Tetrahedron Vol. 45, No. 9, pp. 2615 to 2626, 1989
Printed in Great Britain.

0040-4020/89 $3.00+.00

THE INVENTION OF RADICAL REACTIONS. PART XVIII. DECARBOXYLATIVE RADICAL ADDITION TO ARSENIC, ANTIMONY, AND BISMUTH PHENYLSULPHIDES - A NOVEL SYNTHESIS OF NOR-ALCOHOLS FROM CARBOXYLIC ACIDS

Derek H.R. Barton*[a], Dominique Bridon and Samir Z. Zard[b]

Institut de Chimie des Substances Naturelles, C.N.R.S.
91190 Gif-sur-Yvette, France

(*Received in Belgium* 16 *December* 1988)

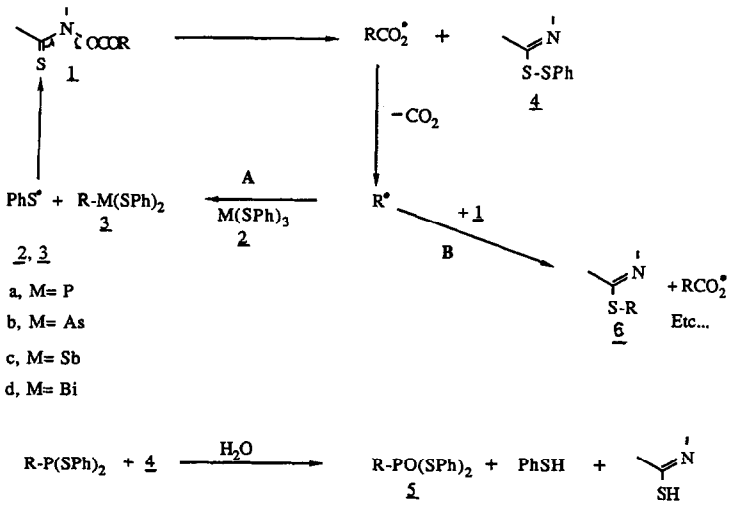
Abstract - Carbon centered radicals obtained by decarboxylative transformation of suitable thiohydroxamate esters react with group Va trisphenylsulphides to give intermediates of general formula $R-M(SPh)_2$ (M = As, Sb, Bi). These react spontaneously with air to give the corresponding alcohols. This procedure is especially useful in the case where M=Sb. It is thus sufficient to stir the thiohydroxamate ester with tris(phenylthio)-antimony under air to obtain the nor alcohol directly and in high yield. The intermediate organometalloid could also be oxidised with nitrogen dioxide to give the expected nitroalkane albeit in only modest yield. The corresponding organobismuth intermediate derived from 3,3-diphenylpropionic acid could actually be isolated thereby providing strong evidence for the proposed mechanism.

The synthetic utility of radical reactions hinges to a large extent on the adroit exploitation of efficient chain processes.[1] In such systems the steady state concentration of the intermediate radicals remains sufficiently low so as to render radical-radical interactions almost insignificant. The appropriate sequence of steps can thus be channeled in the desired direction with little hindrance from unwanted side reactions such as dimerisations and disproportionations.

Over the past few years, we have reported on a novel radical decarboxylation reaction based on the chemistry of thiohydroxamate esters of carboxylic acids.[2] The radical chain sequence involves the intermediacy of a carbon centered radical which can be captured in a variety of ways. In line with the aforesaid, such modifications of the basic process have to be designed so as to maintain an efficient chain reaction in operation. With this constraint in mind, we imagined the possibility of using this decarboxylation reaction to prepare various organic derivatives of the main group elements by trapping the carbon radical with the corresponding phenylsulphides. This step, which may be viewed as an S_H2 proces, liberates a phenylthiyl radical to act as a chain carrier, as outlined in Scheme 1. Previous experience had shown that thiyl radicals were excellent chain propagators in this decarboxylation

Present address: a) Department of Chemistry, Texas A&M University, College Station, Texas 77843, U.S.A. b) Laboratoire de Synthèse Organique, Ecole Polytechnique, 91128 Palaiseau, France.

reaction.[2,3] If successful, this would constitute an unusual and versatile approach to organometalloid, and perhaps even organometallic, compounds. The present study, focused on the heavier elements of group Va, has led to the discovery of a mild method for effecting the decarboxylative hydroxylation of aliphatic and alicyclic carboxylic acids. Our results, briefly reported in a preliminary communication,[4] are now described in detail.



Scheme 1

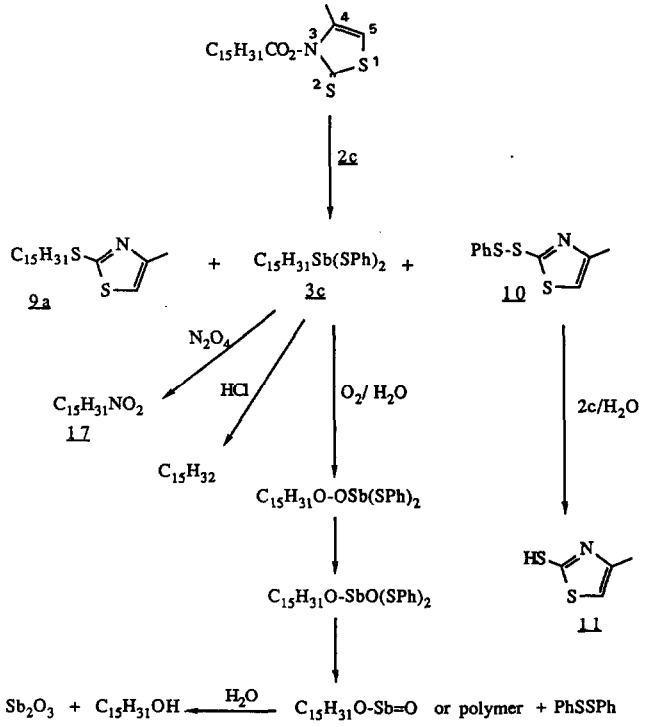
As depicted in Scheme 1, homolytic substitution by the intermediate carbon radical on the trisphenylsulphides of arsenic, antimony and bismuth should lead to the formation of the corresponding adduct 3 with concomitant expulsion of a phenylthiyl radical. The latter could then perpetuate the chain by adding onto the thiocarbonyl group of ester 1 and setting off the fragmentation process. Such a pattern of reactivity seemed to prevail in the related case of decarboxylative phosphonylation using triphenyl trithiophosphite 2a which we had studied earlier.[3] In this instance, the primary adduct 3a was further oxidised by the co-produced mixed disulphide 4 in the presence of water to give finally phosphonate 5.

Because of its immediate availability, we examined first the antimony trisphenylsulphide 2c. This somewhat water and air sensitive compound is easily obtained by reacting sodium thiophenoxide with antimony trichloride in dry tetrahydrofurane.[5] A preliminary exploratory experiment was carried out by heating the palmitic acid derivative 7a, with two molar equivalents of 2c in chlorobenzene for two hours. Work-up of the fairly clean reaction mixture, however, gave pentadecanol 8a in 70% yield as the major palmitic acid derived product, along with a small amount of sulphide 9a. The heterocyclic part was recovered as mixed disulphide 10 and thiol 11. Diphenyl disulphide and a white insoluble solid which was later characterised as antimony trioxide were also isolatd.

Pentadecyl thiazolyl sulphide 9a is produced through pathway B, and its formation was not unexpected. In contrast, the rather high yield of nor-alcohol was at first surprising since utmost care was taken to ensure oxygen-free reaction conditions. As work-up was done under air without any special precautions, it was conceivable that the alcohol arose through autoxidation of the as yet hypothetical organoantimony adduct 3c. Indeed some years ago, Davies and Hook[6] prepared the methyl analogue of 3c by homolytic substitution by phenylthiyl

radicals on trimethyl antimony and found it unstable to air in solution. At the time, however, the nature of the decomposition products was apparently not investigated.

Compelling evidence for the intermediacy of an organoantimony derivative was obtained by repeating the above experiment and exposing only half of the mixture to air while treating the other half with degassed aqueous hydrochloric acid under strictly anaerobic conditions. As expected, the portion which came in contact with oxygen afforded pentadecanol in essentially the same yield as before whereas the fraction treated with acid yielded mainly pentadecane (85%) and only a very small quantity of pentadecanol. Moreover, in a separate experiment, replacement of the hydrochloric acid with nitrogen tetroxide resulted in the formation of 1-nitropentadecane albeit in rather low yield (26%). If iodine is used, the corresponding 1-iodopentadecane is obtained in 55% yield.

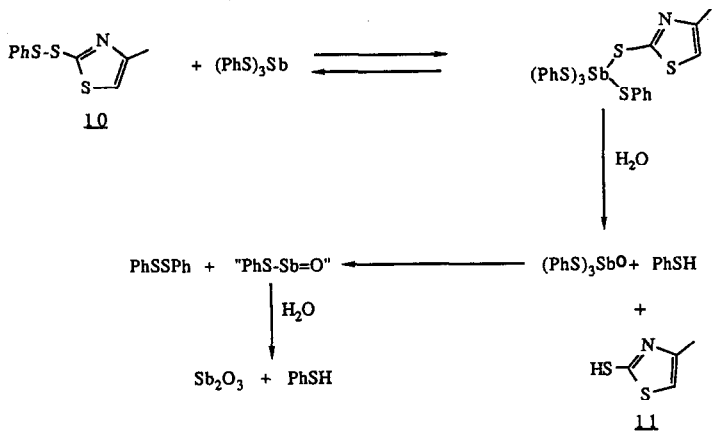


Scheme 2

Undoubtedly, an organoantimony intermediate is produced that is sensitive to air and that can be protonolysed with acid or cleaved by oxidising agents.[7] From mechanistic considerations (Scheme 1), and by analogy with later results obtained in the study of the bismuth analogue (vide infra), its structure must be 3c as proposed above.

The mechanistic manifold displayed in Scheme 2 accounts for the formation of the various products observed. The 2-mercaptothiazole thus arises from the reduction of the first formed mixed disulphide by the excess of the antimony reagent on contact with water as shown

separately in Scheme 3. This sequence of reactions is closely related to the phosphorus case, and evidence for it was obtained by treating the isolated disulphide 10 with tris(phenylthio)-antimony in wet ether. As anticipated, this caused the immediate appearance of thiol 11 and diphenyldisulphide. Furthermore, if the radical reaction is conducted with only one equivalent of the antimony reagent, only the mixed disulphide 10 is produced, clearly indicating the role of the reagent in the reduction of the first formed mixed disulphide.



Scheme 3

In the case of the decarboxylative phosphorylation,[3] we had found that the reaction could be performed at room temperature by allowing a slow aerial oxidation of the trivalent phosphorus reagent to take place. The small amount of phenylthiyl radicals produced by decomposition of the reagent was sufficient to trigger the radical chain process. As the antimony counterpart also exhibited a tendency to decompose in air, it seemed conceivable that a similar, low temperature, oxygen induced initiation of the decarboxylative hydroxylation was feasible. The presence of oxygen would also cause the autoxidation of the organoantimony intermediate leading directly to the nor-alcohol.

Indeed, simply stirring the thiohydroxamate ester 7a with two equivalents of tris(phenylthio)antimony in an open flask for a few hours gave pentadecanol in even better yield. This procedure appears to be applicable to a wide range of aliphatic and alicyclic primary, secondary or tertiary carboxylic acids, as shown by the examples recorded in Table 1. Yields are quite high and reproducible even with complex substrates.

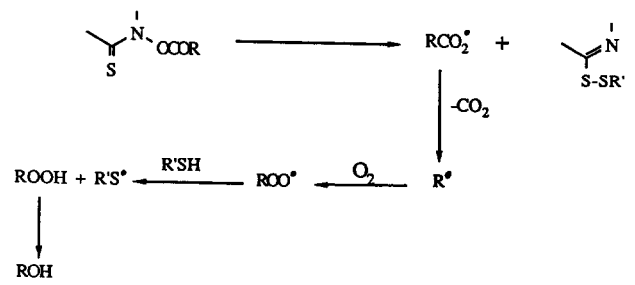
Most of this study was carried out using esters 7 derived from N-hydroxy thiazoline-2-thione as these were quite convenient to handle. The more reactive and light-sensitive esters obtained from N-hydroxy-2-thiopyridone give comparable yields of noralcohols after a much shorter reaction time (entries 4, 10 and 16). In all cases however, a non-nucleophilic solvent must be used as these esters are somewhat activated and exhibit an ionic chemistry based on the acyl group.

Table 1

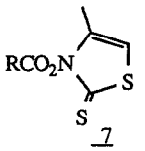
Entry	Thiohydroxamate esters	Solvent[a]	Reaction time (hours)	Noralcohols (yield %)
1	7a	C	3[b]	8a (70)
2	7a	C	4	8a (85)
3	7a	E	12	8a (90)
4	13	E	1	8a (75)
5	7b	C	12	8b (95)
6	7b	E	12	8b (85)
7	7c	D	12	8c (79)
8	7d	D+E	12	8d (84)
9	7e	E	12	8e (75)
10	14	E	1	8e (91)
11	7f	D+E	12	8f (81)
12	7g	E	12	8g (93)
13	7h	C	12	8h (90)
14	7i	C	12	8i (85)
15	7j	D+E	12	8j (93)
16	15	D+E	0.5	8k (77)

a) Solvents: C = chlorobenzene; D = dichloromethane; E = ether; mixtures are 1:1. b) Reaction temperature 90°C. All other reactions were performed at room temperature.

This novel reaction appears to be the most convenient way for replacing a carboxyclic acid function with a hydroxy group. Indeed only a handful of methods are reported in the literature[8] for effecting this transformation or its equivalent, and most are indirect and lengthy. Previously we had shown[9] that the intermediate carbon centered radical can be captured directly with triplet oxygen leading eventually to hydroperoxide which is easily reduced to the corresponding alcohol. As outlined in Scheme 4, the process requires the presence of a thiol to quench the hydroperoxyl radical and to ensure the propagation of the chain; the ensuing hydroperoxide is then reduced either by prolonged contact with the thiol or by treatment with a phosphine. Although the yields are synthetically useful, this first method is in practice somewhat delicate to apply necessitating a proper adjustment of the flow of oxygen and of the concentration of thiol. The present procedure is experimentally quite simple and easily applicable to small scale work.



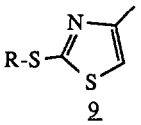
Scheme 4



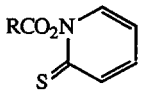
7

R-OH

8



9

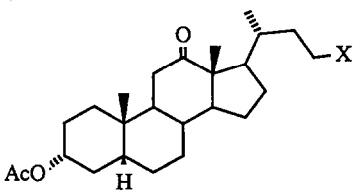


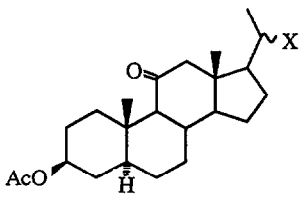
13, R=$CH_3(CH_2)_{14}$-

14, R= 1-adamantyl

7, 8, 9

a, R= $CH_3(CH_2)_{14}$-
b, R= Ph_2CHCH_2-
c, R= cyclohexyl-
d, R= $(PhCH_2)_2CH$-
e, R= adamantyl-
f, R= Ph_3C-
g, R= Ph_2CH-





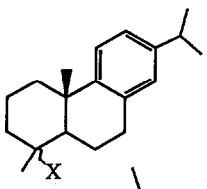
7h, X= -CO_2N(thiazolidine-2-thione)

8h, X= -OH

7i, X= -CO_2N(thiazolidine-2-thione) (20-S)

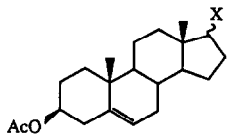
8i, X= -OH

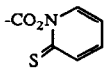
16, X= -CO_2N(pyridine-2-thione) (20-S)



7j, X= -CO_2N(thiazolidine-2-thione) (4α-)

8j, X= -OH



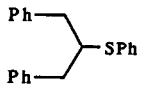
15. X=  (17β -)

8k, X= -OH

$CH_3(CH_2)_{13}X$

17, X= $-CH_2NO_2$

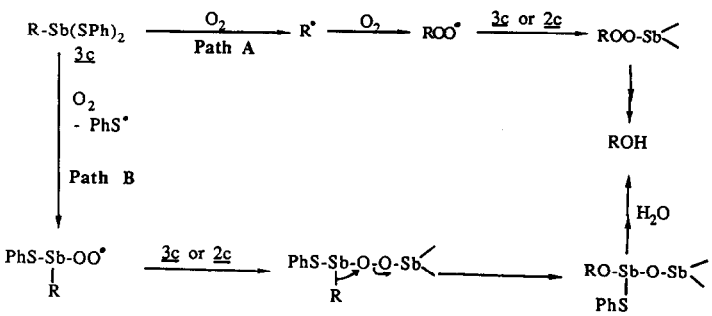
18, X= CO_2H



19

Apart from its preparative value, this novel reaction brings to light some interesting mechanistic questions, some of which have been addressed above. In particular, the passage from the organoantimony intermediate to the alcohol seemed especially intriguing. From a synthetic standpoint, one aspect of this rather complex sequence of events called for closer examination, namely the possible existence of a certain amount of stereoselectivity in the actual C-O bond forming step.

By and large, this crucial step may proceed through either of the following mechanistic pathways. Thus, rupture of the carbon-antimony bond can take place first, followed by rapid reaction of the carbon radical with triplet oxygen as portrayed in Scheme 5, path A.[10] In this case, little stereochemical discrimination is expected given the extremely low energy barrier for radical reactions with oxygen.[11] If, on the other hand, there is some degree of concertedness in the breaking of the C-Sb bond and the linking with oxygen, then a significant part of the stereochemical information contained in the organoantimony intermediate should be transfered to the final nor-alcohol. One variant of such a possibility is shown in Schem 5, path B. In other words, a carbon radical arising from the decarboxylation step and presenting two sterically different faces should react with the bulky antimony reagent from the less hindered side. Discrimination in this step is ensured by the large size of the reagent as well as by its much lower reactivity in comparison with triplet oxygen. If the following formation of the C-O bond proceeds with, say, retention then the stereoselectivity of the overall sequence should be quite high.



Scheme 5

This facet of the decarboxylative hydroxylation was examined by comparing the stereochemistry of the alcohols produced using this method with that of the alcohols obtained by capturing the carbon radicals directly with oxygen in the presence of a thiol. The results are displayed in Table 2. Clearly, the difference between the two processes as far as the stereochemistry of the products is concerned is slight although the variation is in the same direction for all three cases studied. It is possible that both types of mechanism depicted in Scheme 5 are operating with a predominance of the less useful pathway A, at least for secondary and tertiary cases where the C-Sb bond strength is expected to be on the weak side. Nevertheless, this rather disappointing stereochemical outcome should not veil the high chemical yields of nor-alcohols obtained by the present method.

Table 2

Entry	Thiohydroxamate esters	Method[a)]	Noralcohols (yield %)	Ratio of isomers
1	16	A	8i (85)	63/35
2	16	B	8i (16)	60/40
3	15	A	8k (77)	67/33 (17α/β)
4	15	B	8k (71)	59/41 (17α/β)
5	7j	A	8j (93)	73/27 (4α/β)
6	7j	B	8j (28)	58/42 (4α/β)

a) Method A: using $Sb(SPh)_3$; method B: using thiophenol and air.

To complete the study of group Va elements we briefly examined the behaviour of the arsenic and bismuth analogues 2b and 2d, easily obtained from sodium thiophenate and the corresponding trichlorides.[5] With the arsenic derivative a similar but somewhat more complex reaction pattern was observed. The yield of alcohol was consequently lower as can be seen from the results compiled in Table 3. Futhermore, the reaction times were considerably longer (about thirty-fold) than with the antimony derivative. Replacing antimony with arsenic thus offers no advantages as far as the obtention of alcohols is concerned. Its utility for making organoarsenic compounds, however, remains to be assessed.

Table 3

Entry	Thiohydroxamate esters	Solvent	Reaction time (hours)	Noralcohol (Yield %)
1	7a	Ether	120	8a (64)
2	7a	PhCl[a)]	2	8a (55)
3	7e	Ether	96	8e (76)
4	7g	Ether	96	8g (40)

a) Reaction temperature 110°C; all other reactions at room temperature.

Following a preliminary experiment, the organobismuth analogue looked even less promising. Indeed, stirring a solution of ester 7b and two equivalents of tris(phenylthio)bismuth under air for 12 hours gave back the thiohydroxamate ester essentially unchanged even though the bismuth reagent was completely decomposed. This unexpected observation seems to indicate that the room temperature aerial decomposition of the bismuth reagent 2d, unlike that of its lighter congeners, does not involve the formation of phenylthiyl radicals as these would have triggered the usual radical chemistry of the thiohydroxamate ester. In contrast, phenylthiyl radicals appear to implicated in the thermal decomposition of 2d.[5]

A reaction did occur, however, when, in a second experiment, the same mixture in chlorobenzene was heated to 110°C for two hours under strictly anaerobic conditions then exposed to air at room temperature for several hours. After the usual work up, 2,2-diphenylethanol 8b could be isoalted in 67% yield along with small amounts of sulphide 9b (10%) and disulphide 10 (10%). On contact with air, the yellow colour of the reaction mixture was gradually discharged. Thin layer chromatography indicated the presence of an intermediate which appeared to be slowly converted into the alcohol. We therefore repeated the experiment and followed the decomposition by NMR. Indeed, the broad triplet presumed to correspond to the C-1 methylene group in the intermediate slowly disappeared in favour of the lower field triplet of the resulting pentadecanol. This intermediate was later isolated as a yellow crystalline solid by flash chromatography under nitrogen in about 80% yield. Its spectroscopic properties and almost correct microelemental analysis were in accord with the putative primary adduct 3d (R = 2,2-diphenylethyl).

The actual isolation of this unexpectedly,[6,12] stable organobismuth intermediate lends strong support to the mechanism presented in Scheme 1, and for which only indirect evidence was earlier adduced.

With a somewhat more stable intermediate in hand, we examined briefly the possibility of converting it cleanly into 1-nitropentadecane 12, with the hope of extending the synthetic scope of this study to products other than nor-alcohols. We had previously attempted, in connection with another work, to accomplish this transformation directly using the radical decarboxylation reaction but had met with failure.

Addition of nitrogen tetroxide to the reaction mixture in place of aerial decomposition of the intermediate organobismuth derivative did indeed result in the formation of nitropentadecane. Yields were however low as can be judged from the values recorded in Table 4. The major product in fact turned out to be pentadecanoic acid presumably produced by further reaction with the nitrating agent. This oxidation is well known in the chemistry of primary nitroalkanes.[13] As expected, the yield of nor-acid could be improved by increasing the contact time with nitrogen tetroxide (entries 2, 3, 4).

Table 4

Entry	Thiohydroxamate esters	Nitrating agent[a)]	Contact time (hours)	Products (Yield %)
1	7a	N_2O_4	1	17a (35); 18 (35)
2	7a	N_2O_4	12	17a (5); 18 (72)
3	7a	N_2O_4	12	17a (21); 18 (65)
4	7a	N_2O_4/pyridine	12	17a (21); 18 (61)

a) The ester was decomposed thermally (110°C) in chlorobenzene in the presence of 2d and the resulting mixture exposed to the nitrating agent except for experiment 2 where the organobismuth intermediate 3d (R = n-pentadecyl-) was first isolated then treated separately with nitrogen dioxide.

Unfortunately, and despite much effort, the system could not be further ameliorated. Moreover, the decarboxylative radical addition to 2d did not seem to encompass secondary or tertiary carboxylic acid derivatives. For example, ester 7d derived from dibenzylacetic acid gave the corresponding phenylsulphide 19 in 85% yield by attack on the sulphur atom of the thiophenyl ligand whereas ester 7e derived from adamantanoic acid afforded adamantanol in 73% yield.

Experimental

Melting points are uncorrected. Unless otherwise stated, NMR data (60 MHz) are for deuterochloroform solutions with tetramethylsilane as internal standard. I.R. spectra are of chloroform or dichloromethane solutions unless stated to the contrary. Specific rotations were measured using chloroform solutions (C=1). Esters 14, 15, and 16 were prepared according to the published procedure[14] and used without further purification.

General Method for the Preparation of Thiohydroxamate Esters 7

To a solution of 3-hydroxy-4-methylthiazole-2(3H)-thione[14] (1 mmole) in dichloromethane (10 ml) and dry pyridine (1.2 mmoles) was added the corresponding acid chloride (RCOCl, 1 mmole). The mixture was stirred for 1 hour at room temperature under an inert atmosphere. The solvent was removed under reduced pressure and the residue purified by flash chromatography on a short silica colum using pentane-dichloromethane-mixtures followed by crystallisation.[15] These derivatives are best kept away from light. Compound 7a has been described elsewhere.

3-(3,3-Diphenylpropionoxy-)-4-methylthiazole-2(3H)-thione 7b

This compound was obtained in 73% yield as white crystals. It had a m.p. of 112-114°C (pentane-dichloromethane); ν_{max} 1800 cm^{-1}; δ_H: 7.44 (10H, bs), 6.17 (1H, q, J=1 Hz), 4.72 (1H, t, J=7 Hz), 3.50 (2H, d, J=7 Hz), 1.60 (3H, d, J=1 Hz); m/z: 355 (M^+), 311 (M^+, $-CO_2$); (Found: C, 64.13; H, 4.98; N, 3.72; S, 17.79. Calc. for $C_{19}H_{17}NO_2S_2$: C, 64.20; H, 4.82; N, 3.94; S, 18.04).

3-Cyclohexylcarboxy-4-methylthiazole-2(3H)-thione 7c

This compound was obtained in 90% yield as white crystals. It had a m.p. of 99-101°C (pentane-dichloromethane); ν_{max}: 1800 cm^{-1}; δ_H: 6.28 (1H, q, J=1 Hz), 2.78 (1H, m), 2.17 (3H, d, J=1 Hz); m/z: 257 (M^+), 131. (Found: C, 51.32; H, 5.90; N, 5.41; S, 24.69; Calc. for $C_{11}H_{15}NO_2S_2$: C, 51.33; H, 5.87; N, 5.44; S, 24.92).

3-Dibenzylacetoxy-4-methylthiazole-2(3H)-thione 7d

This compound was obtained in 90% yield as white crystals. It had a m.p. of 126-128°C (pentane-dichloromethane); ν_{max} 1805, 1600 cm^{-1}; δ_H: 7.30 (6H, bs), 7.20 (4H, bs); 6.00 (1H, q, J=1 Hz), 2.60-3.70 (5H, broad), 1.42 (3H, d, J=1 Hz); m/z: 369 (M^+), 325. (Found: C, 65.22; H, 5.13; N, 3.88; S, 17.29; Calc. for $C_{20}H_{19}NO_2S_2$: C, 65.01; H, 5.18; N, 3.79; S, 17.35).

3-(Adamantane-1-carboxy)-4-methylthiazole-2(3H)-thione 7e

This compound was obtained in 87% yield as white crystals. It had a m.p. of 121-122°C (pentane-dichloromethane), ν_{max}: 1790 cm^{-1}; δ_H: 6.36 (1H, q, J=1 Hz), 2.17 (10H, bs), 1.80 (6H, bs); m/z: 309 (M^+), 135. (Found: C, 58.24; H, 6.13; N, 4.39; S, 20.77; Calc. for $C_{15}H_{19}NO_2S_2$: C, 58.22; H, 6.19; N, 4.53; S, 20.72).

3-Triphenylacetoxy-4-methylthiazole-2(3H)-thione 7f

This compound was obtained in 93% yield as white crystals. It had a m.p. of 136°C (pentane-dichloromethane); ν_{max}: 1800 cm^{-1}; δ_H: 7.60 (6H, m), 7.28 (9H, m), 5.95 (1H, q, J=1 Hz), 1.29 (3H, d, J=1 Hz); m/z: 417 (M^+). (Found: C, 68.78; H, 4.61; N, 3.39; S, 15.37; Calc. for $C_{24}H_{19}NO_2S_2$: C, 69.04; H, 4.59; N, 3.36; S, 15.36).

3-Diphenylacetoxy-4-methylthiazole-2(3H)-thione 7g

This compound was obtained in 70% yield as white crystals. It had a m.p. of 97-98°C (pentane-dichloromethane); ν_{max}: 1800 cm^{-1}; δ_H: 7.32 (10H, bs), 6.05 (1H, q, J=1 Hz), 5.33 (1H, s), 1.78 (3H, d, J=1 Hz); m/z: 341 (M^+). (Found: C, 63,21; H, 4.23; N, 4.00; S, 18.57; Calc. for $C_{18}H_{15}NO_2S_2$: C, 63.32; H, 4.43; N, 4.10; S, 18.78).

3-(3α-Acetoxy-12-oxo-5β-cholanoxy-)-4-methylthiazole-2(3H)-thione 7h

This compound was obtained in 71% yield as white crystals. It had a m.p. of 145-147°C (pentane-dichloromethane); $[\alpha]_D$ = +85°; ν_{max}: 1820, 1780, 1700 cm^{-1}; δ_H: 6.28 (1H, q, J=1 Hz), 4.69 (1H, m), 2.17 (3H, d, J=1 Hz), 2.02 (3H, s), 1.04 and 1.05 (6H, two s); m/z: 517 ($M^+ - CO_2$). (Found: C, 64.42; H, 7.94; N, 2.58; S, 10.68; Calc. for $C_{30}H_{43}NO_5S_2$: C, 64.14; H, 7.71; N, 2.49; S, 11.41).

3-(3β-Acetoxy-11-oxo-(22,23-bis-Nor-]-cholanoxy-)-4-methylthiazolo-2(3H)-thione 7i

This compound was obtained in 28% yield as white crystals. It had a m.p. of 169-172; $[\alpha]_D$ = +43°; ν_{max}: 1815, 1720, 1700 cm^{-1}; δ_H: 6.29 (1H, q, J=1 Hz), 4.70 (1H, m), 2.16 (1H, d, J=1 Hz), 2.02 (3H, s), 1.04 (3H, s), 0.71 (3H, s); m/z: 489 (M^+, $-CO_2$). (Found: C, 62.43; H, 7.23; Calc. for $C_{28}H_{39}NO_5S_2$: C, 63.01; H, 7.36).

3-(1,4a-dimethyl-7-(1-methylethyl)-1,2,3,4,4a,9,10,10a-octahydrophenanthrene-1α-carboxy-)-4-methylthiazole-2(3H)-thione 7j

This compound was obtained in 90% yield as white crystals. It had a m.p. 126-128°C (dichlromethane-pentane); ν_{max}: 1800 cm^{-1}; δ_H: 6.96-7.23 (3H, m), 6.28 (1H, q, 1 Hz), 2.13 (3H, d, J=1 Hz), 1.54 (3H, s), 1.28 (3H, s), 1.23 (6H, d, J=6 Hz); m/z: 385 ($M^+ - CO_2$). (Found: C, 67.36; H, 7.54; N, 3.46; S, 14.63; Calc. for $C_{24}H_{31}NO_2S_2$: C, 67.09; H, 7.27; N, 3.26; S, 14.93).

General Procedure for the Preparation of nor-alcohols 8

A solution of the esters 7a-j, 14, 16 (1 mmole) and antimony trisphenylsulphide (2 mmole) in 50 ml of the appropriate solvent was stirred for a few hours at room temperature. The white solid was filtered and the solution evaporated to dryness. Purification of the residue by flash chromatography using dichloromethane-ethyl acetate mixtures afforded the desired nor-alcohols. The choice of solvent, the reaction time and the yields are indicated in Table 1. Known alcohols and in particular, both isomers of alcohols 8j (4α- and 4β-)[16] and 8k (17α and 17β) were characterised by comparison with literature data.

3α-Acetoxy-23-hydroxy-12-oxo-24 nor-5β-cholane 8h

This compound was recrystallised from hexane. It had a m.p. of 161-162°C; ν_{max}: 3450, 1720, 1700 cm^{-1}; δ_H: 4.71 (1H, m), 3.72 (2H, m), 2.07 (3H, s), 1.06 (3H, s), 0.92 (3H, s); m/z: 387 (M^+). (Found: C, 74.23; H, 9.72; Calc. for $C_{25}H_{40}O_4$: C, 74.21; H, 9.97).

3β-Acetoxy-20-hydroxy-5α-pregnan-11-one 8i

This compound was obtained as a 65:35 mixture of isomers (20-R and 20-S). No attempt was made to separate them or to assign their absolute configuration. The mixture can be crystallised from hexane. Some of the crystals melted at 123-128°C and the other at 144-146°C; ν_{max}: 3450, 1730, 1710 cm^{-1}; δ_H (major isomer): 4.66 (1H, m), 3.68 (1H, m), 2.01 (3H, s), 1.15 (3H, d), 1.04 (3H, s), 0.69 (3H, s); δ_H (minor isomer): 4.66 (1H, m), 3.68 (1H, m), 2.01 (3H, s), 1.20 (3H, d), 1.04 (3H, s), 0.62 (3H, s); m/z: 376 (M^+). (Found: C, 73.18; H, 9.51; Calc. for $C_{23}H_{36}O_4$: C, 73.27; H, 9.64).

Preparation of 2,2-diphenylethyl-bis(phenylthio)bismuth 3d (R = 2,2-diphenylethyl)

A degassed solution of ester 7b (153 mg, 0.43 mmole) and 2d (463 mg, 0.86 mmole) in dry chlorobenzene (20 ml) was heated to 110°C under an inert atmosphere for 2 hours. The solvent was then removed in vacuo, and the residue purified by flash chromatography on silica first eluting with pentane/dichloromethane (4:1) to remove the diphenyldisulphide, then with pentane/dichloromethane (1:9) to give a yellow crystalline solid (210 mg, 80%). This compound did not give a clean m.p.; δ_H: 7.22 (20H, bs), 4.87 (1H, t, J=7 Hz), 2.91 (2H, d, J=7 Hz); m/z: 608 (M^+). (Found: C, 52.93; H, 3.88; Calc. for $C_{26}H_{23}BiS_2$: C, 51.31; H, 3.81).

REFERENCES

1. B. Giese, "Radicals in Organic Synthesis : Formation of Carbon-Carbon Bonds", Pergamon Press, Oxford, 1986; M. Ramaiah, Tetrahedron, 1987, 43, 3541; D.P. Curran, Synthesis, 1988, 417.
2. For reviews of this work, see: D.H.R. Barton and S.Z. Zard, Pure and Appl. Chem., 1986, 58, 675; idem, Janssen Chim. Acta, 1986, 4, 3; D. Crich, Aldrichimica Acta, 1987, 20, 35.
3. D.H.R. Barton, D. Bridon and S.Z. Zard, Tetrahedron Lett., 1986, 27, 4309, and references there cited.
4. D.H.R. Barton, D. Bridon and S.Z. Zard, J. Chem. Soc., Chem. Commun., 1985, 1066.
5. D.H.R. Barton, H. Dadoun and X. Lusinchi, Nouv. J. Chim., 1982, 6, 53; H.J. Bielig, G. Lutzal and A. Reidies, Chem. Ber., 1956, 89, 775; H. Gilman and H.L. Yale, J. Am. Chem. Soc., 1951, 73, 2880; L. Vanino and F. Mubgnung, Chem. Ber., 1917, 50, 21.
6. A.G. Davies and S.C.W. Hook, J. Chem. Soc. (B), 1970, 735.
7. For a review of the chemistry of organoantimony derivatives, see: J.L. Wardell in Comprehensive Organometallic Chemistry, Vol. 2, Ed., G. Wilkinson, F.G.A. Stone and E.W. Abel, Pergamon Press, 1982.
8. J. Fossey and D. Lefort, Tetrahedron, 1980, 36, 1022; D. Lefort, J. Fossey, M. Gruselle, J.-Y. Nedelec and J. Sorba, Tetrahedron, 1985, 51, 3584; D.B. Denney and N. Sherman, J. Org. Chem., 1965, 30, 3760.
9. D.H.R. Barton, D. Crich and W.B. Motherwell, J. Chem. Soc., Chem. Comm., 1984, 242.
10. See Inter alia: A.G. Davies and B.P. Roberts, J. Chem. Soc. (B), 1967, 17; 1968, 1074; 1969, 311; S.B. Mirviss, J. Org. Chem., 1967, 32, 1713.
11. B. Maillard, K.U. Ingold and J.C. Scaiano, J. Am. Chem. Soc., 1983, 105, 5095.
12. The unexpected stability of the methyl derivative (3d, R=Me) has also been noted: M. Wieber and U. Baudis, Z. Anorg. Allg. Chem., 1976, 423, 40.
13. A.T. Nielsen in "The Chemistry of the Nitro and Nitroso Groups", Ed. H. Feuer, Wiley Interscience, 1969; N. Kornblum, R.K. Blackwood and D.D. Mooberry, J. Am. Chem. Soc., 1956, 78, 1501; N. Kornblum and P.A. Wade, J. Org. Chem., 1973, 38, 1418.
14. D.H.R. Barton, D. Bridon, I. Fernandez-Picot and S.Z. Zard, Tetrahedron, 1987, 43, 2733.
15. D.H.R. Barton, D. Crich and G. Kretzschmar, J. Chem. Soc., Perkin Trans. I, 1986, 39.
16. R. Caputo, L. Previtera, P. Monaco and L. Mangoni, Tetrahedron, 1974, 30, 963; J.W. Huffman, J. Org. Chem., 1970, 35, 478; J.W. Rowe, B.A. Nagasampagi, A.W. Brugstahler and J. Fitzsimmons, Phytochem., 1971, 10, 1647.
17. T. Komeno, Chem. Pharm. Bull., 1960, 8, 680; R. Norman Jones, V.Z. Williams, M.J. Wahlen and K. Dobriner, J. Am. Chem. Soc., 1948, 70, 2024; R. Norman Jones and G. Roberts, ibid, 1958, 80, 6121.