aromatic rings in **3** and **4**. Further, the data in Table II allow a detailed comparison between the electron impact and pyrolytic eliminations. Although the results show a clear qualitative parallel in that $k_a > k_b$ and $k_c > k_d$ and further that I is greater for C_6H_5 in both series, a quantitative correspondence is both lacking and expectable. A significant entropy term ($\Delta\Delta S^{\ddagger}$), absent in the case of the *sec*-butyl acetates but arising from the restricted rotation in the abstraction of H_d, likely contributes to the stereospecificity in the pyrolysis of 1,2-diphenyl ethyl acetate. Since the electron impact induced eliminations take place from molecular ions of low internal energy,[17] a state in which the mass spectral counterpart of the entropy term (frequency factor) is deemphasized,[18] it follows that under electron impact the difference in stereospecificities should be lessened over that observed pyrolytically as is the case.

These results suggest, at least for these molecules, that promotion to the ionized state does not involve a substantial perturbation of the structural parameters of the neutral precursor.

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ratio of their rate constants (actually average rate constants in the case of the ions). The subsequent decomposition of the ions (M − H(D)-OAc) is effectively repressed at beam energies near threshold.

(11) Since Curtin[6] was measuring the deuterium content of *trans*-stilbene, he could seek the stereospecificity of the reaction (*i.e.*, *cis* or *trans* elimination). In our case, we have no reason to suppose that loss of H_c or H_d leads to *trans*- or *cis*-stilbene or even an ion with a stilbene structure at all. See P. F. Donaghue, P. Y. White, J. H. Bowie, B. D. Roney, and H. J. Rodda, *Org. Mass Spectrom.*, **2**, 1061 (1969).

(12) This calculation depends on the spectra showing only local dependence (*i.e.*, M − H(D)OAc) on the stereochemistry. Such local dependence is most likely to be found in compounds which differ by diastereotopic deuterium incorporation—a potentially small perturbation.

(13) Measured by varying the accelerating voltages. See: M. Barber and R. M. Elliott, Abstracts of Papers of 12th Annual Conference on Mass Spectrometry, ASTM E-14, Montreal, 1964, p 150.

(14) We have studied the loss of acetic acid at various temperatures on both the MS-902 and a CEC-103-C spectrometer and find a highly reproducible diminution of the stereospecificity at higher temperatures. For example for CH_3 at 125° $k_a/k_b = 1.3$.

(15) See Briggs and Djerassi in ref 8.

(16) The pyrolytic process is stereospecifically *cis* as shown by Skell.[5] The apparent *trans* elimination in the 1,2-diphenyl ethyl acetates almost surely arises from initially produced *cis*-stilbene isomerizing to *trans* as noted by Curtin (see references to Table I in Curtin's paper[6]).

(17) The invariance of the results on change of beam energy from 70 eV to near threshold (Tables I and II) does not alter this argument since the ions produced near threshold must have low internal energies. The lack of dependence of competitive eliminations on beam energy has precedence in chloride and acetates. See: A. M. Duffield, S. D. Sample, and C. Djerassi, *Chem. Commun.*, 193 (1966); Briggs and Djerassi, ref 8 herein.

(18) This follows from the quasi-equilibrium theory and the derived kinetic expression. See: R. G. Cooks, I. Howe, and D. H. Williams, *Org. Mass Spect.*, **2**, 137 (1969), and numerous references therein.

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The Biogenetically Modeled Total Synthesis of (±)-Minovine[1]

Sir:

The biogenetic speculations of Wenkert[2a] concerning the origin of *Aspidosperma* and *Iboga* alkaloids entail

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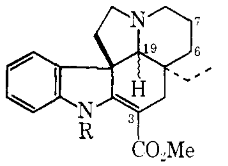
(1) Presented at the Third Natural Products Symposium, Mona, Jamaica, Jan 5–9, 1970.

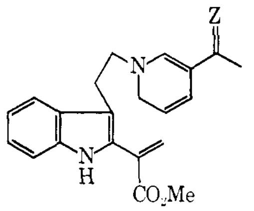
(2) (a) E. Wenkert, *J. Amer. Chem. Soc.*, **84**, 98 (1962); (b) A. A. Qureshi and A. I. Scott, *Chem. Commun.*, 945, 947, 948 (1968); A. I. Scott, P. C. Cherry, and A. A. Qureshi, *J. Amer. Chem. Soc.*, **91**, 4932 (1969).

the intermediacy of indolylacrylic ester **2a**, while Scott[2b] has invoked ester **2b** in establishing the sequence *Corynanthe* → *Aspidosperma* → *Iboga*. We wish to report the total synthesis of $(\pm)$-minovine (**1a**)[3] based upon these considerations.

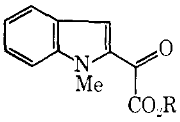
Lithiation[4] of N-methylindole[5] followed by addition to an excess of ethyl oxalate and subsequent saponification with methanolic potassium hydroxide afforded N-methyl-α-indolylglyoxylic acid **3a**, mp 113.5–114.5° (59% yield).[6] Esterification of the acid with ethereal diazomethane provided the methyl ester **3b** as a yellow oil: ir ($CHCl_3$) 1735 and 1650 cm^{-1}; nmr ($CDCl_3$) δ 3.95 (3 H, s), 3.99 (3 H, s), 7.59 (1 H, s), and 6.98–7.83 (4 H, m) (96% yield). Treatment of the ester with methylenetriphenylphosphine in ether produced methyl 2-[α-(N-methylindolyl)]acrylate (**4**) as a yellow oil: ir ($CHCl_3$) 1725 cm^{-1}; nmr ($CDCl_3$) δ 3.54 (3 H, s), 3.75 (3 H, s), 5.93 (1 H, d, J = 2 Hz), 6.49 (1 H, s), 6.58 (1 H, d, J = 2 Hz), and 6.85–7.70 (4 H, m); uv (MeOH) λ_{max} 223 mμ (ϵ 27,400), 2.75 (5200), 283 (5000), and 295 (5000).



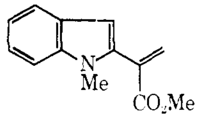
1a, R = Me
b, R = H



2a, Z = O
b, Z = H_2



3a, R = H
b, R = Me



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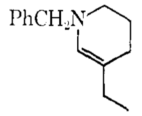

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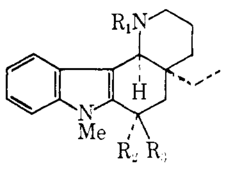

6a, $R_1 = PhCH_2$, $R_2 = CO_2Me$, $R_3 = H$
b, $R_1 = PhCH_2$, $R_2 = H$, $R_3 = CO_2Me$
c, $R_1 = PhCH_2$, $R_2 = CH_2OH$, $R_3 = H$
d, $R_1 = PhCH_2$, $R_2 = H$, $R_3 = CH_2OH$
e, $R_1 = R_2 = H$, $R_3 = CO_2Me$
f, $R_1 = CH_2CH_2Br$, $R_2 = H$, $R_3 = CO_2Me$

Refluxing the acrylic ester (**4**) with an excess of 1-benzyl-3-ethyl-1,4,5,6-tetrahydropyridine (**5**)[7] in methanol afforded a mixture (55% yield) of amino ester **6a**, mp 173–174°, and isomer **6b**, mp 167–168°. These two substances were shown to be epimers at C-3 by refluxing each isomer in methanol-d_1 containing sodium methoxide. Isomer **6a** was converted to **6b**, while **6b** was recovered unchanged. In each case, one deuterium was incorporated into the product. Lithium aluminum hydride reduction of esters **6a** and **6b** provided alcohols **6c**, mp 163–164°, and **6d**, mp 173–174°, respectively. The former alcohol showed typical concentration-dependent intermolecular hydrogen bonding in its infrared spectrum, while the latter alcohol displayed concentration-independent intramolecular hydrogen bonding (3500–2400 cm^{-1}). In addition, the 100-MHz nuclear magnetic resonance spectrum of the hydrochloride of ester **6b** (mp 158–158.5°) showed a one-proton triplet at δ 4.28 (C_3-H), indicating that this proton makes the same dihedral angle with each of the adjacent C-4 protons. Thus, ring C must be in a half-boat conformation with the ester carbonyl hydrogen bonded to the protonated nitrogen. These data are consistent with a *cis*-ring juncture,[8] whereas neither of the possible *trans* isomers can accommodate intramolecular hydrogen bonding.

Hydrogenation over 10% palladium on charcoal in methanolic hydrochloric acid smoothly converted the ester **6b** into the secondary amine **6e**, mp 96–96.5°; ir ($CHCl_3$) 1730 cm^{-1}, mass spectrum (70 eV) M^+ 326 (74% yield). The two-carbon chain necessary to complete the synthesis was introduced in one operation by alkylation with ethylene dibromide in dimethylformamide containing sodium carbonate. Presumably the β-bromoethylamine **6f** is the initially formed product which subsequently undergoes alkylation at the β position of the indole moiety. Chromatography on Florisil afforded $(\pm)$-minovine[9] (25% from **6e**), identical with a sample of natural origin[10] by comparison of infrared spectra, mass spectra, and thin layer chromatography. Ester **6a** could be transformed to $(\pm)$-minovine *via* the same sequence of reactions employed for ester **6b**.

As a consequence of this synthesis, the C_{19}-H of minovine can be assigned as *cis* to the angular ethyl group. Since the chemical interconversion of tabersonine (6,7-dehydro-**1b**),[11] vincadifformine (**1b**), and minovine[3b] has been achieved, all three must be of the same relative configuration. The optical rotatory dispersion curve of natural minovine correlates with that of $(-)$-tabersonine and $(-)$-vincadifformine.[12] Con-

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(3) (a) J. Mokry, L. Dubrakova, and P. Sefcovic, *Experientia*, **18**, 564 (1962); (b) J. Mokry, I. Kompis, L. Dubrakova, and P. Sefcovic, *ibid.*, **19**, 311 (1963).

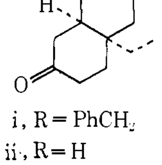
(4) D. A. Shirley and P. A. Roussel, *J. Amer. Chem. Soc.*, **75**, 375 (1953).

(5) K. T. Potts and J. E. Saxton, *J. Chem. Soc.*, 2641 (1954); W. E. Noland, W. C. Kuryla, and R. F. Lange, *J. Amer. Chem. Soc.*, **81**, 6010 (1959).

(6) All new compounds gave satisfactory elemental analyses and/or mass spectra. Melting points are corrected.

(7) F. E. Ziegler, J. A. Kloek, and P. A. Zoretic, *J. Amer. Chem. Soc.*, **91**, 2343 (1969); R. V. Stevens, R. K. Mehra, and R. L. Zimmerman, *Chem. Commun.*, 877 (1969).

(8) It has been reported[7] that annelation of enamine **5** with methyl vinyl ketone provides ketone **i** which can be converted to its debenzylated derivative **ii**, mp 50–51°. Recently, this material has been shown to have a *cis*-ring juncture: Y. Ban., I. Inoue, M. Akagi, and T. Oishi, *Tetrahedron Lett.*, 2067 (1969).



i, R = $PhCH_2$
ii, R = H

(9) Racemic minovine has previously been prepared from $(\pm)$-vincadifformine (**1b**) (ref 3b) and by total synthesis; J. P. Kutney, K. K. Chan, A. Failli, J. M. Fromson, C. Gletsos, and V. R. Nelson, *J. Amer. Chem. Soc.*, **90**, 3891 (1968).

(10) We are indebted to Dr. J. Tomko, Institute of Chemistry, Bratislava, Czechoslovakia, for an authentic sample of minovine (*Vinca minor*), mp 79–81°, $[\alpha]_D$ 0 ± 2°.[3a]

(11) M. Plat, J. LeMen, M. M. Janot, J. M. Wilson, H. Budzikiewicz, L. J. Durham, Y. Nakagawa, and C. Djerassi, *Tetrahedron Lett.*, 271 (1962).

(12) W. Klyne, R. J. Swan, B. W. Bycroft, D. Schumann, and H. Schmid, *Helv. Chim. Acta*, **48**, 443 (1965).

sequently, these Aspidosperma alkaloids have the same absolute configuration designated by structure **1** (C_{19}–$H\alpha$).

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[13] National Institutes of Health Predoctoral Fellow, 1966–1969.

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Fluorescence Lifetimes of Molecules that Undergo Large Configurational Changes upon Excitation[1]

Sir:

Comparison of measured and calculated lifetimes of molecules can lead to important information regarding the nature of the lowest excited singlet state and the corresponding electronic transition. Measured natural lifetimes (τ_{0m}) are obtained from fluorescence decay (τ_F) and quantum yield (ϕ_F) measurements using the relation $\tau_{0m} = \tau_F/\phi_F$. Calculated natural lifetimes τ_{0c} are estimated using Strickler and Berg's relation.[2]

Agreement between τ_{0m} and τ_{0c} is expected in systems where the approximations used in deriving the Strickler and Berg equation are valid. There it is assumed that $B_{uo\rightarrow l} = B_{u\leftarrow lo}$, where $B_{u\leftarrow lo}$ is the sum of the coefficients of induced absorption from the vibrationless lower state (lo) to the upper vibronic states (u) and $B_{uo\rightarrow l}$ is the sum of the coefficients of induced emission from the vibrationless upper state (uo) to the lower vibronic states (l). This approximation makes it possible to calculate lifetimes from absorption intensities and from the reciprocal of the mean value of $\tilde{\nu}_F^{-3}$ in the fluorescence spectrum. However, $B_{uo\rightarrow l}$ is equal to $B_{u\leftarrow lo}$ under certain limited conditions, namely, when the electronic transition moment $M_{lu}(Q)$ is independent of the nuclear coordinates, Q, or if the potential energy surfaces for the upper and lower states are not displaced relative to each other; and when the vibrational wave functions with a given quantum number are the same for the ground and excited states, *i.e.*, potential surfaces of both states have the same shape.

Discrepancies between τ_{0m} and τ_{0c} have been discussed before by Douglas[3] to explain anomalously long lifetimes of small molecules (*e.g.*, SO_2). Birks and Dyson[4] have interpreted anomalously long lifetimes of diphenylpolyenes, *i.e.*, values of α ($\alpha = \tau_{0c}/\tau_{0m}$) less than one, in terms of changes in nuclear configuration as a result of excitation.

Recently, anomalously long lifetimes (10^{-4}–10^{-5} sec) have been observed by Briegleb, *et al.*, for methylpyridinium halides.[5] Large *intermolecular configurational changes* occur during lifetimes of the excited states leading to a configuration unfavorable for the transition. Thus, the transition from the equilibrium excited state is forbidden relative to the transition arising from a ground-state equilibrium configuration.

Here we give an example where the transition becomes more allowed (*i.e.*, $M_{u\rightarrow l}(Q') > M_{u\leftarrow l}(Q'')$) owing to *intramolecular configurational changes* in the excited state which give rise to anomalously short lifetimes. Fluorescence lifetimes and quantum yields were measured for β-naphthylamine degassed solutions in cyclohexane and ethanol at room temperature. Lifetimes were calculated using the Strickler and Berg equation, which includes corrections for the refractive index of the solvent and the frequency of emission. The results are summarized in Table I.

Table I. Fluorescence Lifetimes (in nsec) of β-Naphthylamine at Room Temperature

Solvent	τ_F	ϕ_F	τ_{0m}	τ_{0c}	$\alpha = \tau_{0c}/\tau_{0m}$
Cyclohexane	6.9	0.33	21	41	1.95
Ethanol	16.6	0.46	36	56	1.56

The permanent dipole moment of the fluorescent state of β-naphthylamine is 3.5 D larger than the ground-state dipole moment. To explain this large increase in dipole moment, Mataga[6] suggested a structural change of the amino group from the essentially[7] tetrahedral sp^3 configuration of the ground state to a trigonal sp^2 configuration in the equilibrium excited state. In the trigonal configuration larger overlap occurs between the lone-pair orbital on the amino nitrogen and lowest vacant π molecular orbital of the naphthalene ring leading to a stronger mixing of charge-transfer character into the lowest excited state of β-naphthylamine. Due to this larger overlap the charge-transfer transition is more probable in the sp^2 configuration. Therefore, one expects the electronic transition moment $M_{u\rightarrow l}(Q')$ to be greater than $M_{u\leftarrow l}(Q'')$, where Q' and Q'' represent the equilibrium nuclear configuration of the excited and ground states, respectively. This should lead to a value of τ_{0m} smaller than τ_{0c}. The measured natural lifetime is about half the calculated value, as shown in Table I.

The increase in τ_{0m} in going from cyclohexane to ethanol (as a function of polarity of the medium) can be attributed to changes in the refractive index of the medium, changes in the average frequencies of absorption, and particularly large red shifts of the fluorescence spectrum. The latter arises from the relaxation of the solvent cage during the lifetime of the excited state, which has a different dipole moment from that of the ground state. Lifetimes calculated using the Strickler and Berg equation take into account these factors. It appears, however, that greater interaction between the polar solvent molecules and the polar

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[1] This work was supported by the U. S. Atomic Energy Commission under Contract No. AT(11-1)-2039 and by the National Institutes of Health, National Institute of Neurological Diseases, Blindness and Stroke, Grant No. NB-04145.

[2] S. J. Strickler and R. A. Berg, *J. Chem. Phys.*, **37**, 814 (1962).

[3] A. E. Douglas, *ibid.*, **45**, 1007 (1966).

[4] J. B. Birks and D. J. Dyson, *Proc. Roy. Soc., Ser. A*, **275**, 135 (1963).

[5] G. Briegleb, J. Trensceni, and W. Herre, *Chem. Phys. Lett.*, **3**, 146 (1969).

[6] N. Mataga, *Bull. Chem. Soc. Jap.*, **36**, 654 (1963).

[7] P. J. Krueger, *Spectrochim. Acta*, **19**, 705 (1963).