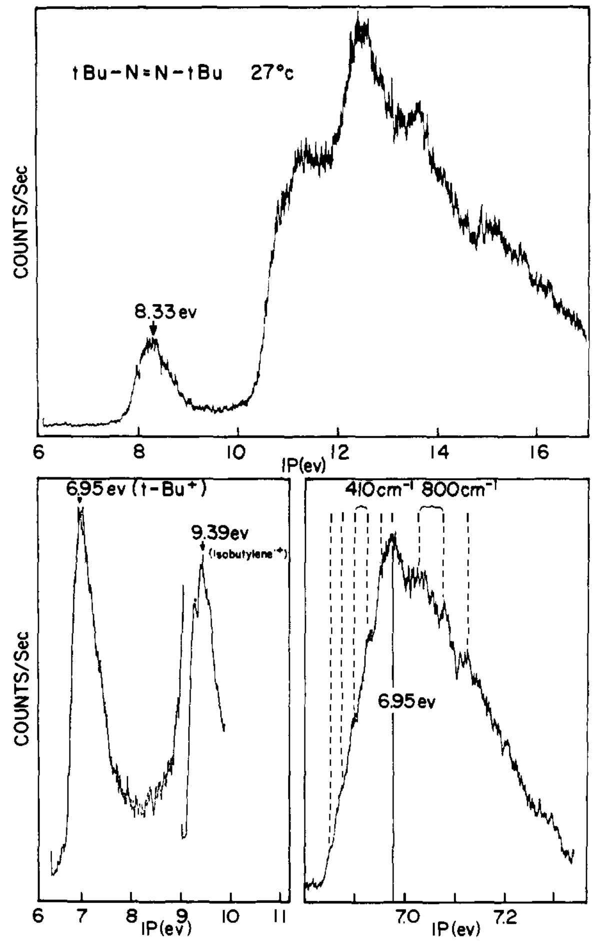

Figure 2. (a) Top, azoisobutane; (b) bottom left, *tert*-butyl (6.95 eV) and isobutylene (9.39 eV); (c) bottom right, *tert*-butyl, expanded.

information indicates that carbonium ions show a strong preference for planarity. We therefore interpret the 720 cm^{-1} vibrational progression in Figure 1c as an indication *that methyl radical is not strictly planar* although the degree of nonplanarity is small.[6] Assignment of the 2720-cm^{-1} frequency as a C–H stretch similarly implies a change in the C–H bond length for the cation compared to the radical. Such changes are not unexpected since the $^2A_1''$ ionic state of ammonia also shows[7] such N–H perturbations.

The spectrum of azoisobutane has not been reported previously and is also shown, for comparison, as Figure 2a. Figure 2b shows the first two bands which were observed at 370°. The first band maximum is at 6.95 ± .05 eV in excellent agreement with the ionization potential for *tert*-butyl, measured using the mass spectrometry technique.[2a] The second band is identical, in position and shape, with isobutylene passed through the furnace at approximately the same temperature. The starting azo compound is completely absent under the conditions giving Figure 2b.

Figure 2c shows an expanded view of the *tert*-butyl band. Two vibrational spacings are apparent as shown ($\nu_1 \sim 410$ and $\nu_2 \sim 800$ cm^{-1}). The 410-cm^{-1} frequency could be assigned to a C–C out of plane bending and the 800-cm^{-1} spacing to a C–C–H bending.[8] If taken at face value these assignments would indicate that *tert*-butyl radical is strongly pyrimidal and that there is considerable change in the C–C–H bond angle in the *tert*-butyl cation as compared to the radical. However, the degree of nonplanarity, implied by the length of the 410-cm^{-1} progression, appears to be too large to be consistent with esr results.[9] An alternative explanation of the 410-cm^{-1} progression is that the *tert*-butyl radical is formed in a highly excited (C–C–C bending) vibrational state. This explanation would require a lifetime, for the excited vibrational states, of the order of 10^{-4} sec^{-1} which also seems too long.

While some ambiguities remain in the interpretation of the band shape of the *tert*-butyl spectrum, a considerable geometric reorganization of the cation relative to the radical seems clearly indicated. The observation of the *tert*-butyl spectrum also establishes that this technique is not restricted to small molecules such as methyl and should be generally useful for the study of organic intermediates.

Studies of the deuterated analogs of the present examples as well as a quantitative analysis of the Frank-Condon factors[10] are presently in progress. Investigation of other alkyl radicals and diradicals have also been initiated.

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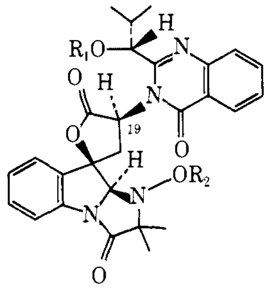
Tryptoquivaline and Tryptoquivalone, Two Tremorgenic Metabolites of *Aspergillus clavatus*

Sir:

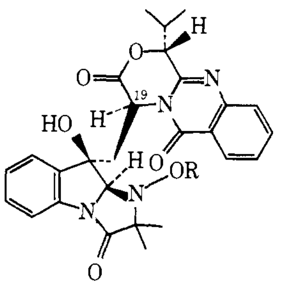
The fungus *Aspergillus clavatus* collected from a sample of mold-damaged rice produces two nontoxic metabolites kotanin and desmethylkotanin[1] and minor amounts of the highly toxic cytochalasin E.[2] More recently we have separated from the same mold isolate two tremor producing metabolites[3] and now report on their structures.

The more polar metabolite, now called tryptoquivaline (**1**) (mp 153–155°; $[\alpha]^{25}D$ 142° (*c* 1.05, $CHCl_3$); *m/e* found 546.2155,[4] calcd for $C_{29}H_{30}N_4O_7$ 546.2114; ir ($CHCl_3$) 3520, 1790, 1735, 1680, 1615 cm^{-1}; uv_{max} (EtOH) 228 nm (ϵ 37,000), 275 (8550), 305 (3800), 317 (3040); nmr ($CDCl_3$) δ 1.03 (d, 3, J = 7 Hz), 1.17 (d, 3, J = 7 Hz), 1.50 (s, 3), 1.52 (s, 3), 2.19 (s, 3), 2.63 (m, 1), 3.10 (d, 1, J = 10 Hz), 3.15 (d, 1, J = 10 Hz), 3.63 (b, 1), 4.04 (b, 1), 5.00 (s, 1), 5.61 (d, 1, J = 9 Hz), 5.70 (t, 1, J =

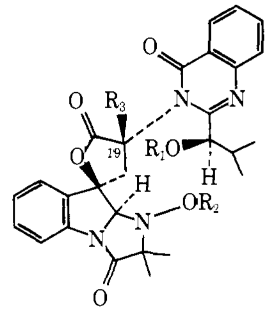
10 Hz), 7.12-7.90 (m, 7), 8.22 (d, 1, J = 8 Hz)) exhibited a positive triphenyltetrazolium chloride (TTC) test suggesting the presence of a hydroxylamine.[5] Methanolysis (0.5% HCl, 5°, 8 hr) gave the desacetyl derivative **4** (mp 252-253°; positive TTC test; ir (CHCl$_3$) 3400, 1765, 1720, 1670, 1605 cm^{-1}) with unchanged uv spectrum that was characterized further by the p-bromobenzoate **5**, mp 192-194°, and the p-bromophenylurethane **6**, mp 196-198°, both exhibiting negative TTC tests.



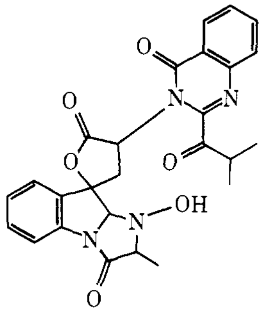
1, R$_1$ = CH$_3$CO; R$_2$ = H
2, R$_1$ = R$_2$ = CH$_3$CO
3, R$_1$ = R$_2$ = H



4, R = H
5, R = p-BrC$_6$H$_4$CO
6, R = p-BrC$_6$H$_4$NHCO
7, R = CH$_3$CO



8, R$_1$ = R$_2$ = R$_3$ = H
9, R$_1$ = R$_2$ = H; R$_3$ = D
10, R$_1$ = R$_2$ = CH$_3$CO; R$_3$ = H



11

Comparisons of carbonyl absorptions in the infrared spectra of tryptoquivaline (**1**) and its methanolysis product **4** excluded the possibility that the former was simply the acetate of the latter. Indeed, acetylation of **1** with acetic anhydride in pyridine yielded a diacetate **2** (mp 171-172°; ir (CHCl$_3$) 1795, 1735, 1685 cm^{-1}) while acetylation of **4** afforded a monoacetate **7** (mp 187-189°; ir (CHCl$_3$) 3430, 1765, 1735, 1685 cm^{-1}). Possibly the intermediate hydroxy γ-lactone **3** had undergone acyl transfer to the more stable trans disubstituted hydroxy δ-lactone **4**. Tryptoquivaline (**1**) thus becomes a spiro-γ-lactone, and related γ-lactones with electron withdrawing α-substituents do indeed exhibit carbonyl absorptions between 1790 and 1800 cm^{-1}.[6]

Base hydrolysis of tryptoquivaline (**1**) (0.2 M Na$_2$CO$_3$ in aqueous dioxane, 20°, 45 min) produced an uncharacterized carboxylate which on acidification was transformed to the hydroxy γ-lactone **8**: mp 175-178°; $[\alpha]^{25}$D − 142° (c 1.02 CHCl$_3$); ir (CH$_3$CN) 3670, 3570, 3420, 1800, 1730, 1685 cm^{-1} with unchanged uv spectrum. Acetylation afforded a diacetate **10**: mp 144-146°; ir (CHCl$_3$) 1795, 1730, 1680 cm^{-1}. The new γ-lactone **8** appeared to be C(19)-epitryptoquivaline and this was verified by formation of the deuteriolactone **9** when the hydrolysis was performed in D$_2$O. Clearly, the lactone in the C(19)-epi series hydrolyzes more rapidly than in the natural series and the γ-disubstituted δ-lactone (epi-C(19) in **4**). Hydrolysis of the δ-lactone **4** in a basic medium followed by acidification gave the epi-γ-lactone **8** again demanding epimerization in **4** or **1** prior to lactone ring opening.

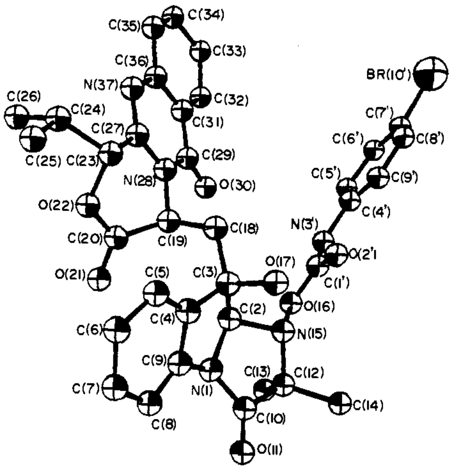


Figure 1. A computer generated perspective drawing of **6**.

The p-bromophenylurethane derivative **6** crystallized from a methylene chloride-heptane mixture in the unambiguous orthorhombic space group $P2_12_12_1$ with cell constants a = 28.493 (3), b = 20.386 (2), and c = 6.6377 (6) Å. All unique reflections within a 2θ sphere of 110° were measured using Ni-filtered Cu Kα X-rays (1.5418 Å). Of the 2827 independent diffraction maxima investigated, 1693 were judged observed after correction for background, Lorentz, and polarization effects. A Patterson map showed the bromine position, and subsequent electron density syntheses revealed the rest of the nonhydrogen atoms. Full-matrix least-squares refinements with anisotropic temperature factors for all nonhydrogen atoms have converged to a standard crystallographic discrepancy index of 0.105.[7] A difference Fourier map indicated that a badly disordered heptane molecule existed in the asymmetric unit. Attempts are presently being made to find a suitable model for this disordering and also to determine the absolute configuration of **6**. Figure 1 is a computer generated drawing of the X-ray model of **6**,[7] while Table I contains a list of the fractional coordinates (supplemental material).

The faster moving metabolite now called tryptoquivalone (**11**) (mp 202-204°; $[\alpha]^{25}$D 254° (c 1.05, CHCl$_3$); m/e found 488.1704, calcd for C$_{26}$H$_{24}$N$_4$O$_6$, 488.1696;[4] uv$_{\max}$ (EtOH) 234 nm (ϵ 34,950), 292 (9550), 320 (6300); ir (CHCl$_3$) 3525, 1790, 1735, 1715, 1680 cm^{-1}; nmr (CDCl$_3$) δ 1.24 (d, 3, J = 7 Hz), 1.31 (d, 3, J = 7 Hz), 1.59 (d, 3, J = 7 Hz), 3.09 (d of d, 1, J = 10, 14 Hz), 3.47 (d of d, 1, J = 11, 14 Hz), 4.12 (quintet, 1, J = 7 Hz), 4.36 (quartet, 1, J = 7 Hz), 5.24 (s, 1), 5.51 (t, 1, J = 10 Hz), 7.12-7.94 (m, 7), 8.28 (d, 1, J = 8 Hz)) gave positive TTC and 2,4-DNP tests. Based on these data we suggest structure **11** and assume without evidence that the configurations of **1** and **11** are identical. These metabolites with novel structures appear to be tetrapeptides derived from trytophan, anthranilic acid, valine, and methylalanine or alanine, respectively.

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Supplementary Material Available. The fractional coordinates (Table I) will appear following these pages in the microfilm edition of this volume of the journal. Photocopies of the supplementary material from this paper only or microfiche (105 × 148 mm, 24× reduction, negatives) containing all of the supplementary material for the papers in this issue may be obtained from the Journals Department, American Chemical Society, 1155 16th St., N.W., Washington, D. C. 20036. Remit check or money order for $3.00 for photocopy or $2.00 for microfiche, referring to code number JACS-75-663.

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Kinetics of Complexation of Potassium Ions with Dibenzo-18-Crown-6 in Methanol by ^{39}K Nuclear Magnetic Resonance

Sir

Synthetic and naturally occurring macrocyclic ionophores, which are capable of forming stable complexes with alkali ions, have recently gained much interest.[1] Such compounds often increase the solubility of electrolytes in hydrophobic media and are thought to play a major role in the process of ion transport in biological membranes. It is therefore of interest to study the kinetics of the complexation reaction between ionophores and cations. Such studies have been performed by chemical relaxation methods, ultrasonic absorption,[2] and by ^{1}H and ^{23}Na nmr spectroscopy.[3,4]

Despite the great importance of potassium binding processes, especially in biological systems, very little use has been made of ^{39}K nmr in their study.[5] This is due to the small gyromagnetic ratio of the ^{39}K nucleus and thus its low nmr sensitivity. To overcome this limitation we have employed a superconducting magnet operating at 60 kG (corresponding to ^{39}K nmr frequency of about 12 MHz) and used it to study the complexation of potassium ions with dibenzo-18-crown-6 (DBC) in methanol. For the nmr measurements we used a pulse spectrometer equipped with a variable temperature probe. The ^{39}K signals were still quite weak, and excessive signal averaging was needed.

For the kinetics studies, the longitudinal relaxation times (T_1) of ^{39}K were measured in methanol solutions containing 0.48 M KI and 0.14 M DBC over a wide range of temperatures. The results of these measurements are presented in Figure 1. Also shown are results for a methanol solution containing 0.5 M KI but no DBC. Comparison of the two sets of data clearly indicates the occurrence of a kinetic process in which potassium ions exchange back and forth between the solvated and complexed form according to eq 1.

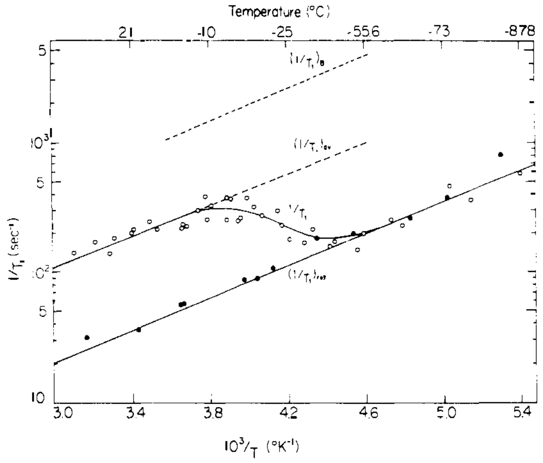

Figure 1. Semilog plots of $1/T_1$ of ^{39}K in a methanol solution *vs.* reciprocal absolute temperatures. The open circles correspond to a solution containing 0.48 M KI and 0.14 M DBC, while the closed circles correspond to a solution containing 0.5 M KI but no DBC. The continuous curves for the DBC solution were calculated using the parameters given in the text. Measurements were done at 12 MHz (60 kG).

$$K^+ + DBC \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} (K^+, DBC) \qquad (1)$$

The interpretation of the results presented in Figure 1 is similar to that given previously for the ^{23}Na case.[4a] It is based on quadrupole relaxation effects of ^{39}K ($I = 3/2$) in the two environments under consideration. In the solvated form, the nmr relaxation rate of ^{39}K is relatively long, due to the more symmetric structure of this form, while in the (K$^+$, DBC) complex the symmetry around the K$^+$ ion is considerably reduced, and at the same time the correlation time is increased, resulting in fast nuclear relaxation. In the low temperature region of Figure 1 (below −55°) the exchange reaction between the two forms (eq 1) is slow, and only the signal of the solvated K$^+$ ions is observed; the free induction decay signal of the (K$^+$, DBC) complex is too fast to detect. On the other hand, in the high temperature region (above −10°) the exchange is fast and the observed relaxation rate is the average of the rates in both environments. In the intermediate region (−55 to −10°) the exchange rate is of the order of the relaxation rates, and by a quantitative analysis of the nmr data in this region kinetic parameters can be derived. The actual derivation of the kinetic parameters was done as described in detail before,[4a] and the following results were obtained: $k_{-1} = 610$ sec^{-1} (at −34°), $\Delta E = 12.6$ kcal/mol. The curve in Figure 1 for the solution containing DBC was calculated on the basis of these results and the assumption of nearly complete complexation.

Similar measurements were also performed on rubidium ions in methanol solutions of RbCNS (0.64 M) and DBC (0.11 M) using ^{87}Rb nmr, (employing a 14-kG magnet which corresponds to 19.5 MHz). In these experiments the transverse relaxation rate of ^{87}Rb was measured from the free induction decay signal following a 90° pulse. The results are shown in Figure 2 together with measurements on a RbCNS solution not containing DBC. Clearly, in this case the exchange rate between the solvated and complexed form is sufficiently fast to average out the nmr signal in the two environments even at −50°. This gives a lower limit of 10^4 sec^{-1} for k_{-1} at this temperature.

The above results for potassium binding to DBC are similar to those found previously[4a] for Na$^+$ (k_{-1} = 800 sec^{-1},