Conversion of Thiocarbonyl Compounds into their Corresponding Oxo-derivatives using Benzeneseleninic Anhydride

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A series of thiocarbonyl compounds including xanthates, thioesters, thioureas, thiocarbonates, and thiones have been converted into their oxo-analogues by treatment with benzeneseleninic anhydride in tetrahydrofuran at room temperature. Except for readily enolised thiones where further oxidation can take place, the method works well and compares favourably with other literature procedures. One example of a selenocarbonyl ester was likewise converted efficiently into the corresponding ester.

THE transformation of a thiocarbonyl group into its corresponding oxo-derivative can be achieved by a variety of methods. For example nitric acid,[1] mercuric acetate,[2] selenium dioxide,[3] potassium permanganate,[4] manganese dioxide,[5] alkyl nitrites,[6] mesitylenenitrile oxide,[7] I_2–DMSO,[8] dimethyl selenoxide,[9] diaryl selenoxides,[10] and diaryl telluroxides [11] have all been used with some degree of success.

Here we report full details of the use of benzeneseleninic anhydride,[12] $[PhSe(O)_2]O$, as a viable new method for effecting this transformation. A number of different thiocarbonyl derivatives have been studied so that the effectiveness of the anhydride could be properly tested: these were xanthates, thio-esters, thioureas, thiocarbonates, and thiones.

RESULTS AND DISCUSSION

Generally high yields of the corresponding oxo-species were formed by reaction with 1 mol equiv. of the anhydride at room temperature in THF over a relatively short period of time (Table). The major by-product of the reaction was diphenyl diselenide which was readily isolated and reoxidised to the anhydride.[13]

In several reactions we have compared the use of SeO_2 as an alternative oxidant. However, only mixtures of products or very long reaction times were, in general, observed. The best of these reactions gave a 97% yield of benzoate after treatment of 5α-cholestan-3β-selenobenzoate (1c) with SeO_2 for 3 d, although the yields were usually very much lower.

A limitation of the anhydride as a reagent for the conversion of the thiocarbonyl group into the oxo-derivative appears to be with thiones which can undergo facile enolisation. Thus thiocamphor (17) only gave a 9% yield of camphor, the major products being 3-*endo*-phenylseleninylcamphor (18) (36%) and camphor quinone (19) (54%). Not surprisingly, compound (18) was unstable and on standing was converted into camphor quinone (19). In a separate experiment 2-phenylselenocamphor was oxidised with *m*-chloroperbenzoic acid to give (18), which again was rapidly transformed to (19) at room temperature. Despite the above limitation, benzeneseleninic anhydride has been shown to be a mild reagent for the conversion of the thiocarbonyl group into the oxo-derivative in yields comparable to, and in some cases better than, the existing literature methods. The rapid conversion of the highly hindered thiofenchone into fenchone is noteworthy.

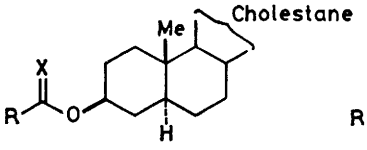
If the reactions were followed by iodometric titration it was found that all the oxidising capacity of the anhydride was consumed. Also, on displacement of the atmosphere above a typical reaction mixture with dry nitrogen, analysis of the effluent gases revealed that a volatile acidic by-product (not found in control mixtures) was produced. When the effluent gases were passed into water and the change in pH followed by a digital pH-meter a gradual change was observed which mirrored the loss of oxidising power of the anhydride. The effluent gases also darkened nickel hydroxide impregnated test paper,[14] which is consistent with the hypothesis that the sulphur moiety departs as sulphur dioxide.

When the reactions were followed spectroscopically under anhydrous and oxygen-free conditions the form-

Reaction of thiocarbonyl derivatives [a] with benzeneseleninic anhydride PhSe(O)–O–Se(O)Ph

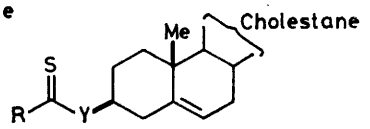
Compound	Reaction time/h	Yield of oxo-derivative (%) [b]
(1a)	12	67
(1b)	3.5	69
(1c)	0.6	83
(2a)	4	59
(2b)	24	73
(2c)	24	50
(2d)	4	35
(3)	2	71
(4)	1 [c]	63
(5)	24	64
(6)	2	75
(7)	5	92
(8)	6	76
(9)	6	54
(10a)	2.5	47
(10b)	2	88
(11)	4	70 [d]
(12a)	3	69
(12b)	5	39
(13)	1	58
(14)	3	84
(15)	5	64
(16)	2	89 [e]

[a] Reactions were performed using 1 equiv. BSA in THF at room temperature, unless otherwise stated. [b] Recrystallized yields of products isolated by preparative layer chromatography. [c] Previously 5 h at room temperature gave no reaction; heated to reflux for 1 h. [d] Isolated by precipitation and recrystallisation. [e] Estimated by g.l.c.



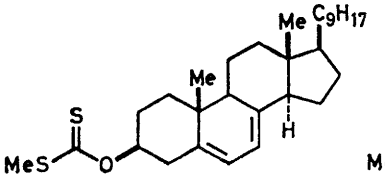
(1)

a; R = SMe, X = S
b; R = Ph, X = S
c; R = Ph, X = Se

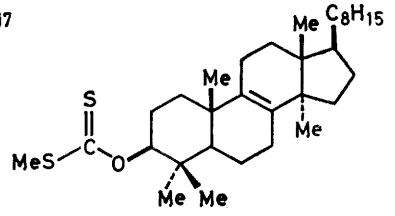


(2)

a; R = Me, Y = O
b; R = Ph, Y = O
c; R = Ph, Y = S
d; R = H, Y = O



(3)



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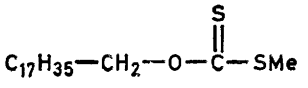

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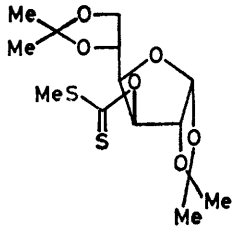

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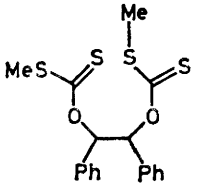

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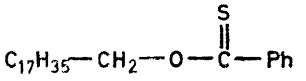
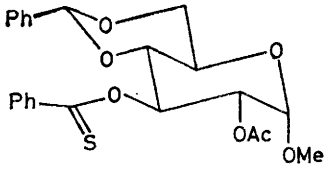


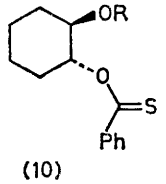
(8)

ation of the carbonyl group could be monitored, thus indicating that the oxygen atom in the product is derived from the reagent and not from external water as in all hydrolytic methods.

From the above evidence a mechanism as outlined in the Scheme seems reasonable to account for the formation of both SO_2 and the oxo-derivative. No carbon radicals could be detected by e.s.r. spectroscopy but, of

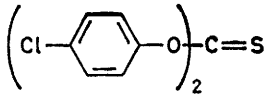


(9)



(10)

a; R = H S
b; R = PhC



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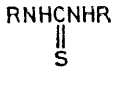
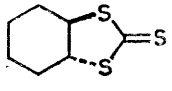
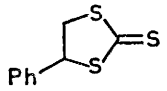


(12)

a; R = H
b; R = Ph



(13)

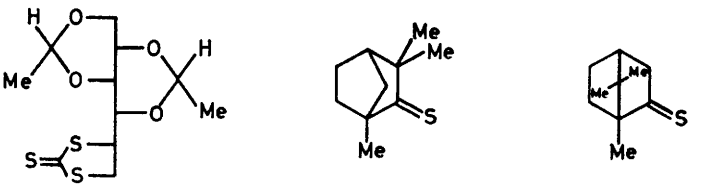


(14)

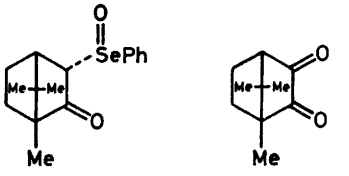
course, the final intermediate could be collapsing into sulphur dioxide and phenylselenyl radicals which would dimerise. The latter radicals would not be detectable by ordinary e.s.r. methods. Other mechanisms similar to those proposed by Mikołajczyk [9] could also be operating.

EXPERIMENTAL

M.p.s were determined with a Kofler hot stage apparatus. ^{1}H N.m.r. spectra were obtained for solutions in $CDCl_3$ ($SiMe_4$ as internal standard) at 60 MHz. Thin layer and preparative layer chromatography were carried out on silica gel (Merck GF_{254} Type 60). Light petroleum refers to the fraction of b.p. 40—60 °C. Solutions were dried over magnesium sulphate, and solvents by standard techniques. Benzeneseleninic anhydride (BSA) was prepared by the literature method.[13]



(15) (16) (17)



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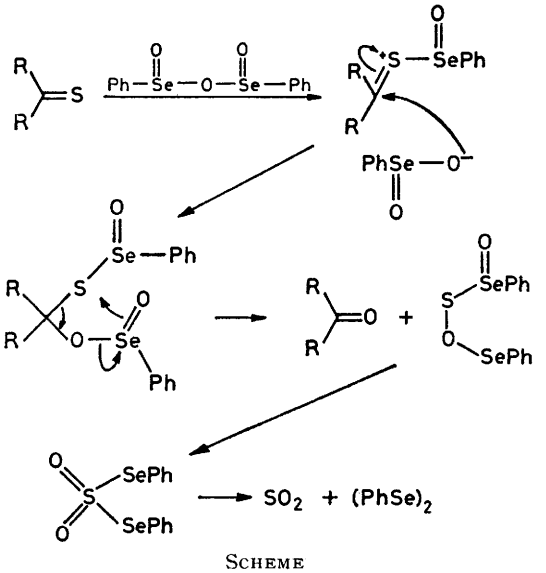

SCHEME

General Procedure for Conversion of Thiocarbonyls into Oxo-derivatives.—All reactions were performed at room temperature (R.T.) under dry N_2 in dry tetrahydrofuran (THF), freshly distilled from calcium hydride, using 3—10 ml of solvent for 50—300 mg of the thiocarbonyl substrate; approximately 1 mol equiv. of BSA was used. Reaction mixtures were concentrated by partial evaporation of the ether and (except where stated) subjected to p.l.c. (silica) prior to the isolation of the products; no aqueous work-up was usually necessary. The product yields (all of re-crystallised material), spectroscopic, and other properties were as follows.

Compound (1a) (302.5 mg, 0.633 mmol) and BSA (260 mg, 0.722 mmol) gave O-5α-*cholestan*-3β-*yl* S-*methyl thiocarbonate* (195 mg, 67%), m.p. (light petroleum) 117 °C; $\nu_{max.}$ ($CDCl_3$) 2 800, 2 760, 1 700 (br d), 1 442, 1 422, 1 245, 1 160 (br d), 1 000, and 840 cm^{-1}; δ($CDCl_3$) 2.28 (3 H, s); *m/e* 462 (M^+) 447, 418, 384, 371, 355, and 215; *m** 433 (calc. for 462→447: *m**, 432.5) (Found: C, 75.35; H, 11.0; S, 6.95. $C_{29}H_{50}SO_2$ requires C, 75.3; H, 10.9; S, 6.9%).

Compound (3) (161.3 mg, 0.332 mmol) and BSA (132.2 mg, 0.367 mmol) gave O-*ergosta*-5,7-*dien*-3β-*yl* S-*methyl thiocarbonate* (110.8 mg, 71%), m.p. (light petroleum) 125 °C; $\nu_{max.}$ ($CDCl_3$) 1 700 cm^{-1}; δ($CDCl_3$) 2.32 (3 H, s), *m/e* 470 (M^+), 468, 426, 424, 378, 376, 363, 337, 253, and 251 (Found: C, 76.4; H, 9.85; S, 6.95. $C_{30}H_{46}SO_2$ requires C, 76.55; H, 9.85; S, 6.8%).

Compound (4) (215.3 mg, 0.417 mmol) and BSA (168.7 mg, 0.469 mmol) refluxed in THF gave *O*-lanost-8-en-3β-yl *S*-methyl thiocarbonate (131.2 mg, 63%).

Compound (5) (218.1 mg, 0.606 mmol) and BSA (241 mg, 0.669 mmol) gave *O*-n-octadecyl *S*-methyl thiocarbonate (133.4 mg, 64%).

Compound (6) (301.9 mg, 0.86 mmol) and BSA (311 mg, 0.86 mmol) gave 3-O-[(*methylthio*)*thiocarbonyl*]-1,2,5,6-*di*-O-*isopropylidene*-α-D-*glucofuranose* (216 mg, 75%), m.p. (light petroleum–benzene) 54—56 °C; $\nu_{max.}$ (CCl_4) 2 900, 1 720, 1 380, 1 375, 1 208, 1 120, 1 080, and 1 030 cm^{-1}; δ(CCl_4) 5.75 (1 H, d, *J* 4 Hz), 5.25 (1 H, d, *J* 2 Hz), 4.43 (1 H, d, *J* 4 Hz), 3.98 (4 H, m, contains d with *J* 2 Hz), 2.33 (3 H, s), 1.47 (3 H, s), 1.37 (3 H, s), and 1.27 (6 H, s); *m/e* 334 (M^+), 319, 279, 261, 233, 201, 175, 127, 113, 101, 75, 59, and 43, *m** 213.5 (calc. for 319→261: *m**, 213.5).

Compound (7) (186.2 mg, 0.427 mmol) and BSA (343 mg, 0.952 mmol) gave 5,6-*diphenyl*-4,7-*dioxa*-2,9-*dithiadecane*-3,8-*dithione* (159 mg, 92%); δ($CDCl_3$) 7.6—7.1 (10 H, Ar), 6.12 (2 H, d), and 2.25 (6 H, s); *m/e* 270 $M^+ - 92$ (*i.e.* $MeSCO_2H$), 227, 181 (M^{2+}), and 153.

Compound (8) (252.3 mg, 0.647 mmol) and BSA (234.2 mg, 0.65 mmol) gave n-octadecyl benzoate (183 mg, 76%), m.p. 42 °C (EtOAc).

Compound (2d) (207.5 mg, 0.483 mmol) and BSA (175.9 mg, 0.489 mmol) afforded cholest-5-en-3β-yl formate (70 mg, 35%), m.p. 93—95 °C (lit.,[15] 96 °C).

Compound (2a) (185.6 mg, 0.418 mmol) and BSA (161 mg, 0.447 mmol) afforded cholest-5-en-3β-yl acetate (105 mg, 59%), m.p. 110—112 °C (lit.,[15] 114—115 °C).

Compound (2b) (224.9 mg, 0.444 mmol) and BSA (176 mg, 0.489 mmol) afforded cholest-5-en-3β-yl benzoate (157.3 mg, 73%), m.p. 148 °C (lit.,[15] 150—151 °C); $\nu_{max.}$ (CCl_4) 1 722, 1 600, and 1 270 cm^{-1}.

Compound (2c) (203.7 mg, 0.39 mmol) and BSA (141.2 mg, 0.39 mmol) gave *S-cholest-5-en-3β-yl thiobenzoate* (99 mg, 50%), m.p. 167 °C; $\nu_{max.}$ (CCl_4) 2 800, 2 750, 1 670, 1 550, 1 250, 1 210, 1 180, 920, 865, 810—740 (br d), and 700 cm^{-1}; *m/e* 506 (M^+), 504, 401, 369, and 353, *m** 339 (calc. for 401→369: *m**, 339.5) (Found: C, 80.6; H, 10.05; S, 6.35. $C_{34}H_{50}SO$ requires C, 80.6; H, 9.95; S, 6.3%).

Compound (1b) (228.5 mg, 0.45 mmol) and BSA (165.1 mg, 0.46 mmol) gave 5α-cholestan-3β-yl benzoate (152.3 mg, 69%), m.p. 136—137 °C (lit.,[15] 136—137 °C).

Compound (1c) (205 mg, 0.369 mmol) and BSA (133 mg, 0.369 mmol) gave 5α-cholestan-3β-yl benzoate (150 mg, 83%), m.p. 137 °C (lit.,[15] 136—137 °C).

Comparison reaction of (1c) *with selenium dioxide.* Compound (1c) (182 mg, 0.328 mmol) and SeO_2 (74.8 mg, 0.674 mmol) were left at room temperature for 3 d; the red solution became colourless. A deposit of red selenium was filtered off, and after evaporation of the filtrate and recrystallisation of the residue (EtOAc), 5α-cholestan-3β-yl benzoate (145.9 mg, 97%) was obtained, m.p. 136—137 °C.

Compound (9) (252.4 mg, 0.568 mmol) and BSA (205 mg, 0.569 mmol) gave 2-O-*acetyl*-3-O-*benzoyl*-4,6-*benzylidene*-1α-O-*methylglucopyranose* (130 mg, 54%), m.p. 144—145 °C; $\nu_{max.}$ (Nujol) 1 745, 1 720, and 1 600 cm^{-1}; *m/e* 428 (M^+), 427, 397, 351, 306, 279, 246, 219, 149, and 105 (Found: C, 64.45; H, 5.6. $C_{23}H_{24}O_8$ requires C, 64.5; H, 5.6%).

Compound (10a) (222.6 mg, 0.94 mmol) and BSA (342 mg, 0.95 mmol) gave 1-*O*-benzoylcyclohexane-*trans*-1,2-diol (97.5 mg, 47%), m.p. 91—92 °C (lit.,[16] 92—93 °C); $\nu_{max.}$ (CCl_4) 3 450 and 1 710 cm^{-1}; *m/e* 221 ($M^+ + 1$).

Compound (10b) (208.4 mg, 0.585 mmol) and BSA (426.8 mg, 1.186 mmol) gave 1,2-di-*O*-benzoylcyclohexane-*trans*-1,2-diol (166.4 mg, 88%), m.p. 94—95 °C (lit.,[16] 94.5 °C); $\nu_{max.}$ (CCl_4) 1 715 cm^{-1}.

Compound (11) (299 mg, 1 mmol) and BSA (360.8 mg, 1 mmol) gave a polar product which was isolated by treatment of the concentrated red solution with light petroleum, to remove Ph_2Se_2, and after filtration and recrystallisation of the residue (benzene–light petroleum) gave bis-(*p*-chlorophenyl) carbonate (195.7 mg, 70%), m.p. 154 °C; $\nu_{max.}$ (CCl_4) 1 780 and 1 485 cm^{-1}; *m/e* 284, 282 (M^+, 240, 238, 176, 174, 113 and 111.

Compound (12a) (221.7 mg, 2.92 mmol) and BSA (1.052 g, 2.92 mmol); after filtration the residue was dissolved in water, treated with aqueous $Na_2S_2O_5$, partitioned with Et_2O to remove Ph_2Se_2, and the aqueous layer evaporated at R.T. under reduced pressure. Recrystallisation (EtOH) gave urea (120.7 mg, 69%); $\nu_{max.}$ (Nujol) 1 660 (br d) cm^{-1}.

Compound (12b) (297.1 mg, 1.303 mmol) and BSA (470.7 mg, 1.308 mmol), work-up as above, afforded *NN'*-diphenylurea (106.5 mg, 39%).

Compound (13) (220 mg, 1.158 mmol) BSA (417 mg, 1.158 mmol) gave *SS'*-cyclohexane-*trans*-diyl dithiocarbonate (117.3 mg, 58%), m.p. 109—110 °C (lit.,[17] 109—110 °C); $\nu_{max.}$ ($CHCl_3$) 1 730 and 1 640 cm^{-1} (br d, C–S overtone); *m/e* 174 (M^+), 146, 114, 99, 81, and 80; and a more polar phenylseleno-derivative (by n.m.r.) (52 mg, 14%); $\nu_{max.}$ ($CHCl_3$) 1 710—1 730 (br d) cm^{-1}.

Compound (14) (157.8 mg, 0.74 mmol) and BSA (268 mg, 0.74 mmol) afforded *SS'*-phenylethane-1,2-diyl dithiocarbonate (145.9 mg, 84%); δ(CCl_4) 7.33 (5 H, m), 5.13 (1 H, t, *J* 8 Hz), and 3.63 (2 H, d, *J* 8 Hz), *cf.* starting material, δ 7.42 (5 H, m), 5.57 (1 H, dd, *J* 7 and 8.8 Hz), and 4.05 (2 H, overlapping dd, *J* 7 and 8.8 Hz).

Compound (15) (84.7 mg, 0.275 mmol) and BSA (102.1 mg, 0.284 mmol, 1.03 equiv.) gave 1,3:2,4-di-*O*-ethylidene-5,6-*SS'*-carbonyl-5,6-dithio-L-mannitol (51 mg, 64%), m.p. 148—150 °C; *m/e* 292 (M^+), 291, 277, 258, 232, 199, 176, 173, 129, 87, 85, and 83.

Thiofenchone (16) (100.8 mg, 0.6 mmol) and BSA (216 mg, 0.6 mmol, 1 equiv.) gave (g.l.c.; column: fluorosilicone oil on Chromosorb W) thiofenchone (retention time 5.9 min), and fenchone (5.2 min) (89%) [internal standard naphthalene (6.5 min)].

Thiocamphor (17) (193.6 mg, 1.15 mmol) and BSA (415 mg, 1.15 mmol, 1 equiv.) for 3 h gave camphor (9%); 3-*endo*-(phenylseleninyl)camphor (18) (36%); δ($CDCl_3$) 7.75—7.22 (5 H, m), 6.38 (1 H, d, *J* 4 Hz), 2.4 (1 H, t, *J* 4 Hz), 2.1—1.4 (4 H, m), 1.23 (3 H, s), and 0.78 (6 H, s); and camphor quinone (19) (54%); $\nu_{max.}$ (CCl_4) 1 780 and 1 760 cm^{-1}; δ(CCl_4) 2.5—1.2 (5 H, m), 1.03 (6 H, s), and 0.9 (3 H, s); m.p. (sealed tube) 196—197 °C (lit.,[18] 199 °C); *m/e* 166 (M^+), 138, 123, 110, 95, 83, 69, 55 and 41, *m** 115, 109.5, and 87.5 (calc. for 166→138: *m**, 114.7; calc. for 138→123: *m**, 109.6; calc. for 138→110: *m**, 87.7).

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