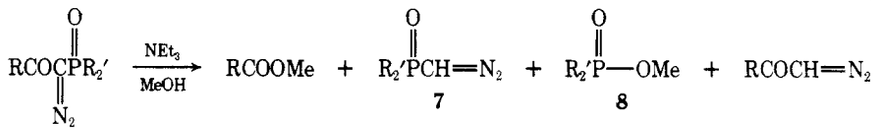

6a, R = Ph; R′ = OEt	80%	78%	<1%	
b, R = Me; R′ = OEt		90%		
c, R = R′ = Ph	88%	86%	12%	10%

identified as tosyl amide by comparison of its IR and NMR spectra with those of an authentic sample.

Ethyl Phosphinate (3b). Using ethanol as solvent in the above procedure gave a 78% yield of **3b:** IR ($CHCl_3$) ν 2140 (C=N_2), 1640 (C=O), 1193 (P=O), and 1035 cm^{-1} (POC); NMR ($CDCl_3$) δ 1.28 (t, J = 7.0 Hz, 3 H, CH_2CH_3), 2.16–2.82 (m, 4 H, $-CH_2-$), 3.86 (d, J_{PH} = 7.0 Hz, of q, J_{HH} = 7.0 Hz, 2 H, $POCH_2CH_3$), 5.24 (s, 1 H, CH=N_2), and 7.26–7.80 (m. 5 H, C_6H_5); mass spectrum *m/e* 238 ($M^+ - 28$), 210, 182.

Attempt to Isolate 2-Diazo-3-phospholanone Oxide (2). To a solution of 194 mg (1.0 mmol) of phospholanone oxide (1) and 140 mg of triethylamine in 2.0 ml of dry acetonitrile was added 198 mg (1.0 mmol) of tosyl azide and the mixture was kept overnight at room temperature. TLC analysis of the reaction mixture showed that no tosyl azide was present at the end of this time.

To one-half of the solution was added 1.0 ml of dry methanol and the resulting solution was allowed to stir overnight. The solvent was removed under reduced pressure and the residue was chromatographed in the usual way. The foreband gave acyclic diazophosphinate (**3a**) (28 mg, 23%); further elution with chloroform afforded tosyl amide (66 mg, 77%).

The second half of the reaction mixture was evaporated under reduced pressure, followed by chromatography. Only tosyl amide (70 mg, 82%) was eluted from the column. The yellow material adsorbed on the alumina at the top of the column was extracted with 10% triethylamine in methanol and the extract was evaporated to dryness under vacuum to give **5** as a sticky yellow oil, which failed to crystallize upon standing: IR ($CHCl_3$) ν 2400, 2250 (N^+H), 2140 (C=N_2), 1640 (C=O), 1190 cm^{-1} (P=O); NMR ($CDCl_3$) δ 1.10 (t, J = 8 Hz, 9 H, CH_2CH_3), 1.75–2.68 (m, 4 H, $-CH_2-$), 2.95 (q, J = 8 Hz, 6 H, CH_2CH_3), 3.41 (s, 1 H, ^+NH), 5.33 (s, 1 H, CH=N_2), and 7.20–7.95 (m, 5 H, C_6H_5).

Photolysis of 3 in Methanol. A solution of 56 mg of **3a** in 1 ml of methanol was placed in a quartz tube and irradiated for 5 h at 12 °C with a 300-W medium-pressure mercury lamp. After removal of solvent under vacuum, the residue was chromatographed on alumina using chloroform to afford 26.7 mg (80%) of methyl carboxylate **4a** as a colorless liquid: ir ($CHCl_3$) ν 1730 (C=O), 1179 (P=O), and 1040 cm^{-1} (POC); NMR ($CDCl_3$) δ 1.65–2.57 (m, 6 H, $-CH_2-$), 3.63 (d, J = 11.3 Hz, 3 H, POMe), 3.65 (s, 3 H, COOMe), and 7.38–8.18 (m, 5 H, C_6H_5); mass spectrum *m/e* 256 (M^+), 225, 197.

Anal. Calcd for $C_{12}H_{17}O_4P$: C, 56.25; H, 6.69; P, 12.09. Found: C, 56.12; H, 6.70; P, 11.96.

Using **3b** in the above procedure gave **4b** in 63% yield: IR ($CHCl_3$) ν 1730 (C=O), 1190 (P=O), and 1036 cm^{-1} (POC); NMR ($CDCl_3$) δ 1.30 (t, J = 6.6 Hz, 3 H, $POCH_2CH_3$), 1.71–2.55 (m, 6 H, $-CH_2-$), 3.46 (s, 3 H, OMe), 4.02 (d, J_{PH} = 6.6 Hz, of q, J_{HH} = 6.6 Hz, 2 H, $POCH_2CH_3$), and 7.37–7.95 (m, 5 H, C_6H_5); mass spectrum *m/e* 270 (M^+), 239, 211.

Anal. Calcd for $C_{13}H_{19}O_4P$: C, 57.77; H, 7.09; P, 11.46. Found: C, 57.60; H, 7.13; P, 11.10.

Diethyl Diazomethylphosphonate (7). A. From Benzoyl Derivative (6a). To a solution of 84 mg (0.3 mmol) of diethyl α-diazophenacylphosphonate (**6a**) in 0.5 ml of dry methanol was added 33 mg (0.32 mmol) of triethylamine in 0.5 ml of methanol at room temperature. The solution was stirred vigorously overnight at the same temperature. GC analysis of the reaction mixture at the end of this time indicated the presence of methyl benzoate and a trace amount of methyl diethyl phosphate. Volatile components were removed from the resulting red solution under reduced pressure at 20 °C and the residue was chromatographed on alumina.

The first fraction was methyl benzoate (33 mg, 80%), identified by IR and NMR comparison with an authentic sample.

The second fraction was diazomethylphosphonate (**7a,** 42 mg, 78%), yellow liquid: IR ($CHCl_3$) ν 2142 (C=N_2), 1250 (P=O), and 1024 cm^{-1} (POC); NMR ($CDCl_3$) δ 1.37 (t, J = 7.2 Hz, 6 H, $POCH_2CH_3$), 3.68 (d, J = 10.8 Hz, 1 H, CH=N_2), and 4.08 (d, J_{PH} = 7.2 Hz, of q, J_{HH} = 7.2 Hz, 4 H, $POCH_2$).

B. From Acetyl Derivative (6b). To a solution of 137 mg (0.62 mmol) of **6b** in 1.0 ml of methanol was added 80 mg of triethylamine. After stirring overnight at room temperature, all volatile components were rigorously evaporated under reduced pressure at 30 °C to give yellow liquid (101 mg, 90%), which showed essentially identical NMR and IR spectra with those of **7** obtained above.

Diphenyldiazomethylphosphine Oxide (7c). Treatment of a suspension of 208 mg (0.6 mmol) of **6c** in 1.0 ml of methanol with 80 mg (0.8 mmol) of triethylamine as above resulted in a clear solution. Chromatography of the reaction mixture as usual manner gave the following products in their order of separation. Methyl benzoate (71.8 mg, 88%); benzoyldiazomethane [8.9 mg, 10%; IR ($CHCl_3$) ν 2125 (C=N_2) and 1612 cm^{-1} (C=O); NMR ($CDCl_3$) δ 5.92 (s, 1 H, CH=N_2) and 7.35–7.84 (m, 5 H, C_6H_5)]; **8c** [17.4 mg, 12%; NMR ($CDCl_3$) 3.67 (d, J_{PH} = 12.0 Hz, 3 H, POMe) and 7.28–7.92 (m, 5 H, C_6H_5)]; **7c** [124.5 mg, 86%; IR ($CHCl_3$) ν 2120 (C=N_2) and 1282 cm^{-1} (P=O); NMR ($CDCl_3$) 4.20 (d, J_{PH} = 12.1 Hz, 1 H, CH=N_2) and 7.34–7.81 (m, 5 H, C_6H_5)].

Acknowledgments. The authors wish to thank Denki Kagaku Kogyo Co. for providing us with chloroprene used in the preparation of the phospholanone.

Registry No.—**1,** 60705-77-3; **3a,** 60705-78-4; **3b,** 60705-79-5; **4a,** 60705-80-8; **4b,** 60705-81-9; **5,** 60705-83-1; **6a,** 19734-16-8; **6b,** 21047-57-4; **6c,** 17507-54-9; **7a,** 25411-73-8; **7c,** 5353-66-2; **8a,** 867-17-4; **8c,** 1706-90-7; PhCOOMe, 93-58-3; PhCOCH=N_2, 3282-32-4; tosyl azide, 941-55-9; tosyl amide, 70-55-3.

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(2) (a) P. Yates and B. L. Shapiro, *J. Org. Chem.*, **23,** 759 (1958); (b) J. B. Hendrickson and W. A. Wolf, *ibid.*, **33,** 3610 (1968).
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A Simple, High Yield Method for the Nucleophilic Substitution of Halonitrobenzenes by Thiols

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Received July 12, 1976

Although the use of direct thioalkylation of halonitrobenzenes is often a convenient route to the corresponding thioanisoles,[1] the desired reaction can be almost completely precluded by reduction of the nitro group.[2] During the course of other work, we required thioanisole **2b** (R = CH_3) as an intermediate. In attempting to prepare this compound by the method of Hodgson and Handley,[1,2] we obtained **2b** (R = CH_3) in only 18% yield, the remainder consisting of the three possible azoxybenzenes **3b–d** (R = CH_3).[3]

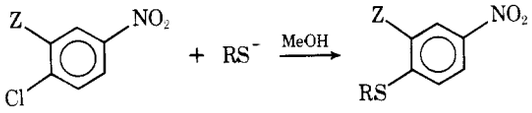
It occurred to us that this problem might be readily overcome by forming the thiolate anion in the presence of both excess thiol[4] and aromatic substrate. This was readily carried out by the dropwise addition of methanolic KOH to **1b** in the

Table I

Reactants	Solvent	Method[a]	Product(s)[b]	Registry no.	% yield[c]	Mp, °C[d]
1. **1a**[r] + CH_3SH[t]	MeOH	A	**2a** (R = methyl)	701-57-5	92[e]	67[f]
2. **1b**[s] + CH_3SH	MeOH	B	**3b**	60789-46-0		144–144.5[h]
			3c (R = methyl)	60789-47-1	81[e,g]	124.5–125[h]
			3d (R = methyl)	60789-48-2		168.5–169
			2b (R = methyl)	60789-49-3	18[e]	
3. **1b** + CH_3SH	MeOH	A	**2b** (R = methyl)		95[e]	54–54.5[h]
4. **1b** + $(CH_3)_2CHSH$[u]	MeOH	B	2-Methoxy-5-nitro-(α,α,α-trifluoro)-toluene	654-76-2	92[e]	79.5–80[i]
5. **1b** + $(CH_3)_2CHSH$	MeOH	A	**3b**		87[e]	
6. **1a** + $(CH_3)_2CHSH$	MeOH	A	**2a** (R = 2-propyl)	7205-63-2	93[e]	45.5[j]
7. **1b** + $(CH_3)_2CHSH$	DMF	B	**2b** (R = 2-propyl)	60789-50-6	34[e,l]	48[k]
8. **1b** + $(CH_3)_2CHSH$	DMF	A	**2b** (R = 2-propyl)		92[e]	
9. **1a** + $PHCH_2SH$[v]	MeOH	B	**2a** (R = benzyl)	27691-43-6	~70[m]	
			3a	614-26-6	6[e]	150.5[n]
			4-Nitroanisole	100-17-4	~23[m]	
10. **1a** + $PhCH_2SH$	MeOH	A	**2a** (R = benzyl)		98[e]	122°
11. **1b** + $PhCH_2SH$	MeOH	B	**2b** (R = benzyl)	60789-51-7	~75[m]	
			2-Methoxy-5-nitro-(α,α,α-trifluoro)-toluene		~19[m]	
12. **1b** + $PhCH_2SH$	MeOH	A	**2b** (R = benzyl)		93[e]	83.5[p]
13. **1b** + $PhCH_2SH$	DMF	B	**2b** (R = benzyl)		~35[m]	
			3b		~60[m]	
14. **1b** + $PhCH_2SH$	DMF	A	**2b** (R = benzyl)		96[e]	
15. **1b** + PhSH[w]	MeOH	B	**2b** (R = phenyl)	3833-18-9	92[e]	51.5[q]
16. **1b** + PhSH	MeOH	A	**2b** (R = phenyl)		95[e]	

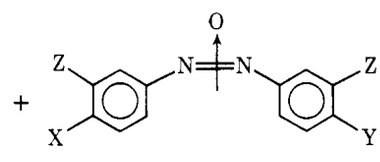
[a] A = new procedure, see Experimental Section; B = literature method, see Experimental Section. [b] Satisfactory IR, NMR, and MS data were obtained for all new compounds in table. [c] No special effort was made to optimize isolated yields. [d] Melting points were determined in capillary tubes using a Thomas-Hoover apparatus, and are corrected. [e] Isolated yield. [f] Reference 7, 66–67 °C. [g] As a mixture. [h] See Experimental Section. [i] Reference 3, 79–79.5 °C. [j] Reference 8, 44.5 °C. [k] Recrystallized from hexane. Anal. Calcd: C, 45.28; H, 3.80; N, 5.28; F, 21.49; S, 12.09. Found: C, 45.44; H, 3.51; N, 5.10; F, 21.42; S, 12.23. [l] The remaining three products (TLC, not isolated) are presumably **3b–d** (R = 2-propyl). [m] Not isolated; yields approximated by NMR. [n] Reference 1, 150–151 °C. [o] Reference 7, 120–122.5 °C; ref 8, 123 °C. [p] Recrystallized from hexane. Anal. Calcd: C, 53.67; H, 3.22; N, 4.47; F, 18.19; S, 10.23. Found: C, 53.64; H, 3.51; N, 4.33; F, 17.95; S, 10.32. [q] Recrystallized from hexane. Anal. Calcd: C, 52.17; H, 2.69; N, 4.68; F, 19.04; S, 10.71. Found: C, 51.90; H, 2.93; N, 4.69; F, 19.03; S, 10.85. [r] Registry no., 100-00-5. [s] Registry no., 777-37-7. [t] Registry no., 74-93-1. [u] Registry no., 75-33-2. [v] Registry no., 100-53-8. [w] Registry no., 108-98-5.

presence of a small stoichiometric excess of methanethiol which, indeed, afforded only the desired substitution product **2b** (R = CH_3); none of the azoxy compounds **3b–d** (R = CH_3)



1
a, Z = H
b, Z = CF_3

2
a, Z = H
b, Z = CF_3



3
a, Z = H; X = Y = Cl
b, Z = CF_3; X = Y = Cl
c, Z = CF_3; X = Cl; Y = RS
d, Z = CF_3; X = Y = RS

were present, as evidenced by TLC. A further significant improvement in this approach was made by the use of dimethylformamide (DMF)[5] instead of methanol, which virtually eliminated other side reactions.[6]

A comparison of the general efficacy of this method vs. the literature procedure was made by reacting the readily reducible substrates **1a** and **1b** with several representative thiols, and the results are summarized in Table I.

The effectiveness of DMF vs. an alcoholic solvent such as methanol is probably due both to its nonnucleophilicity as well as to the approximately 10^5-fold rate enhancement for the desired nucleophilic substitution reaction.[9] This latter point is evidenced by comparison of the reaction of sodium 2-propanethiolate under various conditions with **1a** and **1b**.[10] In methanol, even under the excess thiol conditions of this work, **1b** essentially afforded only reduction product **3b** whereas, under the same conditions, **1a** yielded mainly addition product **2a** (R = 2-propyl). Apparently, in the case of **1b**, steric hindrance caused by the combination of an ortho substituent (CF_3) and a secondary thiol (i.e., 2-propyl vs. methyl) is great enough to retard the rate of substitution relative to the redox reaction. In DMF, however, the rate of the desired substitution reaction is enhanced to the point where it now proceeds faster than the redox process.

In summary, the use of this simple modification, along with the change of solvent to DMF, should greatly increase the versatility of this often unpredictable chemical reaction.

Experimental Section

General New Procedure for Thiolation. To a cold (ca. 0 °C), stirred solution (under nitrogen) of 0.07 mol of thiol and 0.040 mol of 1 in 30 ml of DMF (or 30 ml of MeOH), 3.1 g (0.055 mol) of KOH, dissolved in a mixture of 20 ml of DMF (or 20 ml of MeOH) and 1.5 ml of H_2O, was added dropwise (ca. 40 min), maintaining the temperature at ca. 0 °C. Following addition, the mixture was heated at

80 °C for 1 h (or refluxed when MeOH was used) and poured onto 200 ml of ice–water, and the solid product(s) was filtered. It was subsequently determined that the use of 0.045 mol (1.1 equiv) of thiol gave comparable results.

General Literature[1] Thiolation Method. The thiol (0.05 mol) was added to a cold (ca. 0 °C), stirred solution of 2.8 g (0.05 mol) of KOH in 50 ml of MeOH (or 50 ml of DMF), followed by dropwise addition (ca. 15 min) of 0.04 mol of **1** in 30 ml of MeOH (or 30 ml of DMF), maintaining the temperature at ca. 0 °C. The mixture was refluxed (or heated at 80 °C when DMF was used) for 40 min and poured onto 200 ml of ice-cold 10% HCl, and the solid product(s) was filtered.

Separation of 2b and 3b–d. A portion of the crude solid (7.1 g) obtained from the reaction of CH_3SNa with **1b** was chromatographed on 350 g of silica gel (J. T. Baker Chemical Co., no. 5-3405) in a 5-cm column. After elution of **3b** with CH_2Cl_2–hexane (1:9), the solvent ratio was changed to 3:20 and the remaining compounds were eluted in the order **3c, 2b, 3d.** Azoxybenzenes **3b–d** were recrystallized from ethanol and **2b** was recrystallized from hexane: UV[11] λ_{max} (log ϵ), **3b** 230 (4.07), 268 (4.01), 330 (4.35); **3c** 240 (4.01), 364 (4.38); **3d** 247 (4.09), 380 (4.52); **2b,** 225 (3.84), 334 (4.18). Anal. **3b.** Calcd: C, 41.71; H, 1.50; N, 6.95, Cl, 17.59. Found: C, 41.73; H, 1.75; N, 6.69; Cl, 17.50. **3c.** Calcd: C, 43.43; H, 2.19; N, 6.55; Cl, 8.55; S, 7.73. Found: C, 43.36, H, 2.38; N, 6.66; Cl, 8.71; S, 7.97. **3d.** Calcd: C, 45.06; H, 2.84; N, 6.57; S, 15.04. Found: C, 44.70; H, 3.00; N, 6.45; S, 15.50. **2b.** Calcd: C, 40.50; H, 2.55; N, 5.91; S, 13.52. Found: C, 40.73; H, 2.68; N, 5.87; S, 13.51.

References and Notes

(1) H. H. Hodgson and F. W. Handley, *J. Soc. Chem. Ind., London,* **46,** 435T (1927).
(2) For example, in ref 1, the addition of *p*-chloronitrobenzene (**1a**) to a methanolic solution of sodium methanethiolate affords mainly 4,4-dichloroazoxybenzene (**3a**) and only a "very small amount" of the desired thioanisole (**2a,** R = CH_3).
(3) This is in contrast to the analogous substitution of **1a** by methoxide, which proceeds readily in good yield: R. Filler and H. Novar, *J. Org. Chem.,* **26,** 2707 (1961).
(4) It was expected that the buffering effect of the excess thiol would slow the rate of reduction, presumably by lowering the effective reduction potential of the system.
(5) The success with DMF obviated studies with other potentially useful solvents [e.g., Me_2SO, see R. L. Jacobs, *J. Org. Chem.,* **36,** 242 (1971)].
(6) For example, the addition of solvent (see Table I, entries 4, 9, 11).
(7) W. R. Waldron and E. E. Reid, *J. Am. Chem. Soc.,* **45,** 2399 (1923).
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(9) J. Miller and A. J. Parker, *J. Am. Chem. Soc.,* **83,** 117 (1961).
(10) Table I, entries 4–8.
(11) UV spectra were taken in ethanol on a Cary 14 instrument.

Thermolysis of 4,4,10β-Trimethyl-*trans*-decal-3β-ol Azidoformate

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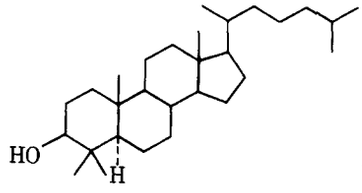
Received July 27, 1976

A recent report[2,23] of thermolysis of the azidoformate derived from lanostanol prompts us to describe the results of an analogous experiment in the decalin series.[3] Our aim, like that of Jones, Alewood, Benn, and Wong,[2] was to see if functionalization of one or both of the C-4 methyl groups of a compound like 4,4-dimethylcholestan-3β-ol (**1**) could be achieved by intramolecular insertion of the nitrene formed from an azidoformate derivative of the C-3 β-hydroxyl group. Although such insertion would lead to a six-membered ring carbamate, rather than the usually predominant[4,5] five-membered ring carbamate which would result from nitrene attack at C-2, molecular models indicate that insertion into either C-4 methyl group is relatively favorable geometrically. Because we had previously succeeded in functionalizing the C-4 β-methyl group via photolysis of a doxyl derivative of 4,4-dimethylcholestan-3-one,[6] our hope was that insertion would occur at the equatorial, 4α-methyl group. As indicated below, this hope was realized in the conversion of **5** to **8,** although in lower yield than in the comparable conversion in the lanostanol series.[2]

Initially, we explored decomposition of diazoacetate **2,** derived from **1** by the method of House,[7] to see if carbenoid insertion at a C-4 methyl group would occur. However, the products from thermolysis or photolysis of **2** were very complex mixtures, which contained predominantly material which afforded **1** upon treatment with $LiAlH_4$. Since these facts indicated that a useful amount of intramolecular insertion had not occurred, we turned to azidoformate decomposition.

The azidoformate selected for thermolysis was **5,** derived from 4,4,10β-trimethyl-*trans*-decal-3β-ol (**3**).[8,9] Preparation



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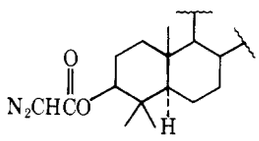
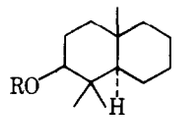
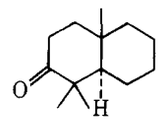


2



3, R = H
4, R = COCl
5, R = CON_3



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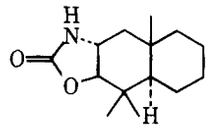
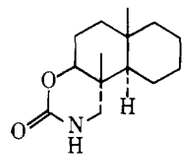


7



8

of **5,** mp 55–57 °C, was accomplished in excellent yield by treatment of **3** with phosgene to afford **4,** which was readily converted to **5** with sodium azide. When a vacuum degassed CCl_4 solution of **5** was heated at 180 °C for 3 h, a much simpler product mixture was formed than from **2,** and the three principal products were easily separated by chromatography. One was readily identified, by comparison with an authentic sample,[10] as 4,4,10β-trimethyl-*trans*-decal-3-one (**6,** 14%), a type of product, like the other two described below, which has previously been obtained from azidoformate decompositions.[2,5]

The other two products both had molecular formula $C_{14}H_{23}NO_2$, consistent with their being intramolecular nitrene insertion products. The major product, mp 185–186 °C (51%), had ν_{max} 1740 cm^{-1} and three methyl peaks in its NMR spectrum suggesting that it was an oxazolidinone formed by insertion at C-2. The third product, mp 164–166 °C (14%), had ν_{max} 1715 cm^{-1} and only two methyl peaks plus a new two-proton signal at ~3 ppm in its ^1H NMR spectrum, suggesting that it was the desired type of product resulting from insertion at a C-4 methyl group. These inferences were confirmed by identification of the two substances as **7** and **8,** respectively, by comparison with authentic samples of **7** and **8** synthesized by the alternate pathways delineated below.

These results are very similar to those obtained in the thermolysis of lanostanyl azidoformate,[2] which afforded ca. 15% of lanostanone, ca. 30% of an oxazolidinone of unassigned stereochemistry at C-2, and ca. 35% of the product analogous to **8.** Assignment of structure to the latter two insertion