Novel Conversions of Benzotriazol-1-ylmethyl Derivatives

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New (benzotriazol-1-yl)methyl derivatives of type $BtCH_2X$ (X = Br, I, ONO_2) have been investigated. Ethyl (benzotriazol-1-yl)acetate ($BtCH_2CO_2Et$) is converted by treatment with butyl nitrite into the oximes BtCH:NOH of which the *E* isomer is stable but the *Z* isomer rapidly undergoes rearrangement to (benzotriazol-1-yl)formamide. X-Ray crystallography proves the structures of the *E* isomer and the amide. Investigation of reactivity of the carbonyl and methylene groups in (benzotriazol-1-yl)acetophenone ($BtCH_2COPh$) led to further interesting transformations.

Dedicated to Professor Salo Gronowitz on the occasion of his 65th birthday.

1-Hydroxymethylbenzotriazole (**1**) from the addition of benzotriazole to formaldehyde[1] and its conversion by thionyl chloride into 1-chloromethylbenzotriazole (**2**)[2] are well known. In recent years, we have developed procedures for the condensation of **1** with a variety of amino compounds (amines, amides, thioamides, sulfonamides, hydroxylamines and hydrazines) giving derivatives **3**, which have become the basis for many new synthetic methods.[3] Reaction of **2** with several classes of anion allowed the preparation of a variety of derivatives **4**, where X is a group linked by an oxygen, sulfur or nitrogen atom.[4] We now report the synthesis of further novel compounds of types **3** and **4**.

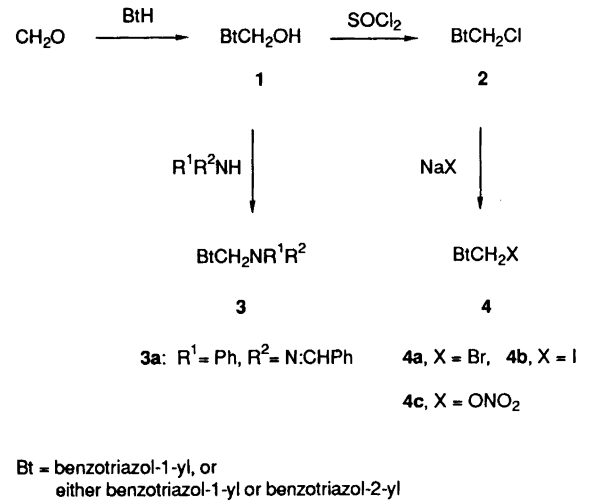
Benzotriazole derivatives of the type $BtCH_2COR$ prepared from benzotriazole and the appropriate bromo or chloro compounds have been known since 1935,[5] but none of their reactions have been reported. We have now studied two such compounds: derivatives of ethyl acetate (**5**)[6] and acetophenone (**17**).[7]

Compounds of type $BtCH_2X$. We find that the chlorine atom of 1-chloromethylbenzotriazole (**2**) is readily substituted with bromine (**4a**) or iodine (**4b**) by treatment of **2** in acetone with sodium bromide or iodide, respectively (Scheme 1). 1-Bromomethylbenzotriazole (**4a**) is relatively stable but 1-iodomethylbenzotriazole (**4b**) is very sensitive to moisture or light. The reactivity of **2** towards nucleophiles is enhanced by using silver instead of sodium salts: thus, treatment with silver nitrate produced benzotriazol-1-ylmethyl nitrate (**4c**) in 72% yield.

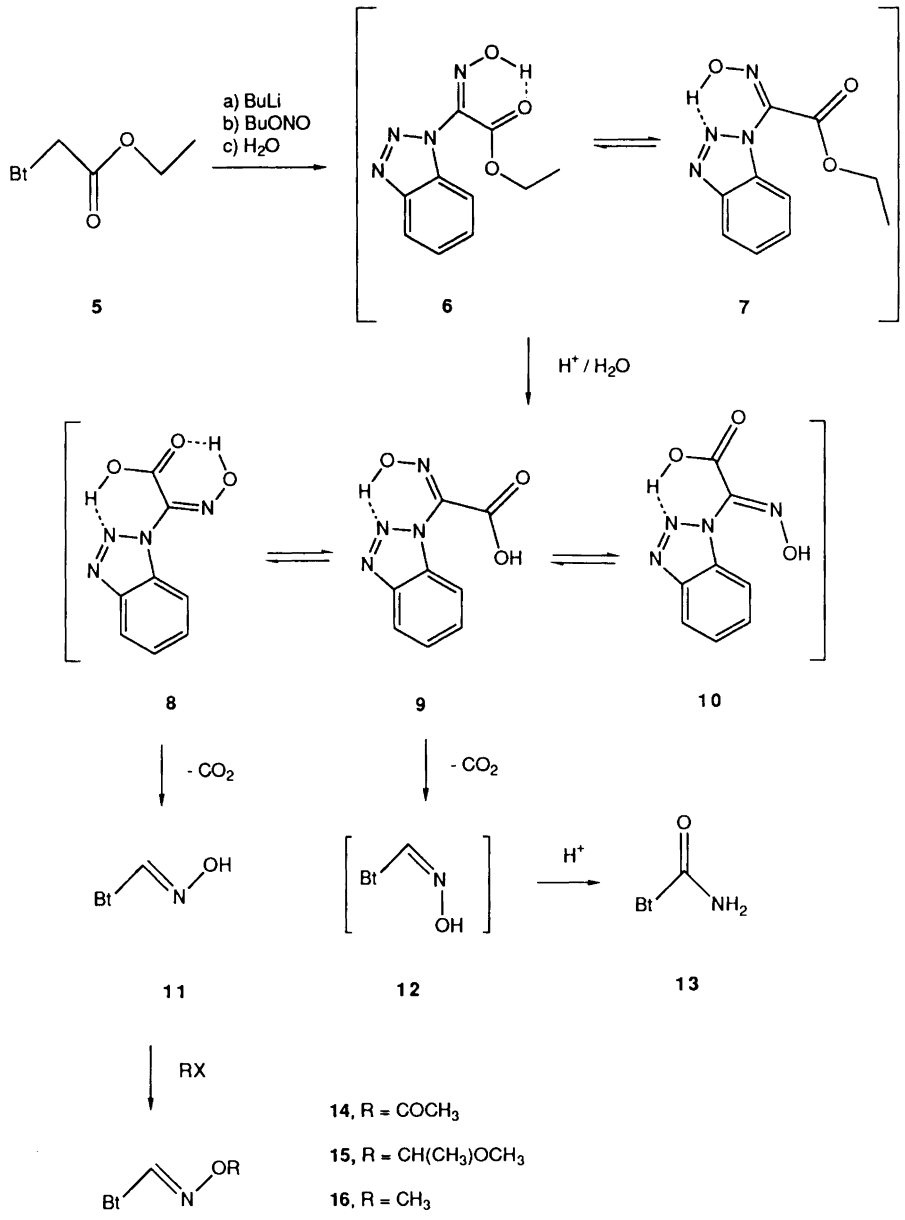
We also find that hydrazones give stable products upon condensation with 1-hydroxymethylbenzotriazole (**1**). Thus, reaction of benzaldehyde phenylhydrazone with **1** gives **3a** in 76% yield.

Conversion of $BtCH_2COOEt$ into $BtCH{=}NOH$ and further reactions. Treatment of lithiated ethyl (benzotriazol-1-yl)acetate **5** with butyl nitrite produced oxime **11**, or amide **13**, in moderate yields (Scheme 2). NMR spectra of the crude reaction mixtures revealed the presence of both compounds in ratios dependent upon work-up conditions. When the reaction mixture was treated with water followed by acidification with dilute sulfuric acid, oxime **11** was formed as the main product. The use of diethyl ether for extraction enabled us to separate **11** in a relatively pure state since amide **13** is insoluble in ether. However, when the reaction mixture was gently treated with acetic acid, amide **13** was isolated as the main product.

We rationalize this phenomenon as follows. In the first step, a mixture of the *E* (**6**) and *Z* (**7**) esters is formed.



Scheme 1.



Scheme 2.

Both forms are stabilized by intramolecular hydrogen bonds, however, the hydrogen bonding of **7** (OH---N) should be stronger than that of **6** (OH---O) owing to the stronger basicity of the nitrogen atom. When isomer **7** is predominant, hydrolysis of the ester formed under mild conditions should lead to acid **9** (or **10**) which spontaneously undergoes decarboxylation to the *Z* oxime **12**. Beckmann rearrangement of **12** (the benzotriazolyl group seems to facilitate such reaction) leads to the amide **13** as the main product.

Hydrolysis of the isomeric ester **6** gives the acid **8**. Two strong intramolecular hydrogen bonds of **8** stabilize it more than **9** and **10**. Under strongly acidic conditions forms **9** and **10** isomerize to **8** making it predominant in the mixture. Decarboxylation of the *E* acid (**8**) produces the *E* oxime (**11**). *cis*-Orientation of the-proton and the hydroxy group in **11** prevents its Beckmann rearrangement[8] and oxime **11** is isolated as the main product. X-Ray crystallographic data proved the *E* configuration of **11** and the molecular structure of amide **13**.

Figs. 1 and 2 show perspective views and atom labelling of the structures of oxime **11** and amide **13** respectively. Tables 1 and 2 list atom coordinates and bonding geometries. The structure of **11** is confirmed as the *trans* isomer, which exists in the solid state in an *anti* conformation about the N1–C1 bond. The benzotriazole ring system is planar to within 0.016 Å and is approximately coplanar with the oxime moiety [angle between mean planes = 12.9(5)°]. As shown in Fig. 3 the molecules pack in chains with the OH group hydrogen

Table 1. Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement coefficients (10^3 Å^2) for oxime **11** and amide **13**.

Atom	*x*	*y*	*z*	U_{eq} [a]
Oxime **11**				
N(1)	4623[b]	−783(5)	2856[b]	21(3)
N(2)	4297(8)	−2046(5)	2082(10)	25(3)
N(3)	3056(7)	−2023(4)	6(10)	26(3)
C(3A)	2534(7)	−737(6)	−608(11)	24(4)
C(4)	1286(10)	−232(6)	−2637(13)	29(4)
C(5)	1091(9)	1100(6)	−2761(12)	33(4)
C(6)	2128(9)	1933(5)	−923(12)	28(4)
C(7)	3364(8)	1436(5)	1094(12)	23(4)
C(7A)	3548(10)	80(4)	1194(13)	19(3)
C(1)	5950(8)	−556(7)	5034(12)	24(4)
N(4)	6160(7)	560(5)	5862(10)	24(3)
O(1)	7574(7)	563(4)	8032(9)	31(2)
Amide **13**				
N(1)	1753(2)	6377(2)	4306(1)	24(1)
N(2)	1829(2)	6096(2)	3206(1)	29(1)
N(3)	2510(2)	4658(2)	3164(1)	30(1)
C(3A)	2901(3)	3955(3)	4248(2)	26(1)
C(4)	3668(3)	2440(3)	4625(2)	32(1)
C(5)	3916(3)	2081(3)	5762(2)	36(1)
C(6)	3420(3)	3193(3)	6507(2)	35(1)
C(7)	2655(3)	4690(3)	6144(2)	29(1)
C(7A)	2408(2)	5048(2)	4990(2)	23(1)
C(1)	1117(3)	7903(2)	4624(2)	26(1)
N(4)	866(2)	9056(2)	3832(1)	32(1)
O(1)	867(2)	8008(2)	5573(1)	33(1)

[a] Equivalent isotropic *U* defined as one third of the trace of the orthogonalized U_{ij} tensor. [b] Origin defining parameter.

bonded to N3 of an adjacent molecule related by a C-centering [O1---N3′ = 2.790(7) Å, H1A---N3′ = 1.85(6) Å, O1–H1A---N3′ = 176(5)°].

Amide **13** exists in the solid state in a conformation with the amide group nearly coplanar with the benzotriazole system [angle between mean planes = 10.6(2)°] and with the NH_2 group *syn* to N2 of the benzotriazole. The benzotriazole system is planar to within 0.011 Å and has similar bonding geometry to that in the oxime. As shown in Fig. 4, there is a system of intermolecular hydrogen bonding that interconnects the molecules in a three-dimensional network. In particular the molecules are connected about a center of inversion by a dimeric NH---O hydrogen bond (N4---O1′ = 2.935(3) Å, H11---O1′ = 1.99(3) Å, N4–H11---O1′ = 171(2)°]. In addition, the remaining NH_2 hydrogen is weakly bonded to N3 of an adjacent molecule related by a twofold screw axis [N4---N3″ = 3.052(3) Å, H12---N3″ = 2.20(3) Å, N4–H12---N3″ = 158(2)°].

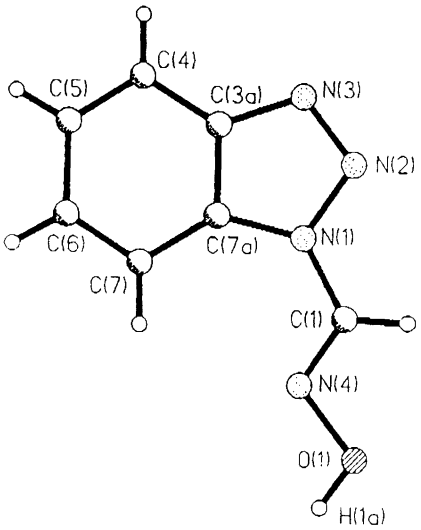


Fig. 1. X-Ray structure and labelling of oxime **11**.

Acetic anhydride converted the oxime **11** quantitatively into the ester **14**. Treatment with 1,1-dimethoxyethane converted the oxime **11** into the mixed acetal **15**. Treatment with methyl iodide and sodium ethoxide in ethanol

Table 2. Bond lengths (Å) and angles (°).

Atoms	Oxime **11**	Amide **13**	Atoms	Oxime **11**	Amide **13**
N(1)–N(2)	1.375(7)	1.374(2)	N(1)–C(7A)	1.393(6)	1.380(2)
N(1)–C(1)	1.404(6)	1.435(3)	N(2)–N(3)	1.312(7)	1.298(2)
N(3)–C(3A)	1.395(8)	1.394(3)	C(3A)–C(4)	1.393(8)	1.398(3)
C(3A)–C(7A)	1.398(8)	1.396(3)	C(4)–C(5)	1.371(9)	1.375(3)
C(5)–C(6)	1.427(9)	1.411(3)	C(6)–C(7)	1.381(8)	1.380(3)
C(7)–C(7A)	1.396(7)	1.396(3)	C(1)–N(4)	1.263(9)	1.327(3)
N(4)–O(1)	1.413(7)		C(1)–O(1)		1.223(3)
N(2)–N(1)–C(7A)	110.5(3)	110.4(2)	N(2)–N(1)–C(1)	118.3(4)	121.1(2)
C(7A)–N(1)–C(1)	131.1(5)	128.5(2)	N(1)–N(2)–N(3)	108.0(4)	108.4(2)
N(2)–N(3)–C(3A)	109.2(5)	108.9(2)	N(3)–C(3A)–C(4)	129.9(6)	129.8(2)
N(3)–C(3A)–C(7A)	108.6(5)	108.6(2)	C(4)–C(3A)–C(7A)	121.4(6)	121.6(2)
C(3A)–C(4)–C(5)	116.6(6)	116.8(2)	C(4)–C(5)–C(6)	121.9(6)	121.3(2)
C(5)–C(6)–C(7)	121.6(5)	122.4(2)	C(6)–C(7)–C(7A)	115.7(5)	116.0(2)
N(1)–C(7A)–C(3A)	103.7(4)	103.7(2)	N(1)–C(7A)–C(7)	133.6(6)	134.4(2)
C(3A)–C(7A)–C(7)	122.7(5)	121.9(2)	N(1)–C(1)–N(4)	119.0(6)	114.9(2)
C(1)–N(4)–O(1)	108.8(5)		N(1)–C(1)–O(1)		117.8(2)
N(4)–C(1)–O(1)		127.2(2)			

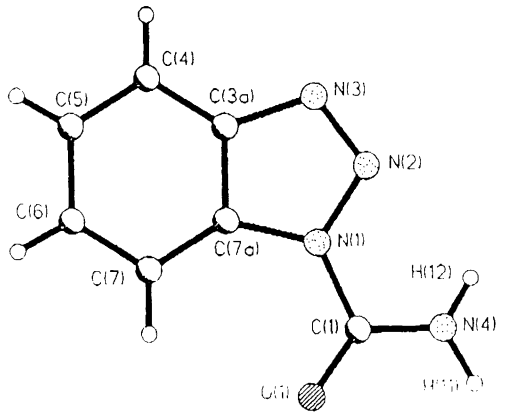


Fig. 2. X-Ray structure and labelling of amide **13**.

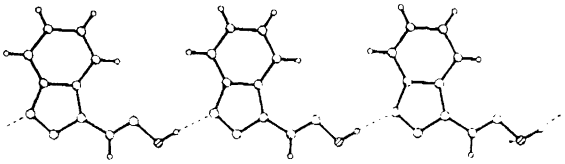


Fig. 3. Intermolecular hydrogen bonding in the oxime **11**.

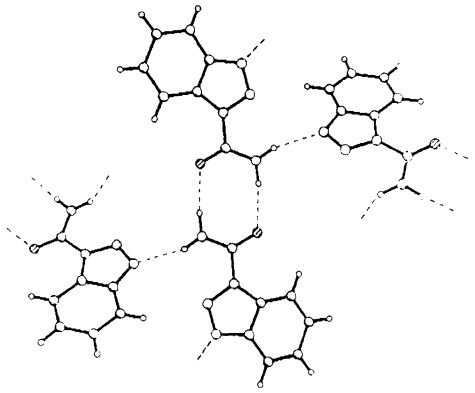
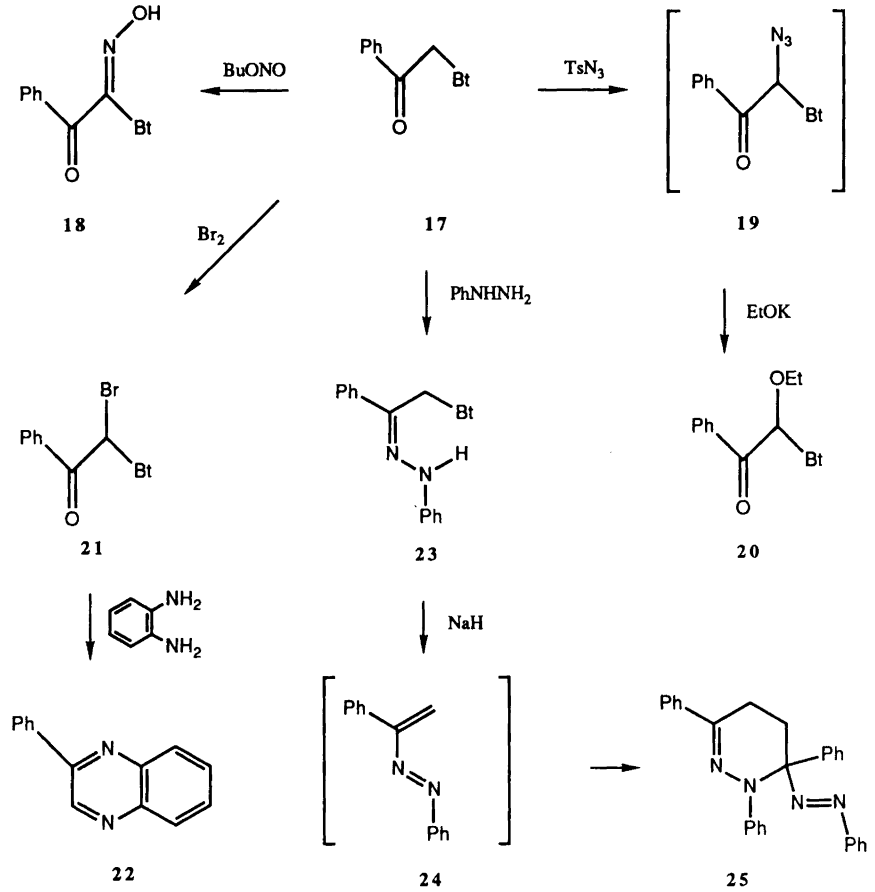


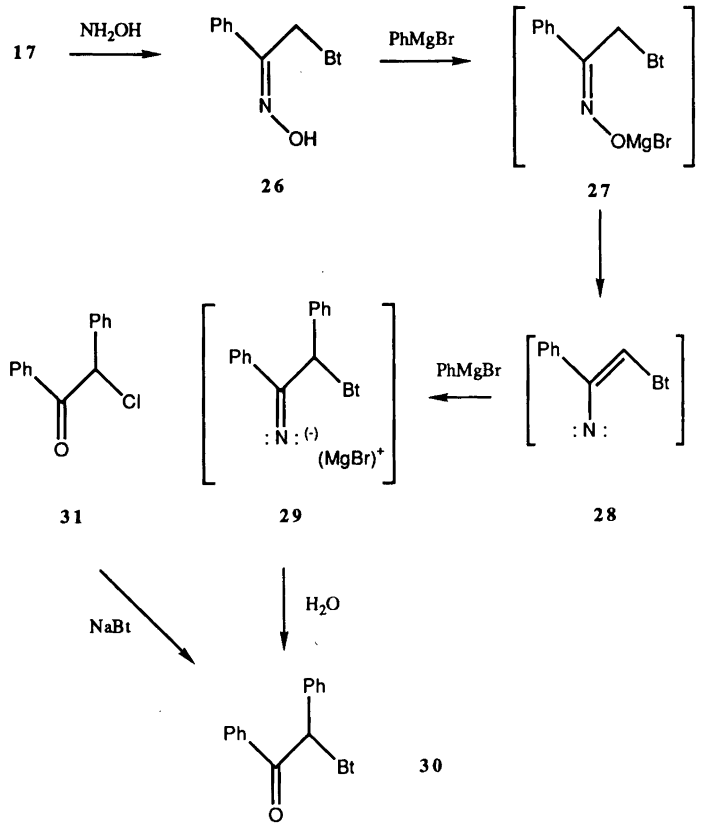
Fig. 4. Intermolecular hydrogen bonding in amide **13**.

gave the methoxy derivative **16** (26%) and a mixture of 1- and 2-methylbenzotriazoles (54%). The methyl benzotriazoles were formed, presumably, by methylation of benzotriazole, which was the alcoholysis product of **16** (or **11**).

Reactions of $BtCH_2COPh$. α-(Benzotriazol-1-yl)acetophenone (**17**) prepared from α-bromoacetophenone and sodium benzotriazolide[7] was transformed by butyl nitrite into the oxime **18** (Scheme 3). Treatment of **17** with



Scheme 3.



Scheme 4.

p-toluenesulfonyl azide in a potassium ethoxide solution gave the ethoxy derivative **20**, probably via substitution of the azido group in intermediate **19** by the ethoxide ion. Bromination of **17** gave the α-bromo derivative **21**, a protected form of phenylglyoxal, which with *o*-phenylenediamine formed 2-phenylquinoxaline (**22**).[9] The hydrazone **23**[7] of **17**, evidently lost benzotriazolide anion on treatment with sodium hydride to give α-(phenylazo)-styrene (**24**), which spontaneously underwent Diels–Alder dimerization to yield **25**[10] in 86% yield.

Oxime **26** reacted with phenylmagnesium bromide to give a complex mixture from which compound **30** was isolated in 6% yield (Scheme 4). To prove the structure of **30**, it was prepared directly by the reaction of 2-chloro-2-phenylacetophenone (**31**) with sodium benzotriazolide. Upon treatment with an excess of the Grignard reagent (reacting as a strong base), salt **27** evidently decomposes to the nitrene **28** in analogy to the mechanism proposed for the Hoch–Campbell reaction.[11] However, owing to its stabilization by resonance with the benzotriazolyl ring, the nitrene **28** does not undergo spontaneous cyclization to an azirine ring,[11] but reacts further with the Grignard reagent to give the iminium salt **29** which hydrolyzes during the work-up to **30**.

Experimental

The NMR spectra were obtained on a Varian VXR-300 MHz spectrometer, and chemical shifts are reported in ppm relative to tetramethylsilane in deuteriochloroform. Assignments of the ^{13}C NMR spectra (C-4, C-5, etc.) refer to the benzotriazolyl carbon atoms. Melting points (°C) were determined on a Thomas–Hoover melting point apparatus and are uncorrected. Chromatography was conducted with silica gel (230–400 mesh) eluted with the solvent given. Compounds **5**,[6] **17**[7] and **23**[7] were obtained according to the literature procedures cited.

X-Ray crystallography. Intensity data were collected at −80°C with a Nicolet R3m four-circle diffractometer by using monochromatized Mo K_α ($\lambda = 0.71073$ Å) radiation. The crystals used were a colorless needle of dimensions $0.60 \times 0.06 \times 0.05$ mm of oxime **11** and a fawn plate of dimensions $0.58 \times 0.32 \times 0.08$ of amide **13**. Cell parameters were determined by least-squares refinement, the setting angles of 25 accurately centered reflections ($2\theta > 15°$) being used. Throughout data collections the intensities of three standard reflections were monitored at regular intervals and this indicated no significant crystal decomposition. The space groups followed from systematic absences and data statistics. The intensities were corrected for Lorentz and polarization effects but not for absorption. Reflections with $I > 2.5\sigma(I)$ and $I > 3\sigma(I)$, for oxime **11** and amide **13** respectively, were used for structure solution and refinement.

The structures were solved by direct methods, and

refined by full-matrix least-squares procedures. All non-hydrogen atoms were refined with anisotropic displacement coefficients. The N–H and O–H hydrogens were located from difference Fourier syntheses, whereas the C–H hydrogen atoms were included in calculated positions. All hydrogens were assigned isotropic displacement coefficients. The functions minimized were $\sum w(|F_o| - |F_c|)^2$, with $w = [\sigma^2(F_o) + 0.0005F_o^2]^{-1}$. The absolute configuration of the oxime was not determined. Final difference maps showed no features greater or less than 0.35 e $Å^{-3}$. Final non-hydrogen atom coordinates, bond lengths and bond angles are listed in Tables 1 and 2. Tabulations of hydrogen atom coordinates, anisotropic thermal parameters, structure factors and equations of meanplanes are available as supplementary material from the author P. J. S.

Crystal data for oxime **11** *at −80°C*: $C_7H_6N_4O$, M_r = 162.2, monoclinic, space group *Cc*, a = 11.835(7), b = 10.210(4), c = 8.198(4) Å, β = 131.80(3)°, U = 738.5(6) $Å^3$, $F(000)$ = 336, Z = 4, D_c = 1.46 g cm^{-3}, μ(Mo-K_α) = 1.0 cm^{-1}, ω scans, $2\theta_{max}$ = 60°, N = 1134, N_o = 569, 107 parameters, S = 1.11, R = 0.047, R_w = 0.047.

Crystal data for amide **13** *at −80°C*: $C_7H_6N_4O$, M_r = 162.2, monoclinic, space group $P2_1/n$, a = 7.607(2), b = 8.222(2), c = 12.160(3) Å, β = 105.98(2)°, U = 731.2(4) $Å^3$, $F(000)$ = 336, Z = 4, D_c = 1.47 g cm^{-3}, μ(Mo-K_α) = 1.0 cm^{-1}, ω scans, $2\theta_{max}$ = 60°, N = 2131, N_o = 1258, 109 parameters, S = 1.41, R = 0.045, R_w = 0.053.

Benzaldehyde N-*(benzotriazolylmethyl)*-N-*phenylhydrazone* (**3a**). A mixture of benzaldehyde phenylhydrazone (1.95 g, 10.0 mmol) and **1** (1.49 g, 10.0 mmol) was refluxed in toluene (20 ml) for 2 h. The solvent was evaporated off and the residue subjected to chromatography (EtOAc–hexane 1:5) to give **3a** as a mixture of benzotriazol-1-yl and benzotriazol-2-yl isomers (2:1), and was recrystallized from ethanol to give pure **3a** as needles; yield 2.49 g (76%), m.p. 123–125°C. Anal. $C_{20}H_{17}N_5$: C, H, N. ^{1}H NMR for Bt-1 isomer: δ 6.52 (2 H, s), 7.08 (2 H, d, *J* 8 Hz), 7.20–7.38 (8 H, m), 7.50 (1 H, s), 7.55 (2 H, d, *J* 8 Hz), 7.68 (1 H, d, *J* 8 Hz), 8.01 (1 H, d, *J* 8 Hz). Bt-2 isomer: δ 6.61 (2 H, s), 7.08 (1 H, m), 7.30–7.42 (7 H, m), 7.67–7.73 (4 H, m), 7.88 (2 H, dd, *J* 3, 7 Hz), 8.22 (1 H, s). ^{13}C NMR for Bt-1 isomer: δ 66.7, 110.9, 119.8, 124.2, 126.4, 126.9, 127.6, 128.6, 128.7, 130.0, 132.9, 135.3, 137.9, 143.3, 146.3. Bt-2 isomer: δ 67.8, 117.8, 118.4, 123.0, 126.7, 126.8, 128.5, 128.7, 129.3, 135.6, 136.8, 144.4, 146.0.

1-Bromomethylbenzotriazole (**4a**). A mixture of 1-chloromethylbenzotriazole (**2**) (10.00 g, 0.06 mol) and sodium bromide (61.4 g, 0.6 mol) in acetone (120 ml) was stirred at room temperature for 21 h. The solution was filtered and stirred with additional sodium bromide (20.0 g, 0.19 mol) for 3 days. The solution was filtered and stirred again with sodium bromide (70.0 g, 0.68 mol) for four more days to convert **2** into pure **4a** as a white solid; yield 9.66 g (76%), m.p. 113–115.5°C. Anal. $C_7H_6BrN_3$: C, H, N. ^{1}H NMR: δ 6.42 (2 H, s), 7.46 (1 H, t, *J* 8.2 Hz), 7.62 (1 H, t, *J* 8.3 Hz), 7.68 (1 H, d, *J* 8.3 Hz), 8.11 (1 H, d, *J* 8.4 Hz). ^{13}C NMR: δ 39.2 (CH_2), 109.8 (C-7), 120.5 (C-4), 125.0 (C-5), 128.5 (C-6), 131.9 (C-7a), 146.5 (C-3a).

1-Iodomethylbenzotriazole (**4b**). A mixture of (**2**) (10.00 g, 0.06 mol) and sodium iodide (35.8 g, 0.239 mol) in acetone (120 ml) was stirred for 15 min. The solution was filtered, the solvent evaporated off at room temperature, and the residue extracted with chloroform (200 ml) followed by evaporation of the solvent to give pure 1-iodomethylbenzotriazole (**4b**) as a yellow solid; yield 13.51 g (87%), m.p. 101–103°C. Anal. $C_7H_6IN_3$: C, H, N. ^{1}H NMR: δ 6.46 (2 H, s), 7.43–7.50 (1 H, m), 7.60–7.68 (2 H, m), 8.10 (1 H, d, *J* 8.4 Hz). ^{13}C NMR: δ 9.5 (CH_2), 110.2 (C-7), 120.5 (C-4), 124.9 (C-5), 128.2 (C-6), 131.7 (C-7a), 146.6 (C-3a).

(Benzotriazol-1-yl)methyl nitrate (**4c**). To a stirred solution of 1-chloromethylbenzotriazole (**2**) (1.00 g, 6.51 mmol) in acetone (10 ml, distilled from phosphorus pentaoxide) was added silver nitrate powder (11.1 g, 6.51 mmol) and the mixture was stirred for 11 h. The mixture was filtered and the solvent evaporated off under reduced pressure at 33°C to give the crude product (**4c**) (0.91 g, 72% yield) as a pale yellow oil. A portion of the crude product was subjected to column chromatography ($CHCl_3$–toluene 1:2) to afford pure **4c** as a colorless oil. HRMS: Calc. $C_7H_6N_4O_3$: 194.0440. Found: 194.0434. ^{1}H NMR: δ 6.90 (2 H, s), 7.44 (1 H, t, *J* 8.2 Hz), 7.60 (1 H, t, *J* 8.1 Hz), 7.72 (1 H, d, *J* 8.3 Hz), 8.08 (1 H, d, *J* 8.4 Hz). ^{13}C NMR: δ 74.0 (CH_2), 109.3 (C-7), 120.2 (C-4), 124.0 (C-5), 128.9 (C-6), 132.5 (C-7a), 145.9 (C-3a). IR (film): 3037, 2970, 1664, 1615, 1495, 1455, 1290, 1161, 1003, 949, 833, 789, 748 cm^{-1}.

(E)-Benzotriazole-1-carbaldehyde oxime (**11**). To a solution of **5** (2.05 g, 10.0 mmol) in THF (30 ml) was added 2.5 M butyllithium in hexane (4.40 ml, 11.0 mmol) dropwise with stirring and external cooling with dry ice–acetone. Butyl nitrite (1.2 g, 12 mmol) was introduced slowly while maintaining the reaction temperature at −78°C. The mixture was stirred for 1 h and allowed to warm to room temperature. After an additional 5 h of stirring, the solvent was evaporated under reduced pressure at 30–35°C and the residue triturated with water (30 ml). The aqueous solution was acidified with 0.5 M sulfuric acid and extracted twice with diethyl ether. The solvent was evaporated off and the residue triturated with ethyl acetate (5 ml). The crude product was collected and recrystallized from ethanol to give **11** as needles; yield 0.6 g (37%), m.p. 160–161°C. Anal. $C_7H_6N_4O$: C, H, N. ^{1}H NMR (DMSO-d_6): δ 7.57 (1 H, dd, *J* 7.0, 8.3 Hz), 7.74 (1 H, dd, *J* 7.0, 8.3 Hz), 8.13 (1 H, d, *J* 8.3 Hz), 8.19 (1 H, d, *J* 8.4 Hz), 9.52 (1 H, s, N:CH), 11.57 (1 H, s, OH). ^{13}C NMR (DMSO-d_6): δ 113.1 (C-7), 119.6 (C-4), 125.6

(C-5), 129.3 (C-6), 129.9 (C-7a), 142.4 (N:CH), 145.5 (C-3a).

Benzotriazole-1-carboxamide (**13**). To a stirred solution of **5** (10.26 g, 50.0 mmol) in THF (150 ml) at −78°C under argon was added dropwise 2.5 M butyllithium in hexane (22.0 ml, 55.0 mmol) and the mixture was stirred for 1 h. Butyl nitrite (6.43 ml, 55.0 mmol) was added dropwise and the mixture was allowed to warm to room temperature overnight. The solvents were removed at 35°C under reduced pressure and water (20 ml) was added. The mixture became hot and the solid dissolved completely. The solution was acidified to pH 4–5 with acetic acid, extracted with ethyl acetate (2 × 30 ml), dried (Na_2SO_4) and the solvent evaporated off to give a yellowish brown mixture of a liquid and a solid. The solid was filtered off, washed with diethyl ether, and triturated with hot ethanol to give **13** as brown needles; yield 0.44 g (28%), m.p. 160–162°C (decomp.). Anal. $C_7H_6N_4O$: C, H, N. ^{1}H NMR (DMSO-d_6): δ 7.54 (1 H, t, *J* 7.7 Hz), 7.71 (1 H, t, *J* 7.7 Hz), 8.19 (1 H, d, *J* 8.3 Hz), 8.25 (1 H, d, *J* 8.3 Hz), 8.31 (1 H, br s, NH), 8.60 (1 H, br s, NH). ^{13}C NMR (DMSO-d_6): δ 113.7 (C-7), 119.5 (C-4), 125.2 (C-5), 129.5 (C-6), 131.3 (C-7a), 145.6 (C-3a), 149.9 (C:O).

(E)-1-Formylbenzotriazole O-*acetyloxime* (**14**). A solution of **11** (0.32 g, 2.0 mmol) and acetic anhydride (0.3 g, 3.0 mmol) in THF (5 ml) was heated under reflux for 3 h. The mixture was then evaporated to dryness under reduced pressure and the solid residue was recrystallized from EtOAc–hexane (1:4) to afford pure **14** as needles; yield 0.4 g (98%), m.p. 91–93°C. Anal. $C_8H_8N_4O_2$: C, H, N. ^{1}H NMR: δ 2.30 (3 H, s, CH_3), 7.52 (1 H, t, *J* 7.3 Hz), 7.67 (1 H, t, *J* 7.3 Hz), 8.12 (1 H, d, *J* 8.3 Hz), 8.30 (1 H, d, *J* 8.3 Hz), 9.47 (1 H, s, CH:N). ^{13}C NMR: δ 19.1 (CH_3), 114.1 (C-7), 120.0 (C-4), 126.2 (C-5), 130.0 (C-6), 130.1 (C-7a), 146.3 (C-3a), 147.9 (N:CH), 167.1 (C:O).

(E)-1-Formylbenzotriazole O-*(1-methoxyethyl)oxime* (**15**). Compound **11** (0.32 g, 2.0 mmol) and *N*-chlorosuccinimide (0.27 g, 2.0 mmol) were heated under reflux for 10 min in a 1:1 mixture of 1,2-dimethoxyethane and 1,1-dimethoxyethane (5 ml). The volatiles were evaporated off, and the residue was dissolved in ether and washed with 2 M NaOH (15 ml) followed by water. After drying and evaporation of the solvent the residual oil was subjected to column chromatography (EtOAc–hexane 1:5), to afford pure **15** as a colorless liquid; yield 0.36 g (82%). Anal. $C_{10}H_{12}N_4O_2$: C, H, N. ^{1}H NMR: δ 1.55 (3 H, d, *J* 5.5 Hz, CH_3), 3.56 (3 H, s, OCH_3), 5.31 (1 H, q, *J* 5.4 Hz, OCHO), 7.47 (1 H, t, *J* 7.2 Hz), 7.61 (1 H, t, *J* 8.2 Hz), 8.08 (1 H, d, *J* 8.3 Hz), 8.15 (1 H, d, *J* 8.3 Hz), 9.27 (1 H, s, N:CH). ^{13}C NMR: δ 19.3 (CH_3), 55.7 (OCH_3), 105.2 (OCHO), 113.4 (C-7), 119.8 (C-4), 125.5 (C-5), 129.2 (C-6), 130.0 (C-7a), 142.3 (N:CH), 146.1 (C-3a).

(E)-1-Formylbenzotriazole O-*methyloxime* (**16**). Compound **11** (0.32 g, 2.0 mmol) was added to a solution of sodium ethoxide prepared from sodium (0.060 g, 2.5 mmol) in ethanol (10 ml) followed by addition of methyl iodide (0.15 ml, 2.5 mmol). The mixture was stirred at 25°C for 1 day and the solvent evaporated off under reduced pressure. The residue was subjected to column chromatography (EtOAc–hexane 1:4) to afford fraction 1, **16** (R_f 0.7) as needles from benzene–hexane; yield 0.09 g (26%), m.p. 92–94°C. Anal. $C_8H_8N_4O$: C, H. ^{1}H NMR: δ 4.05 (3 H, s, CH_3), 7.47 (1 H, t, *J* 8.3 Hz), 7.61 (1 H, t, *J* 8.3 Hz), 8.09 (1 H, d, *J* 8.3 Hz), 8.16 (1 H, d, *J* 8.3 Hz), 9.19 (1 H, s, CH:N). ^{13}C NMR: δ 63.1 (CH_3), 113.7 (C-7), 119.9 (C-4), 125.6 (C-5), 129.2 (C-6), 130.2 (C-7a), 141.7 (N:CH), 146.3 (C-3a); fraction 2, 1-methylbenzotriazole (42%); fraction 3, 2-methylbenzotriazole (12%) recognized by comparison of their spectra with the literature data.[12]

1-(1-Hydroximino-2-oxo-2-phenylethyl)benzotriazole **18**. Ketone **17** (1.2 g, 5.0 mmol) was added in portions to a cold solution of sodium ethoxide prepared from sodium (0.14 g, 6.0 mmol) in ethanol (20 ml), followed by addition of butyl nitrite at a rate to keep the temperature below 0°C. The reaction was stirred at 0°C for 1 h and at 25°C for 6 h, after which the ethanol was removed under reduced pressure and the residue dissolved in water (30 ml), washed with diethyl ether (2 × 15 ml) and acidified with 5 M HCl. An oil separated which slowly solidified. It was filtered off and recrystallized from ethanol–hexane 1:3 to give **18** as prisms; yield 1.1 g (83%), m.p. 157–159°C. Anal. $C_{14}H_{10}N_4O_2$: C, H, N. ^{1}H NMR ($CDCl_3$–DMSO-d_6): δ 7.41–7.67 (6 H, m), 8.08–8.13 (3 H, m). ^{13}C NMR ($CDCl_3$–DMSO-d_6): δ 111.3 (C-7), 119.0 (C-4), 123.8 (C-5), 127.6 (2 C, Ph), 127.7 (C-6), 129.7 (2 C, Ph), 132.6 (Ph), 133.0 (Ph), 134.8 (C-7a), 140.5 (C:N), 143.9 (C-3a), 184.8 (C=O).

α-(Benzotriazol-1-yl)-α-ethoxyacetophenone (**20**). To a solution of **17** (2.37 g, 10.0 mmol) in ethanol (20 ml) was added dropwise a solution of potassium ethoxide prepared from potassium (0.44 g, 11.0 mmol) in ethanol (15 ml) with stirring and external cooling in an ice–salt bath. *p*-Toluenesulfonyl azide (2.17 g, 11.0 mmol) was added slowly while maintaining the temperature between 0 and 5°C. The reaction was stirred at room temperature for 10 h, after which the solvent was evaporated off under reduced pressure at 35°C and the oily residue was dissolved in diethyl ether (50 ml), washed with 10% KOH (2 × 30 ml) and water (25 ml). After drying and evaporation of the solvent at 35°C, the oily residue was subjected to column chromatography (EtOAc–hexane 1:5) to give pure **20** as microcrystals (from petroleum ether); yield 1.6 g (58%), m.p. 65–67°C. Anal. $C_{16}H_{15}N_3O_2$: C, H, N. ^{1}H NMR: δ 1.21 (3 H, t, CH_3), 3.50 (1 H, m), 3.81 (1 H, m), 7.36–7.56 (6 H, m), 7.71 (1 H, d, *J* 7 Hz), 8.07 (3 H, m). ^{13}C NMR: δ 14.4 (Et), 65.5 (Et), 87.7 (NCHO), 111.7 (C-7), 119.7 (C-4), 124.3 (C-5), 127.9 (C-6), 128.6 (2 C, Ph), 129.0 (2 C, Ph), 131.9 (C-7a), 133.2 (Ph), 134.1 (Ph), 146.4 (C-3a), 188.6 (C:O).

α-(Benzotriazol-1-yl)-α-bromoacetophenone (**21a**) *and α-(benzotriazol-2-yl)-α-bromoacetophenone* (**21b**). A mixture of the benzotriazol-1-yl and benzotriazol-2-yl isomers of **17** (1.2 g, 5.0 mmol) was dissolved in dry, alcohol-free chloroform (10 ml) and heated under reflux, while bromine was added with stirring over 5 h. The reaction was refluxed for an additional 20 h, after which the solvent was removed under reduced pressure and the solid residue was subjected to column chromatography (CH_2Cl_2–hexane 1:1) to afford the benzotriazol-2-yl isomer **21b** (R_f 0.5–0.6, 0.34 g, 22% yield), plates from benzene–hexane, m.p. 124–125°C. Anal. $C_{14}H_{10}BrN_3O$: C, H, N. ^{1}H NMR (**21b**): δ 7.35–7.40 (4 H, m), 7.48–7.51 (1 H, m), 7.81–7.84 (2 H, m), 7.94–7.96 (2 H, m), 8.26 (s, 1 H, CHBr). ^{13}C NMR (**21b**): δ 64.1, 118.4, 127.9, 128.9 (2 C), 132.1, 134.3, 145.3, 183.5. Continuation of the elution afforded the benzotriazol-1-yl isomer **21a** (R_f 0.3–0.4, 0.72 g, 45% yield), plates from benzene–hexane, m.p. 124–125°C. Anal. $C_{14}H_{10}BrN_3O$: C, H, N. ^{1}H NMR (**21a**): δ 7.43–7.62 (5 H, m), 7.87–7.90 (1 H, d, *J* 7.5 Hz), 8.07–8.13 (3 H, m), 8.46 (1 H, s). ^{13}C NMR (**21a**): δ 56.9, 113.5, 120.2, 124.9, 128.3, 129.0, 129.2, 131.5, 132.4, 134.7, 147.1, 185.6.

2-Phenylquinoxaline (**22**). A mixture of **21a** (0.32 g, 1.00 mmol) and *o*-phenylenediamine (0.11 g, 1.00 mmol) in a test tube was immersed in an oil bath at 150°C, heated to 192°C over 80 min (until the mixture melted) and kept at 192–195°C for 30 min. The mixture was allowed to cool, dissolved in chloroform, washed with 20% NaOH (2 ×), water (3 ×) and dried (Na_2CO_3). The red glassy residue (0.18) was subjected to column chromatography (toluene) to give **22** as brown needles; yield 0.03 g (15%), m.p. 68–74°C, lit. 75°C.[9] HRMS: Calc. $C_{14}H_{10}N_2$: 206.0844. Found: 206.0839. ^{1}H NMR: δ 7.50–7.60 (3 H, m), 7.72–7.82 (2 H, m), 8.10–8.25 (4 H, m), 9.32 (1 H, s). ^{13}C NMR: δ 127.5 (2 C), 129.09 (2 C), 129.07, 129.5, 129.6, 130.1, 130.2, 136.7, 141.5, 142.2, 143.3, 151.8.

1,3,6-Triphenyl-6-phenylazo-1,4,5,6-tetrahydropyridazine (**25**). To a suspension of sodium hydride (0.28 g, 12 mmol) in dry THF (10 ml) was added a solution of a mixture of the benzotriazol-1-yl and benzotriazol-2-yl isomers **23** (3.27 g, 10 mmol) in THF (25 ml) at a rate to allow gentle evolution of hydrogen at −5 to 0°C. The mixture was heated under reflux for 2 h, and the solvent removed under reduced pressure to afford an oily residue which was dissolved in water (20 ml) and extracted with diethyl ether (2 × 30 ml). After drying, removal of the solvent, and recrystallization from hexane, **25** was obtained as orange plates; yield 1.8 g (86%), m.p. 134–136°C, lit.[10] 137–139°C. ^{1}H NMR: δ 2.28 (2 H, m), 2.57 (1 H, m), 2.72 (1 H, m), 6.71 (1 H, m), 7.00 (4 H, m), 7.33 (10 H, m), 7.76 (5 H, m). ^{13}C NMR: δ 18.8, 33.5, 85.7, 119.7, 120.5, 122.7, 124.7, 126.8, 127.4, 127.5, 127.6, 128.2, 128.6, 129.0, 131.1, 138.3, 138.9, 142.7, 145.3, 151.5.

α-(Benzotriazol-1-yl)acetophenone oxime (**26**). To a solution of hydroxylamine hydrochloride (4.86 g, 70.0 mmol) in water (20 ml) was added 10% NaOH (20 ml) and **17** (mixture of isomers) (2.37 g, 10.0 mmol) in ethanol (60 ml). The mixture was stirred under reflux for 1 h and at 25°C overnight. The crystals formed were filtered off, washed thoroughly with water, and dried to give pure α-(benzotriazol-1-yl)acetophenone oxime (**26**) as microcrystals; yield 1.42 g (56%), m.p. 223–225°C. Anal. $C_{14}H_{12}N_4O$: C, H, N. ^{1}H NMR (DMSO-d_6): δ 6.09 (CH_2, 2 H, s), 7.30–7.40 (4 H, m), 7.56 (1 H, t, *J* 7.6 Hz), 7.71–7.73 (2 H, m), 7.84 (H-7, 1 H, d, *J* 8.3 Hz), 8.00 (H-4, 1 H, d, *J* 8.1 Hz), 12.20 (OH, 1 H, s). ^{13}C NMR (DMSO-d_6): δ 41.0 (CH_2), 110.4 (C-7), 119.1 (C-4), 124.0 (C-5), 126.2 (2 C, *ortho*), 127.4, 128.3 (2 C, *meta*), 129.1, 132.8, 133.9, 144.8 (C-3a), 150.7 (C:N).

α-(Benzotriazol-1-yl)-α-phenylacetophenone (**30**). (*a*) To a solution of phenylmagnesium bromide (from bromobenzene, 4.32 ml, 41.0 mmol) in diethyl ether (20 ml) under argon was added **26** (containing 25% of the Bt-2 isomer) (2.07 g, 8.21 mmol). After addition of toluene (40 ml), diethyl ether was distilled off and the mixture was refluxed for 2 h. The product was poured onto a mixture of ice and water (100 ml), acidified (pH 5) with acetic acid, extracted with chloroform (2 × 70 ml), and the organic phase washed with water (2 × 100 ml) and dried ($MgSO_4$). After removal of the solvent a dark brown viscous oil (2.10 g) was obtained which was subjected to column chromatography (chloroform) to give **30** (R_f 0.43) as needles; yield 0.15 g (6%), m.p. 161–163°C. Anal. $C_{20}H_{15}N_3O$: C, H, N. ^{1}H NMR: δ 7.21–7.46 (10 H, m), 7.57 (1 H, t, *J* 7.3 Hz), 7.88 (s, 1 H), 7.99–8.05 (3 H, m). ^{13}C NMR: δ 68.1 (PhCHBt), 111.4 (C-7), 119.9 (C-4), 123.8 (C-5), 127.5 (C-6), 128.9, 129.0, 129.1, 129.3, 129.4, 132.9, 133.1, 134.2, 134.4, 146.6 (C-3a), 192.6 (C:O).

α-(Benzotriazol-1-yl)acetophenone (**17**) (0.12 g, 0.5 mmol, 6%) was obtained (R_f 0.30) as the second fraction. Starting material **26** was recovered (0.06 g, 0.2 mmol, 3%) as the third fraction (R_f 0.10).

(*b*) A mixture of benzotriazole (1.19 g, 10.0 mmol), sodium methylate (0.54 g, 10.0 mmol) and ethanol (20 ml) was stirred under nitrogen for 1 h and desyl chloride (2.31 g, 10.0 mmol) added. The mixture was heated at 70°C for 14 h. After cooling, the solution was passed through a filter paper and the solvent evaporated off to give a yellow solid (2.98 g) which was subjected to column chromatography (hexane–CH_2Cl_2 1:1) to give **30**; yield 1.09 g (35%), identical with the sample obtained by method (*a*).

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