Syntheses of Showdomycin and its Anomer Using \( N \)-(Triisopropylsilyl)pyrrole as a Synthetic Equivalent for the Maleimide C3-Anion

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Dedicated, with affection and admiration, to Professor Wolfgang Steglich on the occasion of his 70th birthday.

Abstract: Showdomycin (1) and its anomer (2) have been prepared in four steps from readily available trichloroacetimidate 9. The key step involves reaction of the last compound with the title pyrrole 3 so as to form a chromatographically separable mixture of the pyrrole C-glycosides 10 and 11. These pyrroles are desilylated then oxidized to the corresponding maleimides using PCC.

Key words: nucleosides, pyrroles, trichloroacetimidates, C-glycosides, maleimides, oxidation

We have recently reported\(^1\) that various glycosyl trichloroacetimidates react with simple pyrroles in the presence of Lewis acids to give pyrrole C-glycosides, compounds which have considerable potential in the preparation of a significant range of other C-glycosides. In that connection we now detail the application of such methodology to the preparation of the naturally occurring C-riboside (+)-showdomycin (1) and its anomer (Figure 1).

(+) -Showdomycin was first isolated from Streptomyces showdoensis by Nishimura and co-workers in the early 1960’s\(^2\) and was shown to exhibit antibacterial properties.\(^3\) Although the subject of debate,\(^4\) this effect has been attributed\(^5\) to the presence of the maleimide residue which reacts, in a hetero-Michael addition reaction, with biologically relevant thiols, thus inactivating membrane proteins involved in nutrient transport into the target bacterial cells. Compound 1 also displays antitumour activity. Thus, it inhibits the growth of L1210 leukemia, HeLa and Ehrlich ascites tumour cells.\(^6\) As a consequence of such features, numerous synthetic studies have been undertaken and routes to the (+), (−) and (±)-modifications of showdomycin have all been described.\(^7\) A difficulty often encountered in such work is the elaboration of the maleimide unit from precursors such as aldehydes, furans, α-keto-esters and acid anhydrides. Herein we demonstrate that the readily available \( N \)-(triisopropylsilyl)pyrrole (3), which was first introduced by Muchowski,\(^8\) acts as a very effective synthetic equivalent for the maleimide C3-anion.\(^9\)

In our initial approaches to showdomycin the readily available tri-\( O \)-acetyl ribosyl trichloroacetimidate 4\(^9\) was reacted with pyrrole 3 using a minor modification of our previously described\(^1\) conditions involving BF\(_3\)-Et\(_2\)O as promoter. It was expected that anchimeric assistance exerted by the C2’ acetyl group would direct glycosylation and give the β-product 5 preferentially. Disappointingly, however, none of this hoped-for pyrrole C-glycoside was observed. Rather, the acetal 6 (obtained in 65% yield as a 1:1 mixture of epimers) was obtained\(^10\) and this must arise through reaction of 3 with the C1’-C2’-bridged acetoxonium ion produced by ionization of trichloroacetimidate 4. In a further attempt to generate the desired C-1 β-adduct, reaction of the title pyrrole 3 with the readily available tetra-ester 7\(^11\) in the presence of SnCl\(_4\) was examined\(^12\) but only the bis-pyrrole 8 (72%) was obtained.\(^12\)

Figure 1
The ultimately successful route to showdomycin, which circumvented the abovementioned problems by employing a non-participating protecting group at C2', is shown in Scheme 1 and began with reaction of the acetone-protected ribosyl trichloroacetimidate 9 with pyrrole 3 under our previously defined1 conditions. In this manner a chromatographically separable mixture of the pyrrole C-glycoside 10 (40%) and its anomer 11 (21%) was obtained. The lack of selectivity associated with this process is attributed to the operation of a facile, BF₃·Et₂O-catalyzed anomerization process, which results in the interconversion of these products via an open-chain intermediate. Indeed, in control experiments it has been shown that anomers 10 and 11 interconvert at −50 °C in the presence of the Lewis acid and under such conditions the α-anomer predominates. In contrast, treatment of the α-anomer with 80% aq HOAc at 50 °C for 3 h affords mixtures in which the required β-anomer is the major component. The assignment of structure to each of these anomers follows from 1H,1H NOESY experiments. Specifically, and in keeping with expectations,13 in the relevant spectrum of compound 10 an NOE was observed between H1' and H5. In the equivalent spectrum of anomer 11 NOEs were observed between H1' and H4 as well as between the endo-methyl protons of the acetone moiety and H1'.

The next step in the elaboration of compound 11 into target 1 involved desilylation of the former, with tetrabutylammonium fluoride (TBAF),8 thus affording pyrrole 12 (77%). The oxidation of this last material to compound 13 was first carried out using sodium hypochlorite under conditions reported by Steglich and co-workers14 for conversion of a 3,4-disubstituted pyrrole into the corresponding maleimide. While this procedure did indeed produce the target maleimide it was, not unexpectedly,14 contaminated with a chlorinated derivative that proved difficult to remove.

The ready and completely regioselective reaction of pyrrole 3 with electrophiles, including glycosyl trichloroacetimidates, and the ease of oxidation of the resulting 3-substituted pyrroles with PCC suggests that this easily accessible material is an effective synthetic equivalent for the maleimide C3-anion and potentially applicable to the preparation of a wide range of analogues of nucleosides such as showdomycin.

Melting points were measured on a Reichert hot-stage microscope apparatus and are uncorrected. 1H and 13C NMR spectra were recorded on a Varian Inova 500 spectrometer operating at 500 MHz and 126 MHz respectively. In certain cases a Gemini 300 NMR...
Scheme 2

spectrometer, operating at 300 MHz (1H NMR) and 75 MHz (13C NMR) was employed. Spectra were acquired at 20 °C in CDCl3, which had been filtered through basic alumina prior to use, or in CD2OD. Signals arising from the residual protio-forms of the solvent were used as the internal standard. Chemical shifts were recorded as δ values in parts per million (ppm). The assignments of signals observed in the various NMR spectra were often assisted by conducting DEPT, homonuclear (1H/1H) correlation spectroscopy (gDQFCOSY), NOE and/or heteronuclear (1H/13C) correlation spectroscopy (gHMOC or gHMBC) experiments. Infrared spectra were recorded on a Perkin–Elmer 1800 Series FTIR Spectrometer. Samples were analyzed as KBr disks (for solids) or as thin films on NaCl plates (for oils). Low resolution mass spectra were recorded on a Micromass–Waters LC-ZMD single quadrupole liquid chromatograph-MS or VG Quattro II triple quadrupole MS instrument using electrospray techniques in positive and/or negative ionization mode. High resolution mass spectra were acquired by liquid secondary ion MS methods on a Kratos Analytical Concept ISQ instrument. High resolution mass spectra were acquired by liquid secondary ion MS methods on a Kratos Analytical Concept ISQ instrument. High resolution mass spectra were calculated (at the temperature listed) using the equation \[ \delta = 100a/c(l) \] and are given in 10−1 deg.cm2.g−1. Elemental analyses were performed by the Australian National University’s Microanalytical Services Unit based at the Research School of Chemistry, Canberra, Australia. The unit cell parameters were recorded on a Nonius Kappa CCD instrument. CH2Cl2 was distilled under nitrogen atmosphere.

Compounds 6a and 6b
A magnetically stirred mixture of trichloroacetimidate 4 (58 mg, 0.138 mmol), CaH2 (powdered, excess) and N-(trisopropylsilyl)pyrrole 3 (170 µL, 0.154 g, 0.69 mmol) in CH2Cl2 (8 mL) was maintained at r.t. for 0.5 h, then cooled to −50 °C. Neat BF3·OEt2 (20 mL, 0.062 g, 0.23 mmol) was then added, dropwise, and the reaction mixture stirred for 1 h at −50 °C. TLC analysis (silica gel; EtOAc–hexane; 1:3) after this time showed no residual starting material (Rf 0.1) and the formation of two major products [Rf 0.3(4) and 0.3(0)]. As a consequence, Et3N (100 µL) was added, at −50 °C, and the reaction mixture was then poured into NaHCO3 (20 mL of a sat. aq soln), which was extracted with CH2Cl2 (3 × 20 mL). The combined organic extracts were dried (Na2SO4), filtered and concentrated under reduced pressure. The residue was subject to flash chromatography (silica gel; EtOAc–hexane 1:99→1:3) thus affording two fractions, A and B. Concentration of fraction A [Rf 0.3(0)] afforded dioxolane 6a (24 mg, 36%). Concentration of fraction B [Rf 0.3(0)] afforded dioxolane 6b (19 mg, 29%).

Compound 6a (2S-isomer)
[80] D =+3.8 (c 0.2, CHCl3).

IR (NaCl): 2948, 2869, 1746, 1465, 1372, 1238, 1147, 1084, 1017 cm−1.

1H NMR (300 MHz, CD2OD): δ = 1.09 [d, 18 H, J = 7.5 Hz, 3 × CH(CH3)2], 1.47 [sept, 3 H, J = 7.5 Hz, 3 × CH(CH3)2], 1.75 (s, 3 H, CH3), 2.05 (s, 3 H, CH2.CO), 2.12 (s, 3 H, CH2.CO), 4.15–4.19 (m, 1 H, H5′), 4.29–4.39 (m, 2 H, H4′, H5′), 4.63 (dd, 1 H, J = 4.8, 3.8 Hz, H5′), 4.71 (dd, 1 H, J = 9.1, 4.8 Hz, H5′), 5.80 (d, 1 H, J = 8.9 Hz, H4′), 6.17 (dd, 1 H, J = 2.7, 1.5 Hz, H4′), 6.74 (m, 2 H, H2′, H3′).

13C NMR (75 MHz, CD2OD): δ = 12.8, 18.2, 20.5, 26.6, 27.9, 63.7, 73.8, 77.0, 78.6, 106.2, 109.5, 112.4, 122.0, 125.9, 130.0, 171.8, 172.4.

ESMS (+): \[ m/z \text{(%)} = 504 (M + Na+ , 10), 482 (M + H+ , 20), 266 (100). \]

HRMS: \text{m/z} c \text{alcd for C}_{24} \text{H}_{39} \text{NO}_7 \text{Si: C, 59.85; H, 8.16; N, 2.91. Found C, 59.37; H, 8.50; N, 2.63%.}

Compound 6b (2R-isomer)
[80] D =+49.5 (c 0.5, CHCl3).

IR (thin film, NaCl): 2948, 2869, 1747, 1464, 1370, 1238, 1148, 1083, 1017 cm−1.

1H NMR (300 MHz, CD2OD): δ = 1.11 [d, 18 H, J = 7.5 Hz, 3 × CH(CH3)2], 1.48 [sept, 3 H, J = 7.5 Hz, 3 × CH(CH3)2], 1.61 (s, 3 H, CH3), 2.00 (s, 3 H, CH2.CO), 2.08 (s, 3 H, CH2.CO), 3.93–4.02 (m, 2 H, H4′, H5′), 4.13–4.21 (m, 1 H, H5′), 4.65 (dd, 1 H, J = 8.9, 5.0 Hz, H3′), 4.93 (dd, 1 H, J = 5.0, 4.0 Hz, H5′), 5.93 (d, 1 H, J = 4.0 Hz, H4′), 6.32 (dd, 1 H, J = 2.8, 1.5 Hz, H4′), 6.75 (dd, 1 H, J = 2.8, 2.2 Hz, H3′), 6.89 (dd, 1 H, J = 2.2, 1.5 Hz, H2′).

13C NMR (75 MHz, CD2OD): δ = 12.8, 18.3, 20.5, 26.6, 29.1, 63.8, 74.4, 77.3, 79.1, 106.1, 110.1, 113.6, 122.4, 125.6, 130.1, 171.7, 172.3.

ESMS (+): \[ m/z \text{(%)} = 504 (M + Na+ , 10), 482 (M + H+ , 65), 266 (100). \]

HRMS: \text{m/z} c \text{alcd for C}_{24} \text{H}_{39} \text{NO}_7 \text{Si: C, 59.85; H, 8.16; N, 2.91. Found C, 59.28; H, 8.05; N, 3.00.}

Compound 8
A magnetically stirred mixture of compound 7 (40 mg, 0.079 mmol), CaH2 (powdered, excess) and N-(trisopropylsilyl)pyrrole 3 (0.088 g, 0.39 mmol) in CH2Cl2 (4 mL) was maintained at 18 °C for 10 min then neat SnCl2 (28 µL, 0.062 g, 0.23 mmol) was added, dropwise, and the resulting mixture stirred for 1 h. TLC analysis (silica gel; EtOAc–hexane; 1:2) after this time showed one major product (Rf 0.6), the reaction mixture was poured into NaHCO3 (20 mL of a sat. aq soln) which was extracted with CH2Cl2 (3 × 20 mL). The combined organic extracts were dried (Na2SO4), filtered and concentrated under reduced pressure and the residue thus obtained was purified by flash chromatography (silica gel; EtOAc–hexane; 1:99→1:6). Concentration of the appropriate fractions (Rf 0.2) yielded bis-pyrole 8 (51 mg, 72%) as a white foam.
7.48–7.57 (m, 3 H, ArH), 7.93–8.07 (m, 6 H, ArH).

J= (dd, 1 H, –50 °C, and the reaction mixture then poured into a sat. aq soln of BF·OEt2 (12 M H2O). The mixture then poured into a sat. aq soln of NaHCO3 (50 mL) then extracted with CH2Cl2 (3 × 50 mL). The combined organic extracts were dried (Na2SO4), filtered and concentrated under reduced pressure. The residue was purified by flash chromatography (silica gel; EtOAc–hexane, 1:99 → 1:20 → 1:12) and concentration of the appropriate fractions (R0.1; EtOAc–hexane, 1:20) yielded a 1:1 mixture of pyrroles 10 and 11 (20 mg, 87% combined yield).

Method B: A magnetically stirred mixture of trichloroacetimidate 9 (683 mg, 1.19 mmol), CaH2 (powdered, excess) and N-(trisopropylsilyl)pyrrole 3 (588 mL, 532 mmol) in CH2Cl2 (50 mL) was maintained at r.t. for 0.33 h, then cooled to –50 °C. Neat BF3·OEt2 (515 mL, 0.169 g, 1.19 mmol) was then added, dropwise, and the reaction mixture was stirred for 1 h at –50 °C. TLC analysis (EtOAc–hexane, 1:4) showed no residual starting material (R0.5) and the formation of two major products [R0.6 and R0.5(5)]. As a consequence, the mixture was then poured into a sat. aq soln of NaHCO3 (50 mL) then extracted with CH2Cl2 (3 × 50 mL). The combined organic extracts were dried (Na2SO4), filtered and concentrated under reduced pressure. The ensuing residue was subject to flash chromatography (silica gel; EtOAc–hexane, 1:99 → 1:20) and concentration of the appropriate fractions yielded pyrroles 10 (304 mg, 40%) and 11 (155 mg, 21%), respectively, each of which was obtained as a clear, colorless oil.

Compound 10

R0.14 (EtOAc–hexane, 1:20).

1H NMR (500 MHz, CDCl3): δ = 1.08–1.12 (m, 27 H, 9 × CH3 (t-Bu, i-Pr)); 1.38 (s, 3 H, CH3), 1.43 [sept., 3 H, J = 7.8 Hz, CH(CH3)]; 1.56 (s, 3 H, CH3), 1.79 (dd, 1 H, J = 10.7, 3.9 Hz, H5), 3.88 (dd, 1 H, J = 10.7, 4.7 Hz, H5), 4.19 (a-t, 1 H, J = ca. 4.2 Hz, H4), 4.78 (dd, 1 H, J = 5.9, 3.4 Hz, H2), 5.02 (d, 1 H, J = 5.9 Hz, H5), 5.35 (q, 1 H, J = 6.8 Hz, H4). 7.35 (d, 1 H, J = 2.4 Hz, H5), 6.82 (a-t, 1 H, J = 1.5 Hz, H3), 7.37–7.47 (m, 6 H, ArH), 7.68–7.72 (m, 4 H, ArH).

13C NMR (75 MHz, CDCl3): δ = 11.6, 17.8, 19.1, 25.1, 26.4, 26.8, 65.4, 79.2, 83.1, 83.4(7). 83.5(0), 110.8, 121.2, 120.5, 124.1, 127(7), 127(5), 127(7), 129.7, 129.8, 132.9, 133.0, 135.5, 135.6.

ESMS (+): m/z (%) = 672 (M + K+, 8), 656 (M + Na+, 10). 634 (M + H+, 100).

HRMS: m/z calcd for C37H56NO4Si2 (M + H+): 634.3748; found: 634.3754.

Compound 11

R0.08 (EtOAc–hexane, 1:20).

1H NMR (500 MHz, CDCl3): δ = 1.07–1.10 (m, 27 H, 9 × CH3 (t-Bu, i-Pr)); 1.41 (s, 3 H, CH3), 1.42 [sept, 3 H, J = 7.8 Hz, CH(CH3)]; 1.62 (s, 3 H, CH3), 3.82 (dd, 1 H, J = 11.2, 4.4 Hz, H5), 3.87 (dd, 1 H, J = 11.2, 3.9 Hz, H5), 4.14 (a-t, 1 H, J = 4.4, 3.9 Hz, H4), 4.69 (dd, 1 H, J = 6.8, 4.9 Hz, H2), 4.88 (dd, 1 H, J = 6.8, 3.9 Hz, H3), 4.92 (d, 1 H, J = 4.9 Hz, H1'), 6.31 (dd, 1 H, J = 2.4, 1.5 Hz, H4), 6.74 (a-t, 1 H, J = 2.4 Hz, H5), 6.78 (m, 1 H, H2), 7.33–7.45 (m, 6 H, ArH), 7.70–7.75 (m, 4 H, ArH).

13C NMR (126 MHz, CDCl3): δ = 11.6, 17.8, 19.2, 25.6, 26.8, 27.5, 63.9, 81.2, 82.0, 84.0, 86.4, 108.9, 114.0, 121.6, 124.4, 127.8(5), 127.6(4), 129.5, 129.6, 133.3, 133.4, 135.6, 135.7.

Compounds 10 and 11

Method A: A magnetically stirred mixture of trichloroacetimidate 9 (21 mg, 0.037 mmol), CaH2 (powdered, excess) and N-(trisopropylsilyl)pyrrole 3 (45 μL, 0.041 g, 0.183 mmol) in CH2Cl2 (2 mL) was maintained at 18 °C for 0.3 h then cooled to –50 °C. neat BF3·OEt2 (12 μL, 0.013 g, 0.92 mmol) was added, dropwise, and the reaction mixture then stirred for 10 min at –50 °C. TLC analysis (EtOAc–hexane, 1:4) after this time showed no residual starting material (R0.5) and the formation of two major products [R0.6 and R0.5(5)]. As a consequence, Et3N (50 μL) was added, at –50 °C, and the reaction mixture then poured into a sat. aq soln of NaHCO3 (20 mL) and extracted with CH2Cl2 (3 × 20 mL). The combined organic extracts were dried (Na2SO4), filtered and concentrated under reduced pressure. The residue was purified by flash chromatography (silica gel; EtOAc–hexane, 1:99 → 1:20 → 1:12) and concentration of the appropriate fractions (R0.1; EtOAc–hexane, 1:20) yielded a 1:1 mixture of pyrroles 10 and 11 (20 mg, 87% combined yield).
ESMS (+): m/z (%) = 656 (M + Na+, 12), 651 (M + NH4+, 10), 634 (M + H+, 100).
HRMS: m/z calcd for C31H50NO4Si (M + H+): 634.3748; found: 634.3736.

Anal. Calcd for C31H50NO4Si: C, 70.09; H, 8.74; N, 2.21. Found: C, 69.75; H, 9.00; N, 2.36.

Compound 12

TBAF (1.0 M soln in THF, 172 mL, 0.172 mmol) was added, stepwise, to a magnetically stirred 0°C soln of compound 11 (0.110 g, 0.172 mmol) in THF (6 mL). After 10 min, TLC analysis (EtOAc–hexane, 1:4) showed complete conversion of starting material (Rf 0.6) into a single product (Rf 0.2). Consequently, the reaction mixture was diluted further with CH2Cl2 (50 mL) and washed with H2O (30 mL). The separated aqueous layer was extracted further with CH2Cl2 (20 mL). The combined organic layers were washed with brine (20 mL) then dried (Na2SO4), filtered and concentrated under reduced pressure. The residue thus obtained was subject to flash chromatography (silica gel; EtOAc–hexane, 1:4) and concentration of the appropriate fractions (Rf 0.2) gave pyrrole 12 (64 mg, 77%) as a clear, colorless oil.

Compound 13

Concentration of the appropriate fractions (Rf 0.2) yielded maleimide 13 (14 mg, 0.028 mmol) in anhyd CH2Cl2 (1.5 mL) was maintained at 18°C for 0.7 h, TLC analysis (EtOAc–hexane, 1:3) after this time showed complete consumption of starting material (Rf 0.2 in EtOAc–hexane, 1:4) and the formation of a single major product (Rf 0.3 in MeOH–EtOAc, 5:95). As a consequence, the reaction mixture was concentrated under reduced pressure and the residue subjected to flash chromatography (silica gel; MeOH–EtOAc, 2:98). Concentration of the appropriate fractions (Rf 0.25) afforded showdomycin (I) (6 mg, 95%) as a white crystalline solid. Recrystallization (benzene–acetone) of this material afforded compound 1 as colorless needles, mp 148–149°C [Lit.7e 150°C]; NB widely varying mp values (144–161°C) have been reported7d for showdomycin.

ESMS (+): m/z (%) = 287 (M + K+, 77), 252 (M + Na+, 80), 85 (100).
IR (KBr): 436, 404, 3231, 1769, 1717, 1639, 1449, 1371, 1230, 1330, 1207, 1124, 1083, 1064, 867 cm–1.

Compound 14

A magnetically stirred mixture of compound 12 (40 mg, 0.084 mmol), powdered 4 Å molecular sieves (40 mg) and PCC (90 mg, 0.42 mmol) in anhyd CH2Cl2 (1.5 mL) was maintained at 18°C for 16 h. TLC analysis (EtOAc–hexane, 1:3) after this time showed complete conversion of starting material (Rf 0.35) into a single product (Rf 0.3). Consequently, the reaction mixture was diluted with EtO2 (20 mL) then filtered through a pad of Celite, which was washed with EtO2 (50 mL). The combined filtrates were concentrated under reduced pressure to yield an orange residue which was subject to flash chromatography (silica gel; EtOAc–hexane, 1:4). Concentration of the appropriate fractions (Rf 0.2) yielded maleimide 13 (31 mg, 72%), as a clear, colorless oil.

ESMS (+): m/z (%) = 546 (M + K+, 10), 530 (M + Na+, 50), 525 (M + NH4+, 20), 508 (M + H+, 10), 430 (100).
HRMS: m/z calcd for C29H42NO8Si (M + H+): 508.2155; found: 508.2161.

Showdomycin (1)

Compound 13 (14 mg, 0.028 mmol) was dissolved in TFA–H2O (4:1, 1.0 mL) and the resulting soln stirred at 18°C for 1.5 h. TLC analysis (silica gel) after this time showed complete consumption of starting material (Rf 0.2 in EtOAc–hexane, 1:4) and the formation of a single major product (Rf 0.3 in MeOH–EtOAc, 5:95). As a consequence, the reaction mixture was concentrated under reduced pressure and the residue subjected to flash chromatography (silica gel; MeOH–EtOAc, 2:98). Concentration of the appropriate fractions (Rf 0.25) afforded showdomycin (I) (6 mg, 95%) as a white crystalline solid. Recrystallization (benzene–acetone) of this material afforded compound 1 as colorless needles, mp 148–149°C [Lit.7e 150°C]; NB widely varying mp values (144–161°C) have been reported7d for showdomycin.

ESMS (+): m/z (%) = 287 (M + K+, 77), 252 (M + Na+, 80), 85 (100).
IR (KBr): 436, 404, 3231, 1769, 1717, 1703, 1639, 1449, 1371, 1230, 1330, 1207, 1124, 1083, 1064, 867 cm–1.
H, J = 4.6, 2.2 Hz, H2 or H5), 6.89 (m, 1 H, H2 or H5), 7.37–7.46 (m, 6 H, ArH), 7.66–7.71 (m, 4 H, ArH), 8.19 (br s, 1 H, NH).

13C NMR (126 MHz, CDCl3): δ = 19.1, 24.9, 26.4, 26.8, 65.6, 79.2, 83.1, 83.4, 83.7, 109.2, 112.2, 117.5, 117.8, 118.7, 127.8, 129.7(6), 129.8(5), 132.9, 133.0, 135.5(6), 135.6(1).

ESMS (+): m/z (%) = 500 (M + Na+, 100).

HRMS: m/z calc for C38H34NO6Si (M + H+): 508.2414; found: 508.2402.

**Compound 15**

A magnetically stirred mixture of compound 14 (16 mg, 0.034 mmol), powdered 4 Å molecular sieves (16 mg) and PCC (0.036 g, 0.168 mmol) in anhyd CH2Cl2 (0.5 mL) was maintained at 18 °C for 0.5 mL) and the resulting soln stirred at 18 °C for 1.5 h. TLC analysis (silica gel; EtOAc–hexane, 1:3) after this time showed complete consumption of a single major product (R f  0.3 in MeOH–EtOAc, 5:95). As a consequence, the reaction mixture was diluted with Et2O (20 mL) then filtered through Celite, which was washed with Et2O (50 mL). The combined filtrates were concentrated under reduced pressure to yield a light-yellow oil, which was subjected to flash chromato-


(11) Compound 7 can be purchased from the Aldrich Chemical Company.


