Pergamon

Tetrahedron, Vol. 52, No. 24, pp. 8063-8072, 1996

0040-4020/96 $15.00 + 0.00

PII: S0040-4020(96)00390-0

Synthetic Entry to Dibenzo[*b,f*]oxinin and Dibenzo[*b,f*] azonine Derivatives Through a Dibenzo[*a,e*]cycloocten-5-one

I. Wesley Elliott*, Milton J. Sloan[1] and Earl Tate

Department of Chemistry, Fisk University
Nashville, TN 37208

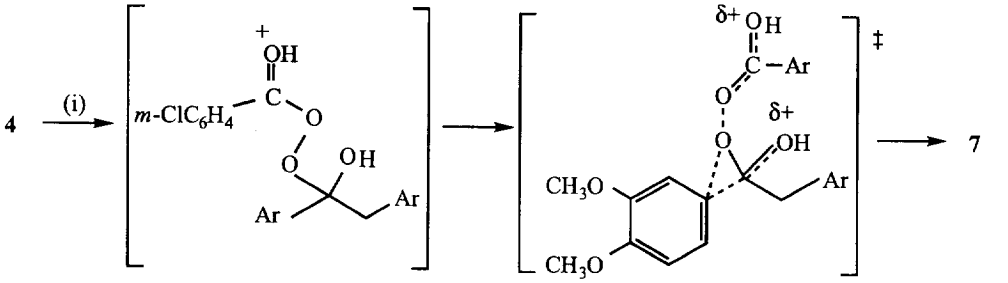
ABSTRACT: 2,3,8,9-Tetramethoxy-5,6,11,12-tetrahydrodibenzo [*a,e*]cycloocten-5-one (**2**) was transformed by Baeyer-Villiger oxidation to the substituted 6-oxodibenzo[*b,f*]oxinin **6**. One-pot Beckmann or Schmidt rearrangements of **2** afforded the 6-oxodibenzo[*b,f*]-azonine **8** which was reduced by BH_3-THF to the tricyclic amine **14**. Parallel reactions with desoxyveratroin gave the ester **7** or amide **12** from preferential migration of the 3,4-dimethoxyphenyl over the 3,4-dimethoxybenzyl group. Copyright © 1996 Elsevier Science Ltd

INTRODUCTION

In a program of synthesis of a series of structurally diverse but biogenetically related isoquinoline alkaloids from the keto acid **1**[2] we prepared 2,3,8,9-tetramethoxy-5,6,11,12-tetrahydrodibenzo[*a,e*]cyclo-octen-5-one (**2**)[3] as a proposed intermediate to pavine, and with moderate quantities of this tricyclic ketone available we decided to examine its behavior in several typical ketone reactions. Since we did not find reports in the literature of the Baeyer-Villiger, Beckmann or Schmidt rearrangements with the tricyclic dibenzo[*a,e*] cycloocten-5-one system, we investigated these reactions, and for comparison we studied a simpler analog, desoxyveratroin (**3**), in the same reactions.

The Baeyer-Villiger[4], Beckmann[5] and Schmidt[6] rearrangements are classical oxidative reactions that ketones undergo. With carbocyclic ketones they are marked by ring expansion to lactones or lactams, and with unsymmetrical ketones (e.g., aryl benzyl ketones) they pose tests of the migratory aptitudes of the carbonyl substituents. In the Baeyer-Villiger oxidation the product is determined solely by the migrating group. The reaction occurs under general acid catalysis and is facilitated by electron-donating groups in the ketone and electron-withdrawing groups in the peracid.[7-10] The relative nucleophilicities of the two groups on the carbonyl carbon generally determine the respective migratory aptitudes. However, a mixture (5:1) of esters was obtained from cyclohexyl phenyl ketone in which the cyclohexyl group migrated predominately.[11] Furthermore, steric and conformational factors can compete with and even dominate electronic factors in determining the stability of the transition state and thus the migratory aptitude.[12]

The mechanism of the Baeyer-Villiger rearrangement has been shown to involve a concerted *O-O* heterolysis-migration which is usually rate determining.[13] The group migrating to the electron deficient atom normally has more nucleophilic character and is better able to accommodate the partial positive charge of the heteroatom in the transition state.[14] In the example with desoxyveratroin, *p*-toluenesulfonic acid catalyzes addition of the peracid with the carbonyl leading to the tetrahedral peroxy adduct (Criegee adduct A) (Fig. 1). The carbonyl substrate can be either an intermolecularly *H*-bonded adduct or a protonated adduct, and the formation of this adduct becomes rate-determining.[9,15] The migration can thus be presumed to be predominately acid-catalyzed and therefore the nucleophilicities should be the major factor in determining migration.



Criegee adduct A
(Ar = 3,4-dimethoxyphenyl)

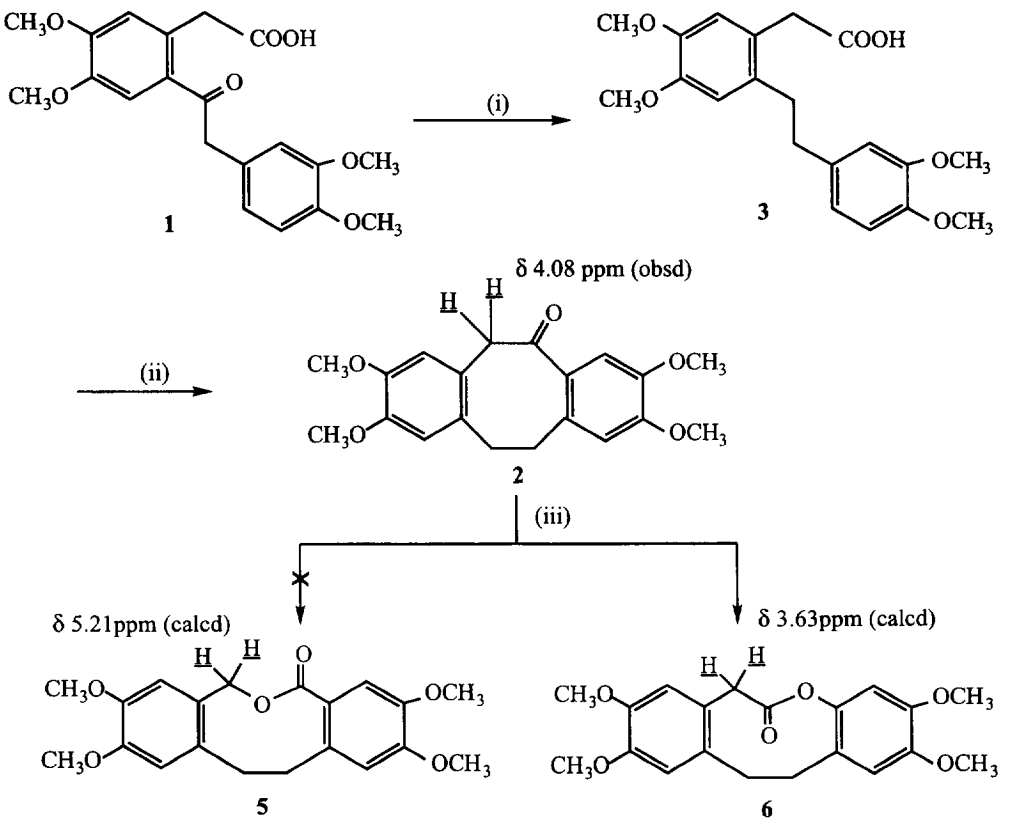
Figure 1. Acid-catalyzed B-V reaction of desoxveratrion showing protonated Criegee Adduct and transition state of dimethoxyphenyl migration (Scheme 2).

Migratory aptitudes are not so important in the traditional Beckmann rearrangement, but the geometry of the intermediate oxime is the key to the product formed. As a rule the group anti to the *OH* in the oxime migrates to the nitrogen. Hydroxylamine-*O*-sulfonic acid was recently introduced as a reagent that permits oximation-rearrangement to be carried out in one pot.[16] Operationally, then, the Beckmann rearrangement resembles the Schmidt reaction for transforming ketones to amides, and without a characterizable intermediate migratory aptitudes become a refuge for predicting product.

In addition to comparing the migratory competition between aryl versus benzyl in three different rearrangements, the reactions with ketone **2** provide new routes to tricyclic oxinin and azonine derivatives.

RESULTS AND DISCUSSION

Ketone **2** was prepared from **1** in three steps (Scheme 1). Catalytic hydrogenolysis of **1** by Pd-C to **3** was achieved in 83% yield in acetic acid solution with a small amount of perchloric acid. The bibenzyl acid **3** was cyclodehydrated to **2** by PPA under mild conditions. Our preparation of **2** differs from Yamato's[3] only in step two, the reduction of keto acid **1** to **3**; we report slightly different mp's for compounds **1**, **2** and **3**.



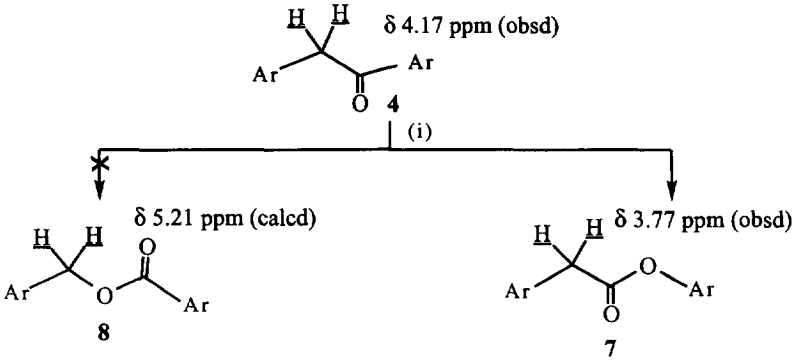
SCHEME 1

(i) H_2/Pd-C, HOAc-$HClO_4$; (ii) PPA; (iii) MCPBA/CH_2Cl_2

Baeyer-Villiger Rearrangements. Compound **2** was treated with *m*-chloroperbenzoic acid (MCPBA) in dichloromethane at room temperature. On work-up only one product was observed by Tlc and the structure of this lactone **6** was established by NMR. The α-methylene protons in **2** absorb at δ 4.08 relative to TMS. These comparable protons in the two possible isomeric lactones **5** or **6** will experience either a downfield shift (for **5**) or an upfield shift (for **6**).[17] By theoretical calculations using Shoolery's rules that are based on the additive effects of shielding constants,[18,19] the corresponding δ-values are predicted to be 5.21 ppm for **5** and 3.63 ppm for **6**. The observed chemical shift of the α-methylene protons in the actual product was upfield at δ 3.58 (Scheme 1).

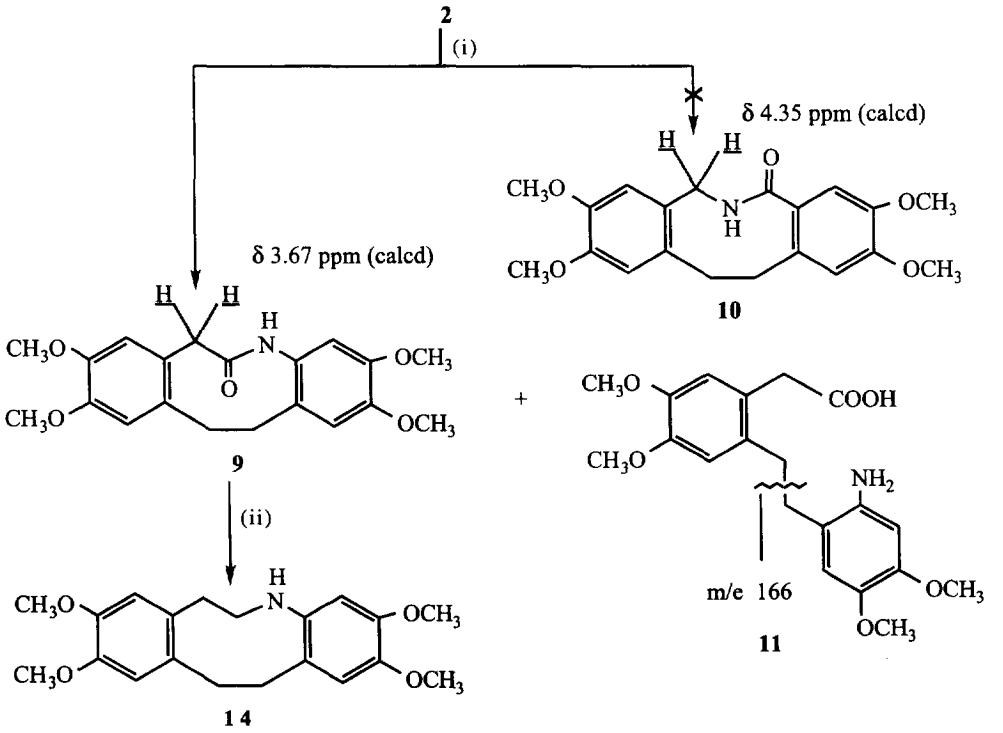
The Baeyer-Villiger oxidation of desoxyveratroin **4** was catalyzed by *p*-toluenesulfonic acid, and again a single ester **7** was obtained (Scheme 2). The chemical shift for the α-methylene proton in **4** absorb at δ 4.17

and in the ester at δ 3.77, supporting structure **7** and indicating that the dimethoxyphenyl group migrated in both ketones **2** and **4**.



SCHEME 2

(i) MCPBA/C_6H_6/*p*-toluenesulfonic acid



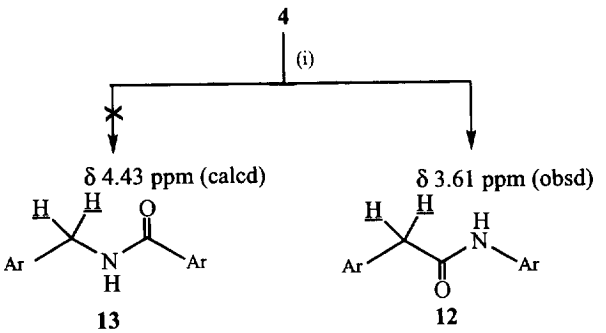
SCHEME 3

(i) H_2NOSO_3H/(DMF or HCOOH); NaN_3/PPA; (ii) BH_3-THF

Beckmann and Schmidt Rearrangements. Ketone **2** was allowed to react with hydroxylamine-*O*-sulfonic acid either in refluxing formic acid or hot DMF. From either system the same, single lactam was obtained in yields of 54 to 72%. In practice concentrated DMF solutions were preferred because near the bp of DMF, the lactam quickly separated, giving a visual indication that the rearrangement was completed. Structure proof in favor of lactam **9** was gained from NMR (Scheme 3). The α-CH_2 group in **2** (δ 4.08) experienced an up field shift to δ 3.36. The calculated chemical shift for these protons in **9** is 3.67 ppm whereas in the isomer **10** the protons are predicted to absorb at 4.35 ppm.

In a few runs, a by-product, identified as the ring-hydrolyzed amino acid **11** was isolated in addition to **9**. Structure **11** was established by elemental composition, NMR and especially the mass spectrum that showed, in addition to the molecular ion at m/e 375, a significant peak at m/e 166 attributable to the anilino fragment from the same lactam.

Hydroxylamine-*O*-sulfonic acid in hot formic acid caused desoxyveratroin **4** to undergo the Beckmann rearrangement to produce a single amide **12** which possessed a NMR spectrum with α-CH_2 at δ 3.61; this corresponded to an upfield shift from desoxyveratoin (δ 4.17) (Scheme 4). The same amide **12** by mp and spectral comparison was independently synthesized from 3,4-dimethoxyphenylacetic acid and 1-amino-3,4-dimethoxybenzene in decalin at 180-190° C. Isomeric compound **13** is predicted to show a peak at δ 4.43 in the NMR.



SCHEME 4

(i) H_2NOSO_3H/ HCOOH

Schmidt rearrangements of **2** were produced by sodium azide in PPA at 80° C, furnishing the same lactam **9** but in isolated yields of 24-30% compared with 66-72% by the modified Beckmann; however, no attempts were made to isolate an amino acid by-product (cf. **10**) from these reactions.

Products **9** and **12** show that from both ketones, Beckmann and Schmidt rearrangements occurred by migration of the 3,4-dimethoxyphenyl group similarly to the Baeyer-Villiger rearrangements.

Reduction of lactam **9** by BH_3-THF afforded 2,3,8,9-tetramethoxytetrahydrodibenzo[*b,f*]azonine (**14**). There are no reported alkaloids with this ring system, unlike the naturally occurring dibenzo[*d,f*]azonines.[20] The rare examples of relatives of **14** known were obtained as by-products from benzyne-mediated syntheses of dibenzopyrrocolines which were shown to be intermediates in the formation of dibenzo[*b,f*]azonines.[21,22]

EXPERIMENTAL

Melting points were taken in open capillary tubes using a Mel-Temp apparatus and are uncorrected. IR spectra were recorded either on a Perkin-Elmer 727 or Beckman 12 spectrophotometer, either as Nujol™ mull or KBr pellets and only noteworthy absorptions (cm^{-1}) are reported. NMR spectra were measured in $CDCl_3$ with δ values relative to TMS at 0 ppm and recorded on a Varian EM390, IBM NR80, Varian Gemini 300 or a GE QE300 spectrometers. Mass spectra data was provided by M.A. Waugh or measured on VG 7070F as EI at 70 eV. Elemental analyses were performed by Atlantic Microlabs, Inc. or Gailbraith Laboratories.

2-[2-(3,4-Dimethoxyphenyl)ethyl]-4,5,dimethoxyphenyl acetic acid (Bibenzyl acid) (3).

To a warm solution of the keto acid **1** (12.0 g; 32.1 mmol) in acetic acid (180 mL) was added 10 drops of 70% perchloric acid and 10% Pd-C catalyst (1.0 g). The solution was hydrogenated for 8 hours at approximately 45 psi. After the catalyst was filtered off, the filtrate was diluted with about 600 mL of water. On cooling a tan solid precipitated. This was collected, and the filtrate was extracted with dichloromethane (3x20 mL). Evaporation of the dichloromethane and dilution of the residue with aqueous methanol gave additional solid. Recrystallization of the solid fractions from aqueous methanol gave the bibenzyl acid: 9.6 g (83%); mp 145-146° C; (lit.[3] mp 92-94° C). IR: 1715; 1585 cm^{-1}. ^{1}H-NMR (300 MHz): δ 2.72-2.92 (4H, m, $ArC\underline{H}_2C\underline{H}_2Ar$), 3.53 (2H, s, $C\underline{H}_2$), 3.67 (3H, s, $OC\underline{H}_3$), 3.81 (3H, s, $OC\underline{H}_3$), 3.86 (6H, s, $OC\underline{H}_3$), 6.55 (1H, d, $Ar\underline{H}$), 6.65-6.82 (4H, m, $Ar\underline{H}$). MS: m/e 360 (M^+), 209, 179, 151 (base peak), 107. Anal. Calcd for $C_{20}H_{24}O_6$: C, 66.65; H, 6.71: Found C, 66.51; H, 6.76.

2,3,8,9-Tetramethoxy-5,6,11,12-tetrahydrodibenzo[a,e]cyclo-octen-5-one (2).

Bibenzyl acid **3** (5.0 g; 13.9 mmol) was stirred into PPA (100 g). The mixture was warmed at 70° C in a water bath and well mixed by hand stirring for 1 h. After an additional 0.5 h the mixture was added to cold water (400 mL) and the grey solid was collected, washed with sodium bicarbonate solution and recrystallized from aqueous methanol to give the ketone: 3.1 g (65%); mp 174-75° C; (lit.[3] mp 167-170° C). IR: 1650, 1590 cm^{-1}. ^{1}H-NMR (90 MHz): δ 3.22 (4H, m, $ArC\underline{H}_2C\underline{H}_2Ar$), 3.84-3.80 (12H, br s, $OC\underline{H}_3$), 4.08 (2H, s, $C\underline{H}_2$), 6.40 (1H, s, $Ar\underline{H}$), 6.53 (2H, s, $Ar\underline{H}$), 7.10 (1H, s, $Ar\underline{H}$). ^{13}C-NMR (20 MHz): δ 34.2, 35.1, 51.1, 55.6,

112.0, 113.0, 114.2, 114.7, 125.8, 130.3, 133.4, 147.6, 147.8, 148.1, 201.7. MS: m/e 342 (M^+), 327, 314, 299, 253. Anal. Calcd for $C_{20}H_{22}O_5$: C, 70.16; H, 6.48: Found: C, 69.98; H, 6.48.

2,3,9,10-Tetramethoxy-6-oxo-6,7,12,13-tetrahydrodibenzo-[b,f]oxinin (6).

Dibenzocyclooctenone **1** (1.0g; 2.9 mmol) was dissolved in dichloromethane (50 mL) and treated with *m*-chloroperbenzoic acid (MCPBA) (0.7 g) at room temperature for 6-8 days. The solution was then extracted with 5% sodium carbonate (2x30 mL) and evaporated to dryness to give 0.9 g of product (86% yield). After successive recrystallizations in ethanol-benzene a constant mp 200-201° C was recorded. IR: 1745 cm^{-1}. ^{1}H-NMR (90 MHz): δ 2.82 (4H, s, ArC$\underline{H}_2$C$\underline{H}_2$Ar), 3.58 (2H, s, ArC$\underline{H}_2$CO), 3.84 (12H, s, OC$\underline{H}_3$), 6.64-6.62 (3H, m, Ar$\underline{H}$), 6.78 (1H, s, Ar$\underline{H}$). MS: m/e 358 (M^+), 342, 330, 313, 299, 284, 191, 167 (base peak), 164, 121, 92. Anal. Calcd for $C_{20}H_{22}O_6$: C, 67.02; H, 6.19: Found: C, 66.66; H, 6.13.

Desoxyveratroin (4).

This compound was prepared in 83% yield from reaction of 3,4-dimethoxyphenylacetic acid with veratrole in PPA: mp 105-106° C; (lit.[23] mp 105-107° C). The spectral data agreed with those previously reported.

3,4-Dimethoxyphenyl)-3,4-dimethoxyphenylacetate (7).

Desoxyveratroin (3.8 g; 12.0 mmol) was dissolved in benzene (60 mL) and treated with a slight excess of MCPBA (2.0 g) and a catalytic amount of *p*-toluenesulfonic acid (0.1 g). The mixture was allowed to stir at room temperature for 4 hours (after about 15 min the solution darkened). Then water (60 mL) was added to quench the excess acid and the reaction solution was extracted with ether (3x30 mL). The combined extracts were washed with aqueous sodium bicarbonate (3x30 mL), with aqueous NaCl (15 mL), dried over magnesium sulfate and evaporated to dryness. After recrystallization in ethanol 2.7 g (68%) was obtained with mp 109-110° C (lit.[24] mp 109° C); R_f = 0.58 ($CHCl_3$/silica gel). IR: 1750, 1610 cm^{-1}. ^{1}H-NMR (300 MHz): δ 3.77 (2H, s, C$\underline{H}_2$), 3.85 (3H, s, OC$\underline{H}_3$), 3.87 (3H, s, OC$\underline{H}_3$), 3.88 (3H, s, OC$\underline{H}_3$), 3.91 (3H, s, OC$\underline{H}_3$), 6.63-6.59 (2H, m, Ar$\underline{H}$), 6.94-6.81 (4H, m, Ar$\underline{H}$). ^{13}C-NMR (75 MHz): δ 40.6, 55.7, 55.9, 60.7, 105.4, 110.8, 114.1, 114.7, 121.1, 121.4, 125.6, 144.4, 146.5, 147.0, 148.0, 148.5, 170.1. MS: m/e 332 (M^+), 178 (base peak), 163, 154, 151, 139, 107, 79, 65. Anal. Calcd for $C_{18}H_{20}O_6$: C, 65.12; H, 6.03: Found: C, 65.27; H, 6.12.

2,3,9,10-Tetramethoxy-6,7,12,13-tetrahydro-6-oxodibenzo [b,f]-azonine (9).

A. Beckmann in DMF. Ketone **2** (4.0 g; 11.7 mmol) and hydroxylamine-*O*-sulfonic acid (3.0 g) were stirred into DMF (35 mL) at RT for 30 min. The solution was gradually heated to bp over 30 min and cautiously kept hot for 5 min longer. The hot solution quickly became turbid and finely-divided solid precipitated. The cooled mixture was added to cold water (200 mL) and the product was collected by suction

filtration, washed with water and redissolved in ethanol-toluene. Lactam **9** (3.0 g; 72%) was obtained in three crops with mp 241-242° C. IR: 3200, 1655, 1610, 1455, 1245cm^{-1}. ^{1}H-NMR (300 MHz): δ2.50 (1H, m, J=12Hz, CH2), 2.65 (1H, m, J=12Hz, CH2), 3.12 (2H, m, J=12Hz, CH2), 3.13 (1H, d, J=13Hz, CH2CO), 3.45 (1H, d, J=13Hz, CH2CO), 3.88 (3H, s, OCH3), 3.89 (3H, s, OCH3), 3.93 (3H, s, OCH3), 3.95 (3H, s, OCH3), 6.64 (1H, s, ArH), 6.68 (1H, s, ArH), 6.78 (1H, s, ArH), 7.09 (2H, s, ArH,NH). ^{13}C-NMR (75 MHz): δ 32.5, 36.5, 37.2, 56.6, 56.7, 56.8, 110.4, 113.2, 113.6, 116.0, 126.3, 128.6, 133.7, 135.5, 148.4, 148.5, 149.9, 174.5. MS: m/e 357 (M^+, base peak), 314, 191, 166. Anal Calcd for $C_{20}H_{23}NO_5$: C, 67.21; H, 6.48; N, 3.92: Found: C, 67.20; H, 6.40; N, 3.79.

B. Beckmann in Formic Acid. Ketone **2** (3.4 g; 9.9 mmol), hydroxylamine-*O*-sulfonic acid (1.9 g) and formic acid (25 mL) were stirred together at RT for 20 min and then heated under reflux 3 hrs. The cooled solution was poured into cold water (200 mL) to give a gummy solid. The solid was recrystallized from ethanol-toluene as colorless crystals: 1.9 g (54%); mp 240-242° C. This product was identical with lactam **9** from Method A.

The aqueous filtrate was neutralized with aqueous NaOH and near pH 6 a grey solid precipitated after *ca.* 30 min, the product **11** (0.8 g) was recrystallized from aqueous methanol with mp 184-185° C. ^{1}H-NMR (90 MHz): 2.65-2.75 (4H, m, ArCH$_2$CH$_2$Ar), 3.50 (2H, s, CH$_2$), 3.70 (3H, s, OCH$_3$), 3.75 (6H, s, OCH$_3$), 3.81 (3H, s, OCH$_3$), 6.30 (1H, s, ArH), 6.50 (1H, s, ArH), 6.60 (1H, s, ArH), 6.80 (1H, s, ArH). MS: m/e 375 (M^+), 357, 209, 181, 166, 122. Anal. Calcd for $C_{20}H_{25}NO_6$: C, 63, 98; H, 6.71; N, 3.73: Found: C, 63.68; H, 6.76; N, 3.68.

C. Schmidt Rearrangement. A mixture of ketone **2**, (3.4 g; 9.9 mmol), sodium azide (0.95 g) and PPA (70 g) was heated on a water bath at 50° C for 8.5 h. The NaN_3 was added in portions over 1 h with stirring. The color of the mixture gradually changed to purple, and the product was isolated by adding cold water (700 mL). The crude, brown solid was purified as colorless crystals (0.86 g, 24%) by recrystallizing from ethanol-benzene with mp 240-242° C.

2,3,9,10-Tetramethoxy-6,7,12,13-tetrahydro-5H-dibenzo[b,f]-azonine (14)

Lactam **9** (0.9 g; 2.5 mmol) was dissolved in BH_3-THF (30 mL, 1M conc) by warming. After 20 h at room temperature, more BH_3-THF (10 mL) was added, and after 2.5 h the mixture was carefully hydrolyzed using cold 10% NaOH. Concentrating the solution *in vacuo*, gave a gummy precipitate that was recrystallized in ethanol-benzene as colorless glistening crystals: 0.4 g (46%); mp 191-193° C. IR (KBr): 3342, 2950, 1610, 1512 cm^{-1}. ^{1}H-NMR (300 MHz): δ 2.50 (3H, m, NH, CH$_2$), 2.80 (4H, br s, CH$_2$), 3.37 (2H, br s,CH$_2$), 3.87 (3H, s, OCH$_3$), 3.88 (3H, s, OCH$_3$), 3.89 (3H, s, OCH$_3$), 3.92 (3H, s,OCH$_3$), 6.62 (1H, s, ArH), 6.67 (1H, s,

ArH), 6.68 (1H, s, ArH), 6.72 (1H, s, ArH). ^{13}C-NMR (75 MHz): δ 32.3, 34.7, 34.8, 55.0, 55.8, 55.9, 56.1, 106.6, 106.7, 112.4, 112.8, 113.0, 126.3, 129.4, 135.1, 139.9, 143.9, 147.6, 148.1. MS: m/e 343 (M^+, base peak), 329, 328, 178, 165, 147. Anal. Calcd for $C_{20}H_{25}NO_4$: C, 69, 95; H, 7.34; N, 4.01: Found: C, 70,15; H, 7.42; N, 4.08.

N-(3,4-dimethoxyphenyl)-2-(3,4-dimethoxyphenyl)acetamide (12)

A. Beckmann Method. Desoxyveratroin (3.1 g; 9.8 mmol), hydroxylamine-*O*-sulfonic acid (2.2 g) and formic acid (15 mL) were allowed to reflux 6 h. On standing overnight a dark slush formed that was stirred into H_2O (50 mL). The solid precipitate was recrystallized from aqueous methanol to give a nearly colorless solid: 1.1 g (33%); mp 141-142° C. IR: 3350, 1675 cm^{-1}. ^{1}H-NMR (300 MHz): δ 3.67 (2H, s, CH_2), 3.83 (3H, s ,OCH_3), 3.85 (3H, s, OCH_3) 3.89 (3H, s, OCH_3), 3.91 (3H, s, OCH_3), 6.74 (2H, d, J=3Hz, ArH), 6.84 (1H, s, ArH), 6.89 (2H, d, J=3Hz, ArH), 7.01 (1H, s, NH), 7.28 (1H, s, ArH). ^{13}C-NMR(75 MHz): δ 45.1, 56.7, 56.8, 105.6, 112.0, 112.5, 113.3, 122.7, 127.6, 132.1, 146.7, 149.3, 150.2, 170.1. MS: m/e 331 (M^+, base peak), 153, 152, 138, 107. Anal Calcd for $C_{18}H_{21}NO_5$: C, 65.24; H, 6.38; N, 4.22: Found C, 65.15, 65.25 ; H, 6.48, 6.59; N, 4.12.

B. Direct Amidation. A mixture of 4-aminoveratrole (1.6 g; 10 mmol), and 3,4-dimethoxyphenylacetic acid (1.9 g; 9.7 mmol) was heated in decalin (110 mL) at bp for 40 min. The cooled mixture was diluted with hexane and the supernatant liquid was decanted from the dark gum. The gum was dissolved in hot hexane-ethanol, treated with charcoal and filtered. Scratching facilitated crystallization of a near-white solid, (0.4 g), 142-143° C. This product was identical with the amide from Beckmann rearrangement of desoxyveratroin.

ACKNOWLEDGEMENT

Partial support of this research was provided through grants from the National Institutes of Health (MBRS-S06-08062) to Fisk University.

REFERENCES AND NOTES

1. Present Address: Laboratory of Bioorganic Chemistry, National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health, Bethesda, MD 20892.
2. (a) Elliott, I. W. *J. Heterocyclic Chem.* **1970**, 7, 1229; (b) Elliott, I. W. *J. Heterocyclic Chem.* **1972**, 9, 853; (c) Elliott, I. W.; Evans, S. L. *J. Org. Chem.* **1973**, 38, 3425; (d) Elliott, I. W. *J. Org. Chem.* **1977**, 42, 1090; (e) Elliott, I. W. *J. Org. Chem.* **1979**, 44, 1162; (f) Elliott, I. W. *J. Org. Chem.* **1982**, 47, 5398; Carty, A.; Elliott, I. W.; Lenoir, G. M. *Canad. J. Chem.* **1984**, 62, 2435.

3. Yamato, T.; Inoue, H.; Fukumoto, M.; Tashino, M. *Org. Prep. Proced. Int.* **1995**, 27, 495.
4. Hassall, C. H. *Organic Reactions* **1957**, 9, 73; Krow, G.R. *ibid.* **1993**, 43, 251.
5. Donarvma, L. G.; Heldt, W. Z. *Organic Reactions* **1960**, 11, 1; Gawley, R. E. *ibid.* **1988**, 35, 1.
6. Wolff, H. *Organic Reactions* **1946**, 3, 307.
7. (a) Trahanovsky, W. S. *Organic Chemistry*; Wasserman, H. H. Ed.; Academic Press: NY; 1978; Part C, 5-C, p. 257, (b) House, H.O. *Modern Synthetic Reactions*; W.A. Benjamin: Menlo Park CA; 1972, 2nd. ed., p. 321.
8. The order of reactivity for migrating groups has been given as tertiary alkyl > cyclohexyl - secondary alkyl - benzyl - phenyl > primary alkyl > cyclopropyl > methyl (Hawthorne, M. F.; Emmons, W. D. *J. Am. Chem. Soc.* **1958**, 80, 6398.
9. Hawthorne, M. F.; Emmons, W. D.; McCallum, K. S. *J. Am. Chem. Soc.* **1958**, 80, 6393.
10. Doering, W. E.; Spears, L. *J. Am. Chem. Soc.* **1950**, 72, 5515.
11. Friess, S.L.; Farnham, N. *J. Am. Chem. Soc.* **1950**, 72, 5518.
12. Meinwald, J.; Frauenglass, E. *J. Am. Chem. Soc.* **1960**, 82, 5235.
13. Ogata, Y.; Sawaki, Y. *J. Org. Chem.* **1972**, 37, 2953.
14. Hudlicky, M. *Oxidations in Organic Chemistry*, ACS Monograph 186; American Chemical Society: Washington, DC; 1990, p. 186.
15. Palmer, B.W.; Fry, A. *J. Am. Chem. Soc.* **1970**, 92, 2580.
16. Olah, G. A.; Fung, A. P. *Org. Syn.* **1984**, 63, 188.
17. Experimental chemical shifts of phenylacetone, benzylacetate and methylphenylacetate are illustrative of this:

C_6H_5-$\underline{CH_2}$-$COOCH_3$ δ 3.59 ppm C_6H_5-$\underline{CH_2}$-$COCH_3$ δ 3.67 ppm C_6H_5-$\underline{CH_2}$-$OCOCH_3$ δ 5.10 ppm

18. Dailey, B. P.; Schoolery, J.W. *J. Am. Chem. Soc.* **1955**, 77, 3977.
19. Silverstein, R. M.; Bassler, G. C.; Morrill, T. C. *Spectrometric Identifications for Organic Compounds*, John Wiley and Sons: NY; 1981, 4th ed., p. 223.
20. Shamma, M.; Moniot, J. L. *Isoquinoline Alkaloid Research*, Plenum Press: NY; (1972-77), Chapter 18.
21. (a) Kessar, S. V.; Randhawa, B.; Gandhi, S. S. *Tetrahedron Lett.* **1973**, 2923; (b) Kessar, S. V.; Singh, P. Gandhi, S. S. *Indian J. Chem.* **1975**, 13, 1116.
22. (a) Kano, S.; Yokomatsu, T.; Shibuya, S. *Chem. Pharm. Bull. (Japan)* **1975**, 23, 1098; (b) Kano, S.; Komiyama, E.; Nawa, K. Shibuya, S. *Chem. Pharm. Bull. (Japan)* **1976**, 24, 310.
23. (A) Dyke, S. F.; Brown, D. W.; Sainsbury, M.; Hardy, T. *Tetrahedron* **1971**, 27 , 3495; (b) Badía, D.; Dominguez, E.; Galarza, J.; Lete,; E.; Martínez de Marigorta, E.; Villa, M. J. *Bull. Soc.Chim. Belg.* **1989**, 98(1), 77.
24. Campbell, R. V. M.; Harper, S. H.; Kemp, A. D. *J. Chem. Soc.* **1969**, 13, 1787.

(*Received in USA* 18 *March* 1996; *revised* 19 *April* 1996; *accepted* 20 *April* 1996)