(12) See M. H. Chisholm et al., references quoted in ref 11 above, and M. H. Chisholm and R. L. Kelly, *Inorg. Chem.*, **18**, 2321 (1979).
(13) One of the referees suggested that, in view of the title, this article should preferentially be published in the April 21st issue of *J. Am. Chem. Soc.* Obviously this referee has both a sense of humor and is well advanced in Stephen Potter's "Game of One Upmanship".
(14) The cluster structure of $MoCl_2$ may be expressed as $(Mo_6Cl_8)Cl_2Cl_{4/2}$ where eight Cl atoms occupy faces of the octahedral Mo_6 moiety, two Cl atoms are terminally bonded to Mo atoms, and four Cl atoms are bridged to neighboring Mo_6 units: H. Schäfer, H.-G. v. Schnering, J. Tillack, F. Kuhnan, H. Wöhrle, and H. Bauman, Z. Anorg. Allgem. *Chem.*, **353**, 281 (1967).
(15) F. A. Cotton, *Acc. Chem. Res.*, **11**, 225 (1978).
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(17) (a) For a recent listing of Mo≡Mo distances see ref 1b. (b) For a review of Mo—Mo single-bond distances which vary greatly depending upon the oxidation of molybdenum and the presence or nature of groups which directly bridge the two metal atoms, see F. A. Cotton, *J. Less Common Met.*, **54**, 3 (1977)
(18) This point was emphasized by one of the referees.

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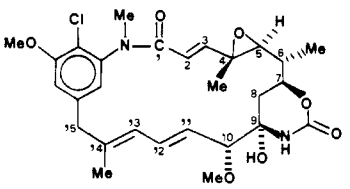
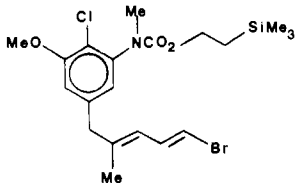
Total Synthesis of (±)-Maysine†[1]

Sir:

We report herein the first total synthesis of a natural maytansinoid, maysine (**1**), originally isolated and characterized by Kupchan.[1] Recently, methodology was described[2,3] which led to the total synthesis of (±)-*N*-methylmaysenine, a related member of this complex family of macrocycles. The route to **1** is based on the key intermediate **2**[3] and the highly functionalized and stereochemically pure moiety **3** which were coupled and elaborated to the target product. The preparation of **3** in



(±)-**1**



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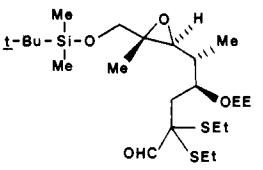
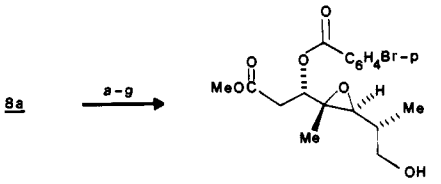


3

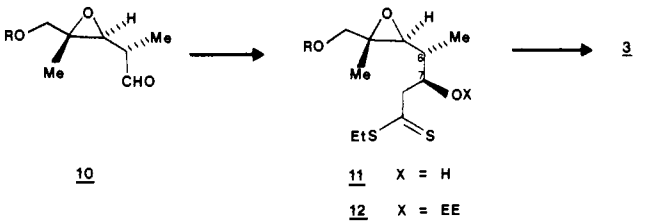
multigram quantities originated with the known aldehyde **4**[3] which was reduced ($NaBH_4$, EtOH, 25 °C) to the allylic alcohol **5** and then protected as the silyl ether **6**. Various epoxidation procedures leading to **7** were attempted, but all gave unsatisfactory mixtures of **7a–7b**.[4] Finally, *m*-chloroperbenzoic acid in CH_2Cl_2 at 0 °C gave a 53:47 mixture of **7a–7b**, which could be readily separated after conversion (MeMgCl, 2.0 equiv, THF, 0 °C) into the corresponding alcohols **8a–8b**.[5] Structure proof for **8a** as the correct precursor to maysine was accomplished by correlation to the epoxy ester **9** whose stereochemistry was established by X-ray techniques several years ago.[6] By using the series of reactions a–g, **9** was prepared from **8a** which proved to be identical in all respects with the X-ray sample. Thus, the important intermediate **8a** is readily prepared in 25% overall yield from the simple α,β-unsaturated aldehyde **4**, in spite of poor selectivity in the epoxidation step. Oxidation via Collins reagent converted **8a** into the aldehyde



8a → (a–g) → **9**

(a) Ethyl vinyl ether, TsOH, Et_2O; (b) Bu_4NF, CH_3CN; (c) $(COCl)_2$, Me_2SO, Et_3N; (d) CH_3CO_2Me, LDA, −78 °C, THF; (e) *p*-BrC_6H_4COCl, pyridine; (f) pyridinium tosylate, MeOH; (g) separation on Waters HPLC-244, 15% THF-hexane gave pure β-acyloxy esters.

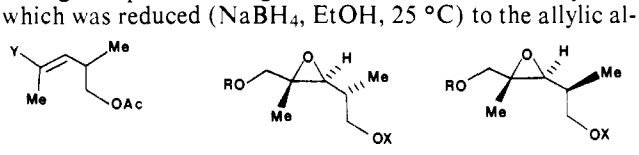
10 which was then treated with ethyl lithiodithioacetate (−78 °C, THF, 6 h) and quenched (1 equiv of HOAc, −78 °C) to provide the β-hydroxy dithioester **11** as a 3:1 mixture of diastereomers. Separation on medium-pressure liquid chromatography[7] (10% acetone–hexane) gave the major isomer which was shown to possess the erythro configuration at C-6,C-7 by NMR.[8] After masking the C-7 alcohol as the ethoxyethyl



10 → **11** X = H; **12** X = EE → **3**

group (EE; ethyl vinyl ether, *p*-$TsOH{\cdot}H_2O$, 25 °C, 1 h), it was treated with 3.0 equiv of ethylmagnesium iodide (−45 °C, THF, 2 h)[3] and then with 4.0 equiv of 2-(*N*-methyl-*N*-formyl)aminopyridine[3] to form the α-formyl dithioacetal **3**.[9] The overall yield of the major maysine fragment **3** was 6.9% (from **4**).

Coupling of major fragments **2** and **3** was accomplished by transforming the diene bromide **2** into its lithium derivative (2.0 equiv of *t*-BuLi, −120 to −90 °C, THF-Et_2O-pentane (4:1:1)), followed by addition of **3** (1.0 equiv, −120 to −60 °C, 30 min), which furnished the carbinol and subsequently the methyl ether **13** (NaH, THF, 15 equiv of CH_3I, 0–25 °C, 2 h, 70% yield for the two steps).[10] Removal of both silyl protecting groups to **14** took place quantitatively when **13** was treated with 7.0 equiv of tetrabutylammonium fluoride in THF for 4 h (Scheme 1). The primary alcohol **14** was oxidized in 70.5% yield to the aldehyde **15** (NMR ($CDCl_3$) δ 8.84 (br s, 1)) using 1,1′-(azodicarbonyl)dipiperidine and *tert*-butoxymagnesium bromide.[11] Treatment of the aldehyde with the phosphonoacetyl chloride in pyridine gave the phosphonoamide **16** in 75% yield (IR (film) 1725, 1663 cm^{-1}; NMR ($CDCl_3$) δ 8.84 (s, 1), 2.71 (d, 2, J = 22 Hz)). At this point, the latter intermediate was properly equipped for ring closure. As already reported[3] for *N*-methylmaysenine, the Wadsworth–Emmons olefination was again attempted (1.0 equiv of KO-*t*-Bu, THF



4, Y = CHO; **5**, Y = CH_2OH; **6**, Y = CH_2OR (R = *t*-$BuMe_2Si$)

7a, X = Ac; **8a**, X = H

7b, X = Ac; **8b**, X = H

† Dedicated to the memory of Professor Robert Burns Woodward.

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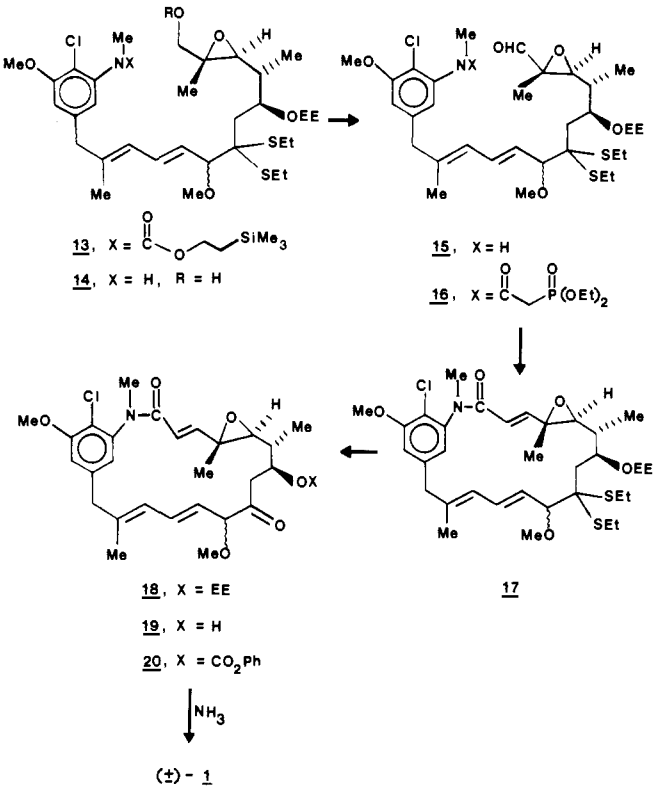
Scheme I



(concentration of **16**, 5×10^{-4} M), −78 to 25 °C, 10 h) and afforded the macrocycle **17** as the pure *E* isomer in 56% yield after PLC (IR (film) 1663 cm^{-1}). The thioacetal was cleanly removed (95%, 2.2 equiv of $HgCl_2$, 2.5 equiv of $CaCO_3$, 4:1 CH_3CN-H_2O) to the ketone **18** (IR (film) 1718, 1663 cm^{-1}) and the ethoxyethyl (EE) group was quantitatively removed (0.5 N HCl-THF, 0 °C) to the hydroxy ketone **19** (IR (film) 3420, 1720, 1660 cm^{-1}). The final synthetic step was carried out by in situ preparation (PhOCOCl, pyridine, Et_2O) of the mixed carbonate **20** (IR (film) 1754 cm^{-1}) and followed immediately with liquid ammonia at −78 °C. After warming to ambient temperature, workup and preparative layer chromatography (silica gel) gave a product (R_f 0.13, 20% benzene-ethyl acetate) which was identical, except for optical rotation, with an authentic sample of (−)- maysine:[1] IR (film) 1709, 1662, 1628, 1575, 1088 cm^{-1}; NMR ($CDCl_3$) of selected proton signals δ 1.00 (s, 3, C-4 CH_3), 1.26 (d, J = 6.1 Hz, C-6 CH_3), 1.64 (br s, C-14 CH_3), 2.62 (d, J = 9.6, C-5 H), 3.27 (s, C-10 CH_3O), 5.66 (d, J = 15.5 Hz, C-2 H), 6.38 (d, J = 15.5 Hz, C-3 H); mass spectrum (70 eV, 170 °C) *m/e* 546 (M^+), 528 ($M^+ - 18$), 485 ($M^+ - 61$, $-(H_2O + HNCO)$, base peak), 470 ($M^+ - 76$), 450 ($M^+ - 96$); UV (EtOH) λ 226, 242, 252, 280, 288 nm. High-pressure liquid chromatographic (Waters 244) comparison using a 4 mm × 30 cm μ-Porasil column and eluting with 50% ethyl acetate-chloroform (0.5% ethanol) at a flow rate of 5 mL/min gave identical peaks for synthetic and natural maysine at a retention time of 5.2 min.

Studies are continuing to reach additional members of this class of macrocycles and these will be described in future reports.

Acknowledgment. The authors are grateful to the National Institutes of Health (CA-16051) for financial support for this program. An NIH postdoctoral Fellowship to D. M. Roland and a travel grant from the Deutsche Forschungsgemeinschaft to R. Henning are also gratefully acknowledged. We thank Dr. Albert T. Sneden for his kind assistance and authentic samples of maysine, Dr. James Frye of the CSU Regional NMR Center for NMR spectra, and Dr. Phillip Ryan for the mass spectral data. Furthermore, it is a pleasure to acknowledge the technical assistance of Dr. Arthur Campbell and Mr. Curtis Gillespie.

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(4) Using various alkyl and acyl substituents on **6** gave epoxide mixtures as high as 10:1, but unfortunately rich in the wrong isomer, **7b**.
(5) Separation on a 10-g scale was carried out using a Waters 500 high-pressure LC system with 10% acetone-hexane. Retention times at 250 mL/min were 12.7 min for **8a** and 15.9 min for **8b**, respectively.
(6) Meyers, A. I., Shaw, C. C.; Horne, D. A.; Trefonas, L. M.; Majeste, R. M. *Tetrahedron Lett.* **1975**, 1745.
(7) Meyers, A. I.; Slade, J.; Smith, R. K.; Mihelich, E. D.; Hershenson, F. M.; Liang, C. D. *J. Org. Chem.* **1979**, *44*, 2247. Alternatively, the mixture in 11 was separated on Waters 500 LC using 7% acetone–hexane.
(8) Both isomers of 11 were obtained pure and examined at 100 MHz. The protons at C-7 (δ 4.05, 4.06) were shown to be a quartet (J = 5.8 Hz) in one isomer and a doublet of doublets of doublets (J_1 = 8.6, J_2 = 5.6, J_3 = 3.1 Hz) for the other. Projections fully support the erythro isomer having the smaller J value between methine protons.
(9) Physical data for **3**: pale yellow viscous oil; NMR ($CDCl_3$) δ 0.07 (s, 6), 0.91 (s, 9), 1.0–2.7 (m), 2.83 (d, J = 9 Hz, 1), 3.2–4.3 (m), 4.7 (m, 1), 8.9 (two formyl signals due to diastereomers generated by the ethoxyethyl masking group).
(10) The ratio of diastereomers in **13** was found to be 1:1 as determined by high-pressure liquid chromatography on **19** and (±)-1.
(11) K. Narasaka, A. Morikawa, K. Saigo, and T. Mukaiyama, *Bull. Chem. Soc. Jpn.*, **50**, 2773 (1977).

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A Weakly Chemiluminescent Dioxetanimine[1]

Sir:

Dioxetanones (α-peroxylactones) are an interesting class of high energy compounds because of their potential involvement in the light-forming step of many luminescent organisms.[2] Particularly noteworthy is the fact that the yield of light production from some simple alkyl-substituted dioxetanones is greatly increased in the presence of fluorescent aromatic hydrocarbons with low oxidation potentials. Schuster and Adam ascribed this interesting finding to the occurrence of a chemically initiated electron-exchange luminescence (CIEEL).[3] Recently, the reaction of ketenes with singlet oxygen has been found to be an useful method for the synthesis of dioxetanones.[4] As the continuation of our search for new chemiluminescent systems,[5] we now report the synthesis of *N-tert*-butyldimethyldioxetanimine (**2**) through the photooxygenation of *N-tert*-butyldimethylketenimine (**1**) and show its chemiluminescence properties.

Photooxygenation[6] of **1** (0.1 M) for 1 h at −78 °C in $CFCl_3$ using tetraphenylporphine as sensitizer led to complete disappearance of **1**. Direct ^1H NMR analysis (100 MHz) of the reaction solution at low temperature (−70 °C) indicated a mixture of **2** (65%), acetone (**3**, 30%), *tert*-butyl isocyanate (**4**, 30%), and *tert*-butyl isocyanide (**5**, 5%).[7] The dioxetanimine **2** showed two singlet resonances at δ 1.22 (9 H) and 1.64 (6 H). When the reaction solution was warmed to temperatures above −30 °C, the ^1H NMR spectrum of **2** was completely converted into that of a mixture of **3** and **4** within a few minutes.[15]

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