Anodic Acetamidosulphenylation and Trifluoroacetoxysulphenylation of Steroidal Alkenes

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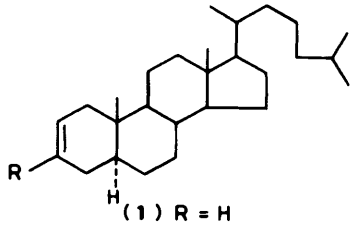
Electrochemical acetamidosulphenylation of a number of steroidal alkenes is described *via* oxidation of diphenyl, di-*p*-tolyl, dibenzyl and dipropyl disulphide in acetonitrile. The regiochemistry and stereochemistry of addition are established by analysis of the products to obtain n.m.r. coupling constant data, and by relation of the products to known steroidal amides *via* reductive desulphurisation. The addition of the same disulphides to steroidal alkenes promoted by lead(IV), manganese(III), and copper(II) salts in trifluoroacetic acid gave trifluoroacetoxy sulphides. Reaction of these esters with acetonitrile gave acetamido sulphides. Mechanisms and the relative merits of the direct and indirect methods of acetamidosulphenylation are discussed.

The recent studies of the synthesis of A-ring fused heterocyclic steroids, and in particular steroidal thiadiazoles,[1] as possible male contraceptives, have directed our attention to the need to develop simple routes to steroids vicinally substituted with sulphur and nitrogen functionality. Although routes to vicinal steroidal amino alcohols are well established[2] and such compounds are known to display antiarrhythmic activity[3] there is a surprising paucity of information concerning vicinal steroidal amino thiols and their derivatives. For example, even cholestanes and androstan-17-ones substituted with vicinal amino and thiol groups have never been reported.

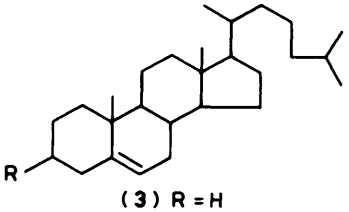
Although vicinally substituted amino thiols and their derivatives have been prepared in non-steroidal cases by opening of aziridines[4,5] or episulphides[6] with an appropriate nucleophile, a more direct synthesis would proceed by direct addition to an alkene. Additions[4] to cholest-2-ene using diphenyl disulphide and chloramine-T showed the promise of such an approach. More recently a variety of methods[7-11] have been developed for direct addition of nitrogen and sulphur functionality to alkenes, and have been applied to non-steroidal examples. Less direct methods of functionalisation of alkenes have proceeded *via* initial addition of sulphenyl halides,[12] *via* halogenoisothiocyanation, which has been applied[13] to steroidal alkenes, and *via* initial trifluoroacetoxysulphenylation[14] followed by acetamidation *via* a Ritter[15,16] reaction.

Our studies of addition to alkenes have been based on anodic oxidation of dialkyl and diaryl disulphides[11] in acetonitrile which permits direct acetamidosulphenylation of alkenes, and on the less direct alternative[15,16] of prior metal ion-promoted oxidation of a disulphide in trifluoroacetic acid, which permits the trifluoroacetoxysulphenylation of an alkene, followed by the Ritter reaction to complete overall acetamidosulphenylation of the alkene in two steps. In our earlier work we have not studied the functionalisation of steroidal alkenes. Anodic functionalisation of steroids[17] has been limited to aromatic cases. However, the first preliminary report of trifluoroacetoxysulphenylation of alkenes[14] includes the successful functionalisation of two steroids. With the major uncertainty concerning the possible application of electrochemical methods to the functionalisation of steroidal alkenes we chose to study additions to such alkenes by the direct and indirect methods that we had developed. Here we describe such additions and compare methods based on anodic oxidation,[11] on lead(IV)- and manganese(III)-promoted oxidations,[15] and on copper(II)-promoted oxidations.[16]

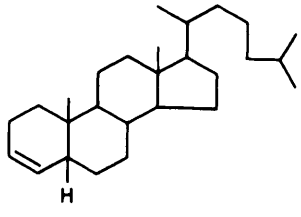
Our earlier procedure for anodic acetamidosulphenylation[11] was conducted using acetonitrile as the solvent in the anolyte compartment. The lack of solubility of steroidal alkenes in acetonitrile necessitated the investigation of the use of dichloromethane–acetonitrile (1:1) as an appropriate anolyte medium. Electroanalytical studies established that using Bu_4NBF_4 as electrolyte no modification was required to the previous procedure of electrolysis of the appropriate disulphides at *ca.* 1.3 V. Typically in the acetamidosulphenylation of 5α-cholest-2-ene (**1**) with diphenyl disulphide (**6**) satisfactory currents were maintained for the complete period of electrolysis by application of a cathodic pulse (to −0.1 V for 1 ms every 3 s).



(**1**) R = H
(**2**) R = D



(**3**) R = H
(**4**) R = OBz



(**5**)

RSSR
(**6**) R = Ph
(**7**) R = C_6H_4Me-*p*
(**8**) R = CH_2Ph
(**9**) R = Pr
(**10**) R = 2—C_5H_4N
(**11**) R = $C_6H_4NH_2$-*o*

PhSeSePh
(**12**)

Table 1. Additions to 5α-cholest-2-ene by anodic- and Pb^{IV}-promoted oxidation of organic disulphides

Disulphide	Product of anodic oxidation	Yield of vicinal acetamidosulphide by anodic oxidation (%)	Yield of vicinal acetamidosulphide by trifluoroacetoxy-sulphenylation and Ritter reaction
Diphenyl (**6**)	(**13**)	58	52
Di-*p*-tolyl (**7**)	(**14**)	35	61
Dibenzyl (**8**)	(**15**)	27	40
Dipropyl (**9**)	(**16**)	31	37

Table 2. Anodic functionalisation of steroidal alkenes

Substrate	Alkene	Product of anodic oxidation	Yield of vicinally substituted product (%)
Ph_2S_2 (**6**)	Cholest-5-ene (**3**)	(**29**)	11
Ph_2S_2 (**6**)	Cholesteryl benzoate (**4**)	(**31**)	28
Ph_2S_2 (**6**)	5β-Cholest-3-ene (**5**)	(**35**)	20
Ph_2Se_2 (**12**)	5α-Cholest-2-ene (**1**)	(**19**) and (**20**)	11

With this regime electrode fouling was minimal. Work-up and purification afforded the acetamido sulphide (**13**) in 58% yield with respect to 5α-cholest-2-ene. Results of other additions to 5α-cholest-2-ene (**1**) are shown in Table 1, and of additions of diphenyl disulphide to other steroidal alkenes, and of the related addition of diphenyl diselenide (**12**) to 5α-cholest-2-ene, in Table 2.

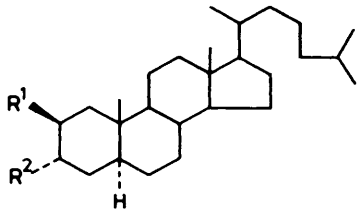
Structural assignments, defining both the modes of regio- and stereo-chemical addition to 5α-cholest-2-ene (**1**) were established using three separate considerations: (i) evidence from ^1H n.m.r. spectra, (ii) the outcome of addition to [3-^{2}H]-5α-cholest-2-ene (**2**), and (iii) desulphurisation experiments which related the acetamido sulphides to the known 2β-acetamido-5α-cholestane (**18**).[18]

For the acetamido sulphide (**13**), the product of addition of diphenyl disulphide to 5α-cholest-2-ene, signals associated with methine protons are observed at δ 3.60 and 4.21. The former is associated with a methine group α to the sulphide functionality and the latter with a methine group α to the amide functionality. This assignment is confirmed by observation of the coupling between the amide proton at δ 5.80 and the signal at δ 4.21. Irradiation to remove this coupling permits the observation of the signal at δ 4.21, which then shows a value for $W_{\frac{1}{2}} \simeq 7$ Hz. Similarly the signal at δ 3.60 is characterised by a narrow band width ($W_{\frac{1}{2}} = 7$ Hz). These values are indicative of a *trans*-diaxial relationship of the substituents in the acetamido sulphide (**13**) and are in accord with related examples previously reported.[19]

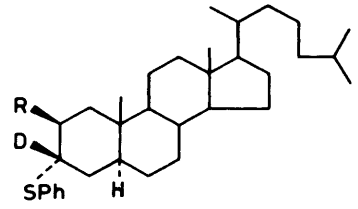
Anodic functionalisation of the known[20] [3-^{2}H]-5α-cholest-2-ene (**2**) afforded the acetamido sulphide (**26**). The formation of a 3-substituted sulphide was clearly established by absence of that signal at δ 3.60, observed in the sulphide (**13**).

Finally, reductive desulphurisation of the sulphide (**13**) afforded the known[18] amide (**18**). Hence together these results unequivocally establish that the *trans*-diaxial product (**13**) is obtained by addition of diphenyl disulphide to 5α-cholest-2-ene. They suggest initial formation of an episulphonium ion at the less hindered α-face, which then opens to give a *trans*-diaxial product by attack of solvent from the β-face.

Reductive desulphurisation of the other acetamido sulphides (**14**)—(**16**) reported in Table 1 similarly afforded in each case 2β-acetamido-5α-cholestane (**18**). Hence the major product of each addition corresponds to initial episulphonium ion



(**13**) R^1 = NHAc, R^2 = SPh
(**14**) R^1 = NHAc, R^2 = SC_6H_4Me-*p*
(**15**) R^1 = NHAc, R^2 = SCH_2Ph
(**16**) R^1 = NHAc, R^2 = SPr
(**17**) R^1 = SPr, R^2 = NHAc
(**18**) R^1 = NHAc, R^2 = H
(**19**) R^1 = NHAc, R^2 = SePh
(**20**) R^1 = SePh, R^2 = NHAc
(**21**) R^1 = $OCOCF_3$, R^2 = SPh
(**22**) R^1 = OH, R^2 = SPh
(**23**) R^1 = OH, R^2 = H
(**24**) R^1 = $OCOCF_3$, R^2 = $SC_6H_4NH_2$-*o*
(**25**) R^1 = OH, R^2 = $SC_6H_4NH_2$-*o*



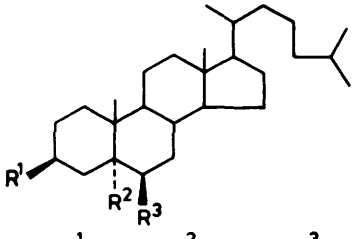
(**26**) R = NHAc
(**27**) R = OH
(**28**) R = $OCOCF_3$

formation at the less hindered α-face. In the case of the addition of dipropyl disulphide (**9**), a second minor (5%) product was isolated and tentatively characterised on the basis of spectroscopy as the diaxial product (**17**) formed through the intermediacy of an episulphonium ion at the more hindered β-face. Although no pure products were isolated from the attempted oxidative addition of dimethyl disulphide to 5α-cholest-2-ene the reaction clearly afforded a mixture of acetamido sulphides which proved to be difficult to separate.

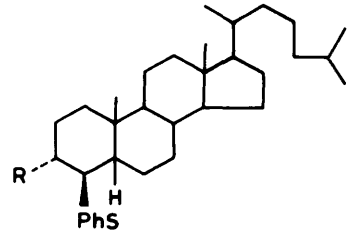
The outcome of addition to 5α-cholest-2-ene is determined by the steric requirements of the alkyl or aryl function of the disulphide. Large groups dictate a highly stereoselective or even stereospecific attack at the α-face and subsequent opening to give a *trans*-diaxial product. Smaller groups permit some attack at the β-face with consequent opening of the episulphonium ion to give the second possible *trans*-diaxial product.

The results of other anodic additions to steroidal alkenes are reported in Table 2. Addition of diphenyl diselenide (**12**) to 5α-cholest-2-ene proved to be more complex than the analogous addition of diphenyl disulphide. Analysis of the crude reaction mixture showed formation of at least four products. The two *trans*-diaxial acetamido selenides (**19**) and (**20**) were isolated in poor yield and structures were assigned as indicated above. The origin of the lower stereoselectivity is not clear. Addition to cholest-5-ene (**3**) of diphenyl disulphide (**6**) is also complex; at least four products were observed by t.l.c. analysis. Only the hydroxy sulphide (**29**) could be isolated and characterised, although spectroscopic analysis showed the presence of acetamido sulphides in the crude product mixture. The regio-

chemistry of addition to give (**29**) is defined by observation of the methine resonance at δ 3.90, and the coupling constants indicate a 6β-axial substituent. It is assumed that formation of an episulphonium ion at the less hindered α-face leads to the observed stereochemistry. In marked contrast, a single acetamidosulphide (**31**) was obtained from cholesteryl benzoate (**4**). The regiochemistry of addition is clearly defined by the absence of any methine resonance adjacent to an acetamido group. The observed methine resonance at δ 3.10 indicates that the thiophenyl group occupies the 6β-position. The 5α-acetamido assignment is made tentatively on the basis of likely precedent of opening of the episulphonium ion to give a *trans*-diaxial product, and the observation of the 19-Me resonance at δ 0.86. If the acetamido group occupied the 5β site a shift of this resonance to higher field[21] would be expected. Formation of the acetamido sulphide (**31**) appears to proceed *via* an episulphonium ion at the more hindered β-face. In view of the low product yields, the complexity of the reaction products, and the possible effects of traces of water in the acetonitrile it is not possible to analyse these apparently conflicting results in detail. As equilibration of nitrilium ions under electrolysis conditions is well substantiated[22] in the absence of water, it is also possible that equilibration between the two episulphonium ions formed on the α-and β-faces may also occur. Under such circumstances products would be determined by a complex mixture of kinetic and thermodynamic factors.



(**29**) R^1 = H, R^2 = SPh, R^3 = OH
(**30**) R^1 = H, R^2 = SPh, R^3 = $OCOCF_3$
(**31**) R^1 = OBz, R^2 = NHAc, R^3 = SPh
(**32**) R^1 = OBz, R^2 = SPh, R^3 = OH
(**33**) R^1 = OBz, R^2 = OH, R^3 = SPh
(**34**) R^1 = H, R^2 = $SC_6H_4NH_2$-*o*, R^3 = OH



(**35**) R = NHAc
(**36**) R = $OCOCF_3$

Anodic addition of diphenyl disulphide (**6**) to 5β-cholest-3-ene (**5**) gave the acetamido sulphide (**35**) isolated in 20% yield. In contrast to all the other acetamido sulphides in the ^{1}H n.m.r. spectrum of (**35**) the two methine resonances are characterised by large $W_{\frac{1}{2}}$ values associated with axial protons and hence a 3α,4β-disubstituted product is indicated. The resonance at δ 3.45 is a triplet (*J* 11 Hz) and the greater complexity of the resonance at δ 4.06 indicates the regiochemistry of addition. Irradiation experiments confirm this assignment. Hence the acetamido sulphide must be formed *via* an episulphonium ion on the β-face. Preference for attack on this face in the chemistry of 5β-cholest-3-ene (**5**) has precedent.[23] The examples reported above proceed in each case *via* a *trans*-diaxial opening but formation of the *trans*-diequatorial product (**35**) is an exception. Steric factors will adversely affect possible entry of acetonitrile to occupy the 4α-position. Hence the rearside attack from the α-face at the less hindered 3-position to give a 3α,4β-disubstituted product is not unexpected and again has precedent.[23]

Although anodic acetamidosulphenylation is a single-step process, the direct procedure, for which results are given in Tables 1 and 2, does not give very satisfactory yields. Our earlier[15] studies indicate that an alternative procedure is trifluoroacetoxysulphenylation followed by the Ritter reaction. Our results with steroidal alkenes are reported in Tables 1 and 3. The efficiency of different methods of trifluoroacetoxysulphenylation using diphenyl disulphide and bis(2-aminophenyl) disulphide (**11**) are reported in Table 3, and a comparison of the yields for direct anodic acetamidosulphenylation, and indirect acetamidosulphenylation *via* initial trifluoroacetoxysulphenylation of 5α-cholest-2-ene (**1**) with different disulphides in Table 1.

Trifluoroacetoxysulphenylation of 5α-cholest-2-ene (**1**) has been reported[14] previously. The structure (**22**) assigned earlier to the hydrolysis product of the ester (**21**) is confirmed now by desulphurisation of the hydroxy sulphide (**22**) to afford the known[24] 5α-cholestan-2β-ol (**23**), by the outcome of addition to [3-^{2}H]-5α-cholest-2-ene (**2**) to give (**28**) and hence by hydrolysis the alcohol (**27**), and by ^{1}H n.m.r. analysis of the alcohol (**22**) and the corresponding ester (**21**). As expected from our earlier work[15,16] lead(IV) and manganese(III) promoted this addition much more efficiently than copper(II). Ritter reaction[15] with the ester (**21**) gave the same acetamidosulphide (**13**), which was obtained by direct anodic oxidation. In a similar manner lead(IV)-promoted additions of di-*p*-tolyl, dibenzyl, and dipropyl disulphides gave the acetamido sulphides (**14**)—(**16**). Yields *via* the two-step procedure are generally higher than by direct anodic oxidation.

Trifluoroacetoxysulphenylation of cholesteryl benzoate (**4**)[14] is reported to give at −40 °C a 1:1 mixture of the isomers (**32**) and (**33**). We find that at −60 °C addition of diphenyl disulphide to cholest-5-ene (**3**) permits isolation of the single hydroxy sulphide (**29**), following hydrolysis of the ester (**30**). Hence the same product (**29**) is obtained either by direct anodic oxidation or indirectly. It is interesting to note that at −40 °C addition to cholest-5-ene (**3**) gives much more complex product mixtures. In contrast, either lead(IV)- or better manganese(III)-promoted addition of diphenyl disulphide (**6**) to 5β-cholest-3-ene (**5**) gives as major product the solid ester (**36**) even at −40 °C. The assignment of structure to this ester is based on ^{1}H n.m.r. analysis as reported above for the related amide (**35**). Hence this addition to 5β-cholest-ene (**5**) also is initiated by attack from the β-face and is followed by attack to give a diequatorial product.

Although the anodic addition of 2,2′-dipyridyl disulphide (**10**) and bis(2-aminophenyl) disulphide (**11**) to alkenes has been studied, we find that in contrast to the earlier study,[11] 2,2′-dipyridyl disulphide (**10**) does not undergo addition to steroidal alkenes. Metal ion-promoted oxidations also failed. However addition of bis(2-aminophenyl) disulphide to 5α-cholest-2-ene promoted by copper(II) gave the ester (**24**) in 92% yield. Hydrolysis of this ester (**24**) gave the alcohol (**25**) which was converted into the known[24] 5α-cholestan-2β-ol (**23**) by reductive desulphurisation. A similar addition to cholest-5-ene (**3**) gave only a low yield of the alcohol (**34**) after hydrolysis. The varying efficiency of these metal ion-promoted additions shows that they depend not only upon the nature of the metal ion, a point already investigated,[15,16] but also upon the nature of the

Table 3. Vicinal trifluoroacetoxysulphenylation of steroidal alkenes

Disulphide	Alkene	Oxidant	Product	Yield of vicinal trifluoroacetoxysulphide (%)
Ph_2S_2 (**6**)	5α-Cholest-2-ene (**1**)	Pb^{4+}	(**21**)	66
Ph_2S_2 (**6**)	5α-Cholest-2-ene (**1**)	Cu^{2+}	(**21**)	32
Ph_2S_2 (**6**)	5α-Cholest-2-ene (**1**)	Mn^{3+}	(**21**)	63
Ph_2S_2 (**6**)	Cholest-5-ene (**3**)	Pb^{4+}	(**30**)	41
Ph_2S_2 (**6**)	5β-Cholest-3-ene (**5**)	Pb^{4+}	(**36**)	41
Ph_2S_2 (**6**)	5β-Cholest-3-ene (**5**)	Mn^{3+}	(**36**)	91
$(o\text{-}NH_2C_6H_4)_2S_2$ (**11**)	5α-Cholest-2-ene (**1**)	Cu^{2+}	(**24**)	92

alkene. The more substituted alkenes adversely affect acetamidosulphenylation and trifluoroacetoxysulphenylation to a comparable degree.

Experimental

General methods have been described earlier.[11] N.m.r. spectra were recorded for $CDCl_3$ solutions with a Bruker AM-360 spectrometer using tetramethylsilane as internal standard.

[3-^{2}H]-5α-*Cholest*-2-*ene* (**2**).—To a suspension of 2β-bromo-5α-cholestan-3-one (2.0 g) in methan[^{2}H]ol (40 ml) at 25 °C sodium borodeuteride (1.2 g) was added. The reaction mixture was stirred at room temperature for 1 h, after which it was poured into water and the products extracted into ether (3 × 100 ml). The ethereal solution was washed with water (3 × 100 ml), dried ($MgSO_4$), and evaporated under reduced pressure. The residual oil was crystallised from methanol to give 2β-bromo [3α-^{2}H]-5α-cholestan-3β-ol as white needles (1.7 g, 84%), m.p. 102—104 °C; $\nu_{max.}$($CHCl_3$) 3 500—3 300 cm^{-1};δ_H 0.65—2.5 (44 H), 4.05 (1 H, br s, CHBr), and 4.45 (1 H, br s, OH, removed by addition of D_2O).

The bromohydrin (1.64 g) and zinc powder (3.28 g) were heated and stirred under reflux in acetic acid (82 ml) for 30 min. The cold solution was filtered, the residue washed with ether, and the combined filtrates worked up to afford crude product. Crystallisation from ethanol gave the title compound (**2**) as white needles (726 mg, 56%), m.p. 68—70 °C (Found: M^+, 371.3601. $C_{27}H_{45}D$ requires 371.3662), *m/z* 371 (M^+, 95%), 316 (74%), 258 (21%), and 216 (100%); $\nu_{max.}$($CHCl_3$) 2 960, 2 860, and 1 640 cm^{-1}; δ_H 0.68—2.1 (44 H) and 5.50 (1 H, C*H* = CD).

Typical Procedure for Anodic Acetamidosulphenylation: 2β-*Acetamido*-3α-*phenylthio*-5α-*cholestane* (**13**).—Diphenyl disulphide (54 mg) and 5α-cholest-2-ene (**1**) (200 mg) were dissolved in acetonitrile–dichloromethane (1:1; 40 ml) containing Bu_4NBF_4 (0.1M-solution). This anolyte was electrolysed in a three-compartment cell at 1.3 V at a platinum foil anode (3 cm^2) until 52 C had been passed (6 h). The anolyte was poured into water and extracted with ether (3 × 50 ml). The combined extracts were washed with water, dried ($MgSO_4$), filtered, and evaporated under reduced pressure to afford the crude product. Purification by p.l.c. afforded a white solid, which was further purified by recrystallisation (dichloromethane–pentane) to give the *title compound* (**13**) (168 mg, 58%), m.p. 181—182 °C (Found: C, 78.1; H, 10.2; N, 2.8; S, 6.1. $C_{35}H_{55}NOS$ requires C, 78.2; H, 10.2; N, 2.6; S, 6.0%) (Found: M^+, 538.4087. $C_{35}H_{55}NOS$ requires *M*, 538.4086); *m/z* (C.I. using NH_3) 538 (M^+, 0.03) and 478 (100%); $\nu_{max.}$ 3 480, 3 070, 2 950, 2 870, 1 670, 1 590, 1 500, 1 470, and 1 380 cm^{-1}; δ_H 0.65—2.0 (44 H), 1.96 (3 H, s, CH_3CO), 3.60 (1 H, br s, $W_{\frac{1}{2}}$ 7 Hz, C*H*S), 4.22 (1 H, br s, $W_{\frac{1}{2}}$ 14 Hz, C*H*NH), 5.80 (1 H, d *J* 7 Hz, NH), and 7.20—7.50 (5 H); δ_C 169.09 (CO), 135.78, 130.54, 128.96, and 126.48 (ArC), 55.12 (CHNH), and 49.80 (CHS).

2β-*Acetamido*-3α-*phenylthio*[3-^{2}H]-5α-*cholestane* (**26**). Diphenyl disulphide (45 mg) and [3-^{2}H]-5α-cholest-2-ene (150 mg) were electrolysed at 1.3 V at a platinum anode with passage of 40 C over 5 h. Work-up by the above procedure and p.l.c. afforded an oil, which was further purified by crystallisation (dichloromethane–pentane) to give the *title compound* (**26**) (70 mg, 33%), m.p. 180—182 °C (Found: M^+, 539.4134. $C_{35}H_{54}DNOS$ requires 539.4149) *m/z* (C.I. using NH_3) 539 (M^+, 5%) and 479 (100%); $\nu_{max.}$ 3 480 and 1 675 cm^{-1}; δ_H 0.65—2.0 (44 H), 1.96 (3 H, s, CH_3CO), 4.20 (1 H, br s, $W_{\frac{1}{2}}$ 12 Hz C*H*NH), 5.80 (1 H, d, *J* 7 Hz, NH), and 7.2—7.5 (5 H).

2β-*Acetamido*-3α-p-*tolylthio*-5α-*cholestane* (**14**). Bis-*p*-tolyl disulphide (**7**) (200 mg) and 5α-cholest-2-ene (300 mg) were electrolysed at 1.3 V at a platinum anode with passage of 156 C over 7 h. Work-up by the above procedure and p.l.c. afforded a crystalline product which was further purified by recrystallisation from methanol to give the *title compound* (**14**) as white needles (158 mg, 35%), m.p. 187—188 °C (Found: C, 78.25; H, 10.5; N, 2.5; S, 5.9. $C_{36}H_{57}NOS$ requires C, 78.3; H, 10.4; N, 2.5; S, 5.8%), *m/z* (C.I. using NH_3) 552 (M^+ + 1, 2%) and 492 (29%); $\nu_{max.}$($CHCl_3$) 3 480 and 1 675 cm^{-1}; δ_H 0.65—2.00 (44 H) 1.90 (3 H, s, CH_3CO), 2.30 (3 H, s, CH_3-Ar), 3.50 (1 H, br s, $W_{\frac{1}{2}}$ 10 Hz, CHS), 4.20 (1 H, br s, $W_{\frac{1}{2}}$ 15 Hz, CHNH), 5.99 (1 H, d, *J* 7 Hz, NH), 7.10 (2 H, d, ArH), and 7.39 (2 H, d, ArH); δ_C 169.10 (CO) 136.75, 131.90, 131.62, and 129.71 (ArC), 55.20 (CHNH), and 50.00 (CHS).

2β-Acetamido-3α-*p*-tolylthio-5α-cholestane (**14**) was further prepared in 61% overall yield from 5α-cholest-2-ene (300 mg) *via* oxidation of bis-*p*-tolyl disulphide (**7**) (100 mg) with lead tetra-acetate (90 mg) followed by the work-up procedure and Ritter reaction as described below.

2β-*Acetamido*-3α-*benzylthio*-5α-*cholestane* (**15**). Dibenzyl disulphide (**8**) (100 mg) and 5α-cholest-2-ene (**1**) (300 mg) were electrolysed at 1.3 V at a platinum anode with passage of 78 C over 5 h. Work-up by the above procedure and column chromatography [silica gel eluant light petroleum–acetone (4:1)] afforded a crystalline product, which was further purified by recrystallisation from methanol to give the title compound (**15**) as white needles (120 mg, 27%), m.p. 191—192 °C (Found: C, 78.3; H, 10.4; N, 2.5; S, 5.8. $C_{36}H_{57}NOS$ requires C, 78.3; H, 10.4; N, 2.5; S, 5.8%), *m/z* (C.I. using isobutane) 552 (M^+ + 1, 1%), 493 (14%), and 492 (34%); $\nu_{max.}$($CHCl_3$) 3 480 and 1 675 cm^{-1}; δ_H 0.6—2.00 (44 H), 1.98 (3 H, s, CH_3CO), 2.88 (1 H, br s, $W_{\frac{1}{2}}$ 9 Hz, CHS), 3.97 (2 H, s, $PhCH_2$), 4.36 (1 H, br s, $W_{\frac{1}{2}}$ 17 Hz, CHNH), 5.62 (1 H, d, NH), and 7.2—7.45 (5 H, ArH); δ_C 169.1 (CO), 137.8, 128.5, 128.4, and 126.8 (ArC), 55.10 (CHNH), 48.9 ($CHSCH_2$), and 45.5 (CH_2).

2β-Acetamido-3α-benzylthio-5α-cholestane (**15**) was further prepared in 40% overall yield from 5α-cholest-2-ene (300 mg) *via* oxidation of dibenzyl disulphide (**8**) (100 mg) with lead tetra-acetate (90 mg) followed by the work-up procedure, and Ritter reaction as described below.

2β-*Acetamido*-3α-*propylthio*-5α-*cholestane* (**16**).—Dipropyl disulphide (**9**) (0.13 ml) and 5α-cholest-2-ene (**1**) (300 mg) were electrolysed at 1.25 V at a platinum anode with passage of 156 C

over 5 h. Work-up by the above procedure and column chromatography [silica gel eluant light petroleum–acetone (85:15)] afforded two crystalline fractions. The first on recrystallisation from methanol gave the *title compound* (**16**) as white needles (92 mg, 31%), m.p. 184—185 °C (Found: $M^+ + 1$, 504.4242. $C_{32}H_{57}NOS$ requires $M^+ + 1$, 504.4239); *m/z* (C.I. using isobutane) 504 ($M^+ + 1$, 1%) and 444 (25%); $\nu_{max.}$($CHCl_3$) 3 450 and 1 670 cm^{-1}; δ_H 0.65—2.10 (49 H), 2.00 (3 H, s, CH_3CO), 2.65 (2 H, t, *J* 7 Hz, CH_2S), 3.02 (1 H, br s, $W_{\frac{1}{2}}$ 8 Hz, CHS), 4.17 (1 H, br s, $W_{\frac{1}{2}}$ 15 Hz, CHNH), and 5.79 (1 H, d, *J* 7 Hz, NH); δ_C 169.10 (CO), 55.20 (CHNH), and 54.50 (CHS). The second fraction on recrystallisation from methanol gave 3α-*acetamido*-β-*propylthio*-5α-*cholestane* (**17**) as white needles (21 mg, 5%[23]), m.p. 140—142 °C (Found: $M^+ + 1$, 504.4285. $C_{32}H_{57}NOS$ requires $M^+ + 1$, 504.4239), *m/z* (C.I. using isobutane) 504 ($M^+ + 1$, 1%), 444 (4%), and 428 (6%); $\nu_{max.}$($CHCl_3$) 3 450 and 1 670 cm^{-1}; δ_H 0.65—2.00 (49 H), 1.98 (3 H, s, CH_3CO), 2.65 (2 H, t, *J* 7 Hz, CH_2S), 3.02 (1 H, br s, $W_{\frac{1}{2}}$ 9 Hz, CHS), 4.15 (1 H, br s, $W_{\frac{1}{2}}$ 15 Hz, CHNH), and 5.81 (1 H, d, *J* 7 Hz, NH).

2β-Acetamido-3α-propylthio-5α-cholestane (**16**) was further prepared in 37% overall yield from 5α-cholest-2-ene (200 mg) *via* oxidation of dipropyl disulphide (**9**) (81 mg) with lead tetra-acetate (62 mg) followed by the work-up procedure, and Ritter reaction as described below.

6β-*Hydroxy*-5α-*phenylthiocholestane* (**29**). Diphenyl disulphide (**6**) (59 mg) and cholest-5-ene (**3**) (200 mg) were electrolysed at 1.3 V at a platinum anode with passage of 104 C over 5 h. Work-up by the above procedure and p.l.c. afforded a crystalline product, which was further purified by recrystallisation from methanol to give the *title compound* (**29**) (29 mg, 11%), m.p. 122—124 °C (Found: M^+, 496.3780. $C_{33}H_{52}OS$ requires 496.3742), *m/z* 496 (10%) and 371 (100%); $\nu_{max.}$($CHCl_3$) 3 480 cm^{-1}; δ_H 0.68—2.1 (44 H), 3.90 (1 H, br d, *J* 9 Hz, CHOH), 5.90 (1 H, br s, OH), and 7.1—7.4 (5 H, ArH). Addition of trifluoroacetic anhydride to the alcohol (**29**) afforded the ester (**30**) identical with a sample prepared by lead(IV)-promoted addition of diphenyl disulphide to cholest-5-ene (see below).

5α-*Acetamido*-6β-*phenylthiocholesteryl benzoate* (**31**). Diphenyl disulphide (**6**) (89 mg) and cholesteryl benzoate (**4**) were electrolysed at 1.3 V at a platinum anode with passage of 160 C over 7 h. Work-up by the above procedure and p.l.c. [eluant light petroleum–acetone (4:1)] afforded a crystalline product which was further purified by recrystallisation from methanol to give the *title compound* (**31**) (150 mg, 28%), m.p. 193—195 °C; *m/z* 428 (73%), 426 (30%), and 368 (20%); $\nu_{max.}$($CHCl_3$) 3 470, 1 725, and 1 670 cm^{-1}; δ_H 0.7—2.1 (43 H), 2.04 (3 H, s, CH_3CO), 3.10 (1 H, br s, $W_{\frac{1}{2}}$ 10 Hz, CHS), 4.72 (1 H, br s, CHOCOPh), 5.32 (1 H, br s, NH), and 7.2—8.1 (10 H, ArH).

3α-*Acetamido*-4β-*phenylthio*-5β-*cholestane* (**35**). Diphenyl disulphide (**6**) (59 mg) and 5β-cholest-3-ene (**5**) (200 mg) were electrolysed at 1.3 V at a platinum anode with passage of 104 C over 5 h. Work-up by the above procedure and column chromatography [eluant light petroleum–acetone (4:1)] afforded the *title compound* (**35**) as an oil (58 mg, 20%) (Found: $M^+ + 1$, 538.4093. $C_{35}H_{55}NOS$ requires *M*, 538.4086); *m/z* (C.I. using isobutane) 538 ($M^+ + 1$, 1%) and 478 (100%); $\nu_{max.}$(neat film) 3 450 and 1 670 cm^{-1}; δ_H 0.65—1.85 (44 H), 1.99 (3 H, s, CH_3CO), 3.45 (1 H, t, *J* 11 Hz, CHS), 4.06 (1 H, br t, $W_{\frac{1}{2}}$ 27 Hz, CHNH), 5.50 (1 H, br d, *J* 5 Hz, NH), and 7.1—7.6 (5 H, ArH).

2β-*Acetamido*-3α-*phenylseleno*-5α-*cholestane* (**19**). Diphenyl diselenide (**12**) (84 mg) and 5α-cholest-2-ene (**1**) (200 mg) were electrolysed at 1.1 V at a platinum anode with passage of 160 C over 3 h. Work-up by the above procedure and column chromatography [eluant light petroleum–acetone (85:15)] gave two fractions. The first on recrystallisation from methanol gave the *title compound* (**19**) (16 mg, 5%), m.p. 152—155 °C (Found: M^+, 584.3891. $C_{35}H_{55}NOSe$ requires 584.3884), *m/z* (C.I. using isobutane) 584 (M^+, 1%) and 525 (100%); δ_H 0.6—2.3 (44 H), 1.82 (3 H, s, CH_3CO), 2.90 (1 H, br s, $W_{\frac{1}{2}}$ 8 Hz, CHSe), 3.80 (1 H, br s, $W_{\frac{1}{2}}$ 15 Hz, CHNH), 5.40 (1 H, d, *J* 7 Hz, NH), and 7.2—7.6 (5 H, aromatic). The second fraction on recrystallisation from methanol gave 3α-*acetamido*-2β-*phenylseleno*-5α-*cholestane* (**20**) (20 mg, 6%), m.p. 114—116 °C (Found: M^+, 584.3889. $C_{35}H_{55}NOSe$ requires *M*, 584.3884), *m/z* (C.I. using isobutane) 584 (M^+, 1%) and 525 (100%); δ_H 0.6—2.3 (44 H), 1.86 (3 H, s, CH_3CO), 3.00 (1 H, br s, $W_{\frac{1}{2}}$ 8 Hz, CHSe), 4.00 (1 H, br s, $W_{\frac{1}{2}}$ 16 Hz, CHNH), 5.3 (1 H, d, *J* 7 Hz, NH), and 7.3—7.65 (5 H, ArH).

Typical Procedure for Lead(IV)*-promoted Trifluoroacetoxysulphenylation:* 2β-*Hydroxy*-3α-*phenylthio*-5α-*cholestane* (**22**).—Lead tetra-acetate (120 mg) was dissolved in dichloromethane (50 ml) at −40 °C (bath temperature). Diphenyl disulphide (**6**) (118 mg) was added and the mixture stirred for 5 min. Trifluoroacetic acid (1.84 mg) was then added, and the strong turquoise colour, which was immediately produced, rapidly faded to give a yellow solution. 5α-Cholest-2-ene (**1**) (400 mg) was added, the yellow colour faded, and the solution was stirred at −40 °C for 30 min and then poured into water. The mixture was extracted with ether (3 × 50 ml) and the combined extracts were washed with aqueous potassium hydrogen carbonate (3 × 50 ml) and water (3 × 50 ml), dried ($MgSO_4$), filtered, and concentrated under reduced pressure to afford a crude product. Column chromatography [silica gel eluant light petroleum–acetone (9:1)] gave 3α-*phenylthio*-2β-*trifluoroacetoxy*-5α-*cholestane* (**21**) as a colourless oil (422 mg, 66% w.r.t. 5α-cholest-2-ene) (Found: M^+, 592.3595. $C_{35}H_{51}F_3O_2S$ requires *M*, 592.3564); *m/z* 593 ($M^+ + 1$, 35%), 592 (M^+, 100%), and 478 (15%); $\nu_{max.}$ 1 780 cm^{-1}; δ_H 0.65—2.4 (44 H), 3.50 (1 H, br s, $W_{\frac{1}{2}}$ 9 Hz, CHS), 5.22 (1 H, br s, $W_{\frac{1}{2}}$ 9 Hz, $CHOCOCF_3$), and 7.15—7.5 (5 H, ArH).

The trifluoroacetate (**21**) (200 mg) was dissolved in dichloromethane (20 ml) and sodium hydroxide in methanol (15% solution; 20 ml) was added. The mixture was thoroughly stirred at room temperature for 15 min, poured into water, and extracted with ether (3 × 50 ml). The combined extracts were washed with aqueous potassium hydrogen carbonate (3 × 50 ml) and water (3 × 50 ml), dried ($MgSO_4$), and evaporated under reduced pressure to afford a yellow oil. Purification of this by column chromatography [silica gel eluant light petroleum–acetone (4:1)] and recrystallisation from methanol gave the *title compound* (**22**) as white *needles* (106 mg, 63%), m.p. 118—119 °C (Found: C, 79.5; H, 10.35; S, 6.3. $C_{33}H_{52}OS$ requires C, 79.75; H, 10.55; S, 6.4%) (Found: M^+, 496.3740. $C_{33}H_{52}OS$ requires *M*, 496.3742), *m/z* 496 (M^+, 13%); $\nu_{max.}$ 3 470 cm^{-1}; δ_H 0.65—2.2 (44 H), 3.45 (1 H, br s, $W_{\frac{1}{2}}$ 10 Hz, CHS), 3.50 (1 H, br s, removed by addition of D_2O, OH), 4.05 (1 H, br s, $W_{\frac{1}{2}}$ 10 Hz, CHOH), and 7.72—7.5 (5 H, ArH); δ_C 136.16, 130.97, 129.03 and 126.66 (ArC), 71.03 (CHOH), and 50.70 (CHS).

3α-Phenylthio-2β-trifluoroacetoxy-5α-cholestane (**21**) was also prepared by copper(II) acetate-promoted addition of diphenyl disulphide to 5α-cholest-2-ene as described below in 32% yield. Similarly manganese(III) acetate-promoted addition gave 3α-phenylthio-2β-5α-cholestane (**21**) in 63% yield.

2β-*Hydroxy*-3α-*phenylthio*-[3β-^{2}H]-5α-*cholestane* (**27**). Diphenyl disulphide (**6**) (60 mg) was oxidised by lead tetra-acetate (62 mg) in the presence of [3-^{2}H]-5α-cholest-2-ene (**2**) (200 mg) by the above procedure. After work-up, p.l.c. afforded as a colourless oil 3α-*phenylthio*-2β-*trifluoroacetoxy*-[3β-^{2}H]-5α-*cholestane* (**28**) (247 mg, 62%) (Found: M^+, 593.3627. $C_{35}H_{50}DF_3O_2S$ requires *M*, 593.3627) *m/z* 594 ($M^+ + 1$, 45%) and 593 (M^+, 100%); δ_H 0.65—2.4 (44 H), 5.28 (1 H, br s, $W_{\frac{1}{2}}$ 6 Hz, $CHOCOCF_3$), and 7.2—7.6 (5 H, ArH). Hydrolysis of the trifluoroacetate (**28**) (230 mg) as described above, and work-up gave a crude product. Column chromatography and further

purification by recrystallisation from methanol gave the *title compound* (**27**) (157 mg, 81%), m.p. 118—119 °C (Found: M^+, 497.3814. $C_{33}H_{51}DOS$ requires M, 497.3804), m/z 497 (M^+, 10%) and 479 (100%); δ_H 0.65—2.2 (44 H), 3.55 (1 H, br s, removed by addition of D_2O, OH), 4.10 (br t, $W_{\frac{1}{2}}$ 6 Hz, CHOH), and 7.2—7.55 (5 H, ArH).

5α-*Phenylthio*-6β-*trifluoroacetoxycholestane* (**30**). Diphenyl disulphide (**6**) (147 mg) was oxidised by lead tetra-acetate (149 mg) in the presence of cholest-5-ene (**3**) (500 mg) at −60 °C by the above procedure. After work-up, column chromatography [eluant light petroleum] afforded the *title compound* (**30**) as a colourless oil (325 mg, 41%) (Found: M^+, 592.3606. $C_{35}H_{51}F_3O_2S$ requires M, 592.3564), m/z 592 (M^+, 51%), 483 (5%), and 478 (100%); $\nu_{max.}$($CHCl_3$) 1 785 cm^{-1}; δ_H 0.65—2.5 (44 H), 5.00 (1 H, br s, $W_{\frac{1}{2}}$ 10 Hz, $CHOCOCF_3$), and 7.1—7.5 (5 H, ArH).

Hydrolysis of the trifluoroacetate (**30**) (300 mg) as described above and work-up gave a crude product. Column chromatography and further purification by recrystallisation from methanol gave 6β-hydroxy-5α-phenylthiocholestane (**29**) (100 mg, 40%). The product was identical (^1H n.m.r., i.r., m.s., t.l.c., and m.p.) with the sample obtained by anodic oxidation (see above).

4β-*Phenylthio*-3α-*trifluoroacetoxy*-5β-*cholestane* (**36**). Diphenyl disulphide (**6**) (88 mg) was oxidised by lead tetra-acetate (90 mg) in the presence of 5β-cholest-3-ene (**5**) (200 mg) at −40 °C by the above procedure. After work-up column chromatography afforded a colourless oil, which was crystallised from methanol to give the *title compound* (**36**) (130 mg, 41%), m.p. 90—91 °C (Found: C, 71.0; H, 8.6; S, 5.4. $C_{35}H_{51}F_3O_2S$ requires C, 70.9; H, 8.7; S, 5.4%) (Found: M^+, 592.3534. $C_{35}H_{51}F_3O_2S$ requires M, 592.3564), m/z 592 (M^+, 11%); $\nu_{max.}$ 1 775 cm^{-1}; δ_H 0.65—2.4 (44 H), 3.40 (1 H, t, J 11 Hz, CHS), 4.95 (1 H, dt, J 11, 11, 5 Hz, $CHOCOCF_3$), and 7.2—7.5 (5 H, ArH); δ_C 155.40 (CO), 80.20 ($CHOCOCF_3$), and 50.10 (CHS).

4β-Phenylthio-3α-trifluoroacetoxy-5β-cholestane (**36**) was also prepared by manganese(III) acetate-promoted addition of diphenyl disulphide to 5β-cholest-3-ene as described above in 91% yield.

Typical Procedure for Copper(II)-promoted Trifluoroacetoxysulphenylation; 3α-(2-*Aminophenylthio*)-2β-*hydroxy*-5α-*cholestane* (**25**).—Copper(II) acetate monohydrate (108 mg) was dissolved in dichloromethane (50 ml). Bis(2-aminophenyl) disulphide (**11**) (268 mg) and trifluoroacetic acid (1.26 ml) were added, followed immediately by 5α-cholest-2-ene (**1**) (400 mg). The reaction mixture was stirred at room temperature for 5 days, poured into water, and extracted with ether (3 × 70 ml). The combined ether extracts were washed with aqueous potassium hydrogen carbonate (3 × 100 ml) and water (3 × 100 ml), dried ($MgSO_4$), and filtered, and evaporated under reduced pressure to afford a yellow oil which was purified by column chromatography to give 3α-(2-*aminophenylthio*)-2β-*trifluoroacetoxy*-5α-*cholestane* (**24**) as a pale yellow oil (603 mg, 92%) (Found: M^+, 607.3649. $C_{35}H_{52}F_3NO_2S$ requires M, 607.3670); δ_H 0.65—2.4 (44 H), 3.30 (1 H, br s, $W_{\frac{1}{2}}$ 9 Hz, CHS), 5.20 (1 H, br s, $W_{\frac{1}{2}}$ 9 Hz, $CHOCOCF_3$), and 6.7—7.5 (4 H, ArH).

Hydrolysis of the trifluoroacetate (**24**) (603 mg) as described above, and work-up after 6 h, gave a crude product, column chromatography (eluant chloroform) and recrystallisation from dichloromethane–pentane of which gave the *title compound* (**25**) as a pale brown solid (424 mg, 86%), m.p. 161—163 °C (Found: M^+, 511.3856. $C_{33}H_{53}NOS$ requires M, 511.3851), m/z 512 (M^+ + 1, 2%) and 511 (M^+, 5.5%); $\nu_{max.}$($CHCl_3$) 3 420 and 3 325 cm^{-1}; δ_H 0.55—2.2 (44 H), 3.18 (1 H, br s, $W_{\frac{1}{2}}$ 9 Hz, CHS), 3.97 (1 H, br s, $W_{\frac{1}{2}}$ 9 Hz, CHOH), 4.32 (3 H, br s, removed by addition of D_2O, NH_2 and OH), and 6.67—7.4 (4 H, ArH).

Typical Procedure for Acetamidosulphenylation using a Ritter Reaction with a Trifluoroacetate: 2β-*Acetamido*-3α-*phenylthio*-5α-*cholestane* (**13**).—The trifluoroacetate (**21**) (422 mg) was dissolved in acetonitrile–dichloromethane (1:1; 50 ml) containing concentrated sulphuric acid (1 ml) and the resulting solution was stirred for 24 h. The solution was then poured into water (150 ml) and made alkaline by addition of solid sodium carbonate. The mixture was extracted with chloroform (3 × 50 ml) and the combined extracts were washed with water, dried ($MgSO_4$), filtered, and evaporated under reduced pressure. The residue was column chromatographed [eluant light petroleum–acetone (4:1)] and recrystallised from pentane to give the title compound (**13**) (313 mg, 82%). The product was identical (^1H n.m.r., i.r., m.s., t.l.c., and m.p.) with a sample obtained by anodic oxidation.

2β-*Acetamido*-5α-*cholestane* (**18**). 2β-Acetamido-3α-phenylthio-5α-cholestane (**13**) (138 mg) and Raney nickel (W4, 2 g) were heated under reflux in ethanol (50 ml) for 3 h. The cold reaction mixture was filtered through Celite and the filtrate evaporated under reduced pressure to give a white solid which on recrystallisation from methanol afforded the *title compound* (**18**) as white needles (100 mg, 90%), m.p. 114—115 °C and 147—148 °C (lit.,[18] 117—118 °C and 148—150 °C) (Found: M^+, 429.3971. Calc. for $C_{29}H_{51}NO$: M, 429.3973), m/z 429 (M^+, 4%); δ_H 0.65—2.2 (46 H), 2.00 (3 H, s, CH_3CO), 4.22 (1 H, br s, $W_{\frac{1}{2}}$ 17 Hz, CHNH), and 5.80 (1 H, d, J 7 Hz, NH); δ_C 169.05 (CO) and 55.6 (CHNH).

In a similar manner 2β-acetamido-5α-cholestane (**18**) was obtained by reductive desulphurisation of 2β-acetamido-3α-*p*-tolylthio-5α-cholestane (**14**) (85%), 2β-acetamido-3α-benzylthio-5α-cholestane (**15**) (85%), and 2β-acetamido-3α-propylthio-5α-cholestane (**16**) (57%).

2β-*Hydroxy*-5α-*cholestane* (**23**). 2β-Hydroxy-3α-phenylthio-5α-cholestane (**22**) (100 mg) and Raney nickel (W4, 1.5 g) were heated under reflux in ethanol for 3 h. Work-up as described above and recrystallisation of the product from acetone–pentane gave the title compound (**23**) as white needles (60 mg, 77%), m.p. 153—155 °C (lit.,[24] 155 °C) (Found: M^+, 388.3715. Calc. for $C_{27}H_{48}O$: M, 388.370), m/z 388 (M^+, 7%) and 370 (100%); $\nu_{max.}$($CHCl_3$) 3 460 cm^{-1}; δ_H 0.65—2.1 (46 H), 3.55 (1 H, br s, removed by addition of D_2O, OH), and 4.10 (1 H, br s, $W_{\frac{1}{2}}$ 18 Hz, CHOH).

In a similar manner 3α-(2-aminophenylthio)-2β-hydroxy-5α-cholestane (**25**) gave 2β-hydroxy-5α-cholestane (**23**) in 78% yield.

References

1 T. C. Britton, T. J. Lobl, and C. G. Chidester, *J. Org. Chem.*, 1984, **49**, 4773.
2 M. M. Campbell, R. C. Craig, A. C. Boyd, I. M. Gilbert, R. T. Logan, J. Redpath, R. G. Roy, D. S. Savage, and T. Sleigh, *J. Chem. Soc., Perkin Trans. 1*, 1979, 2235.
3 B. B. Vargaftig, M. F. Sugrue, W. R. Buckett, and H. van Riezen, *J. Pharm. Pharmacol.*, 1975, **27**, 697; R. J. Marshall and J. R. Parratt, *Brit. J. Pharmacol.*, 1975, **55**, 359; L. A. Salako, E. M. Vaughan Williams, and J. K. Wittig, *ibid.*, 1976, **57**, 251.
4 D. H. R. Barton, M. R. Britten-Kelly, and D. Ferreira, *J. Chem. Soc., Perkin Trans. 1*, 1978, 1090.
5 K. Nakajima, H. Oda, and K. Okawa, *Bull. Chem. Soc. Jpn.*, 1983, **56**, 520.
6 P. M. R. Barkworth and T. A. Crabb, *J. Chem. Soc., Perkin Trans. 1*, 1982, 2777; M. Taddei, A. Papini, M. Fiorenza, and A. Ricci, *Tetrahedron Lett.*, 1983, **24**, 2311.
7 B. M. Trost and T. Shibata, *J. Am. Chem. Soc.*, 1982, **104**, 3225; B. M. Trost, T. Shibata, and S. J. Martin, *J. Am. Chem. Soc.*, 1982, **104**, 3228; M. C. Caserio and J. K. Kim, *J. Am. Chem. Soc.*, 1982, **104**, 3231.
8 T. Ohsawa, M. Ihara, K. Fukumoto, and T. Kametani, *J. Org. Chem.*, 1983, **48**, 3644; M. Ihara, Y. Haga, M. Yonekura, T. Ohsawa, K. Fukumoto, and T. Kametani, *J. Am. Chem. Soc.*, 1983, **105**, 7345.

9 L. Benati, P. C. Montevecchi, and P. Spagnolo, *Tetrahedron Lett.*, 1984, **25**, 2039.
10 P. Brownbridge, *Tetrahedron Lett.*, 1984, **25**, 3759.
11 A. Bewick, D. E. Coe, J. M. Mellor, and W. M. Owton, *J. Chem. Soc., Perkin Trans. 1*, 1985, 1033.
12 W. A. Smit, M. Z. Krimer, and E. A. Vorob'eva, *Tetrahedron Lett.*, 1975, 2451; W. A. Smit, N. S. Zefirov, I. V. Bodrikov, and M. Z. Krimer, *Acc. Chem. Res.*, 1979, **12**, 282.
13 R. C. Cambie, H. H. Lee, P. S. Rutledge, and P. D. Woodgate, *J. Chem. Soc., Perkin Trans. 1*, 1979, 765; R. C. Cambie, D. Chambers, P. S. Rutledge, and P. D. Woodgate, *ibid.*, 1981, 40; R. C. Cambie, G. D. Mayer, P. S. Rutledge, and P. D. Woodgate, *ibid.*, 1981, 52.
14 B. M. Trost, M. Ochiai, and P. G. McDougal, *J. Am. Chem. Soc.*, 1978, **100**, 7103.
15 A. Bewick, J. M. Mellor, and W. M. Owton, *J. Chem. Soc., Perkin Trans. 1*, 1985, 1039.
16 A. Bewick, J. M. Mellor, D. Milano, and W. M. Owton, *J. Chem. Soc., Perkin Trans. 1*, 1985, 1045.
17 K. Ponsold and H. Kasch, *Tetrahedron Lett.*, 1979, 4463 and 4465.
18 C. W. Shoppee, R. J. W. Cremlyn, D. E. Evans, and G. H. R. Summers, *J. Chem. Soc.*, 1957, 4364.
19 L. M. Jackman and S. Sternhell, 'Applications of Nuclear Magnetic Resonance Spectroscopy in Organic Chemistry,' Pergamon Press, Oxford, 1978.
20 J. Y. Satoh and C. A. Horiuchi, *Bull. Chem. Soc. Jpn.*, 1979, **59**, 2653.
21 C. R. Narayanan, A. K. Kulkarni, A. B. Landge, and M. S. Wadia, *Synthesis*, 1977, 35.
22 E. Laurent and R. Tardivel, *Tetrahedron Lett.*, 1976, 2779.
23 V. Sanda and J. Fajkos, *Collect. Czech. Chem. Commun.*, 1967, **32**, 3726.
24 A. A. Pavlic and H. Adkins, *J. Am. Chem. Soc.*, 1946, **68**, 1471.

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