

β -Substituted Organolithium Compounds from Chlorohydrins: Application to the Direct Synthesis of Bifunctionalized Organic Compounds †

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The reaction of different chlorohydrins with *n*-butyl-lithium at -78°C followed by metallation with lithium naphthalenide at the same temperature leads to very reactive organolithium compounds bearing an alkoxide function at the β -position with respect to the metal. The reaction of these intermediates with several electrophiles leads to mono- as well as bi-functionalized organic compounds. Thus, treatment of these dianions with deuterium oxide, oxygen, carbon dioxide, benzyl bromide, dimethyl disulphide, and carbonyl compounds, gave 2-deuterioalcohols, 1,2-diols, β -hydroxy-acids, 2-benzyl alcohols, 2-hydroxy-thioethers, and 1,3-diols respectively. The preparation of β -substituted organolithium derivatives can be alternatively carried out starting from α -chloroketones by the same procedure. When the lithium atom is linked to a secondary carbon atom the dianions are very unstable and decompose, even at -100°C , by β -elimination yielding the corresponding olefins.

The preparation of organometallic derivatives of main group elements substituted at the β -position by heteroatoms is greatly hindered by the tendency of these systems to undergo β -elimination reactions which lead to the formation of olefins¹ (Scheme 1). In some cases the β -elimination occurs so readily that the organometallic compound cannot be isolated, and this has proved to be useful in the synthesis of unsaturated compounds.²

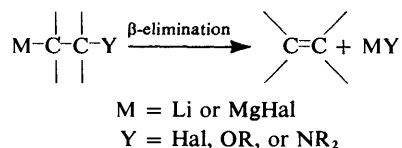
Recently, β -substituted organometallic compounds derived from lithium,^{3a} sodium,^{3b} and potassium,^{3b} in which the metal is linked to a sp^3 hybridized carbon atom, have been prepared by mercury-alkali metal transmetallation at low temperatures from β -substituted organomercury compounds (Scheme 2). These dianionic intermediates are stable at low temperatures owing to the loss of electronegativity of the heteroatom at the β -position with respect to the metal atom, thus hindering the β -elimination. The reactivity of these new synthons with electrophilic reagents has also been investigated.^{3b,4}

We report here the direct preparation of organolithium compounds bearing an alkoxide function in the β -position with respect to the metal, starting from readily available chlorohydrins, and the application of these dianions to the synthesis of bifunctionalized organic compounds.

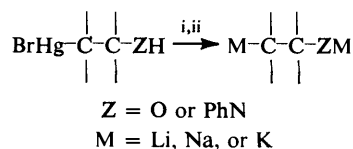
Results and Discussion

Treatment of the chlorohydrins (1) with *n*-butyl-lithium at -78°C and then lithium naphthalenide^{5,†} at the same temperature led to the β -functionalized organolithium compounds (2) (Scheme 3). These dianionic intermediates are stable at -78°C , but above this temperature they decompose *via* β -elimination^{1,2} or proton abstraction from the solvent.⁷

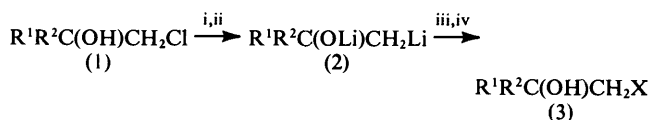
The method of preparation of the starting chlorohydrins (1) depends on the substituents R^1 and R^2 . Compounds (1a) and (1d) were prepared by reduction of the corresponding commercially available chloromethylketones (1') with sodium borohydride⁸ (method A). Compounds (1b), (1c), and (1e) were obtained by the Nierstein chloromethylation reaction⁹



Scheme 1.



Scheme 2. Reagents: i, PhM; ii, M



- a; $R^1 = \text{H}$, $R^2 = \text{Me}$
b; $R^1 = \text{H}$, $R^2 = \text{Pr}^i$
c; $R^1 = \text{H}$, $R^2 = \text{Bu}^t$
d; $R^1 = \text{H}$, $R^2 = \text{Ph}$
e; $R^1 = \text{H}$, $R^2 = \text{PhCH}_2$
f; $R^1 = \text{Me}$, $R^2 = \text{allyl}$
g; $R^1 = R^2 = \text{allyl}$
h; $R^1 = \text{allyl}$, $R^2 = \text{Ph}$
i; $R^1 = R^2 = \text{Ph}$

Scheme 3. Reagents and conditions: i, Bu^nLi , -78°C ; ii, $\text{Li}^+-\text{C}_{10}\text{H}_8^-$, -78°C ; iii, $\text{E}^+ = \text{D}_2\text{O}$, O_2 , CO_2 , PhCH_2Br , Me_2S_2 , Pr^iCHO , PhCHO , $[\text{CH}_2]_5\text{CO}$, or PhCH_2COMe , -78 to 20°C ; iv, $\text{HCl}-\text{H}_2\text{O}$

† Preliminary communication, J. Barluenga, J. Flórez, and M. Yus, *J. Chem. Soc., Chem. Commun.*, 1982, 1153.

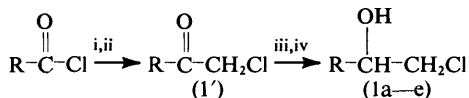
‡ The metallation with lithium metal at low temperature failed. In some cases the separation of the reaction product and naphthalene was difficult by distillation, and lithium 1-dimethylaminonaphthalenide⁶ was used (see footnote c in Table 2 and Experimental section).

(using carboxylic acid chlorides as the starting materials) and further reduction of the corresponding chloromethylketone (1') as above (method B, Scheme 4). The preparation of the chlorohydrins (1f) and (1h) was carried out by addition of allylmagnesium bromide to the commercially available chloromethylketone (1') (method C). Finally, compounds (1g) and (1i) were obtained by addition of the corresponding

Table 1. Preparation of chlorohydrins (1)

Entry	Chlorohydrin ^a	Method ^b	Yield (%) ^c	B.p. (°C/mmHg) or m.p. (°C)
1	(1a)	A	31 ^d	129–132/760 ^e
2	(1b)	B	37 ^f	^g
3	(1c)	B	69 ^f	36–38/0.1
4	(1d)	A	70 ^d	48–51/0.001 ^h
5	(1e)	B	88 ^f	104–105/0.1
6	(1f)	C	50 ^d	58–61/15
7	(1g)	D	82 ^f	85–88/15
8	(1h)	C	69 ^d	110–111/0.1
9	(1i)	D	72 ^f	51–54 ⁱ
10	(1l)	A	87 ^d	^g

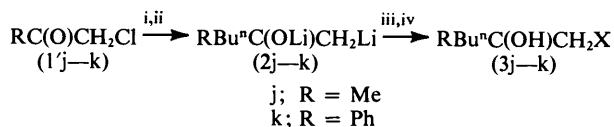
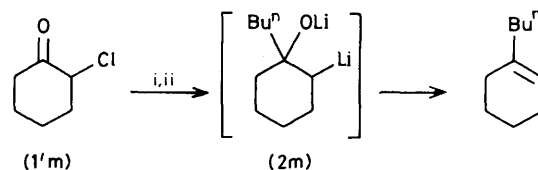
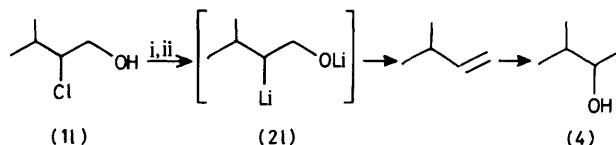
^a See Scheme 1. ^b A: α -chlorocarbonyl compound (1') + sodium borohydride; ^b B: stepwise chloromethylation of carboxylic acid chlorides⁹ and reduction as above (Scheme 2); C, compound (1') + allylmagnesium bromide; D: chloroacetyl chloride + Grignard reagent (1:2 molar ratio). ^c Isolated yield. ^d Based on compound (1'). ^e Lit.,¹⁰ b.p. 126–127 °C/750 mmHg. ^f Based on the corresponding starting carboxylic acid chloride. ^g Isolated and purified by trap-to-trap distillation (0.1 mmHg) (50 °C bath temperature). ^h Lit.,¹⁰ b.p. 91.5 °C (15 mmHg). ⁱ From hexane.

**Scheme 4.** Reagents: i, CH₂N₂-ether; ii, HCl-ether; iii, NaBH₄-EtOH; iv, H₂SO₄-H₂O

Grignard reagent to commercially available chloroacetyl chloride (2:1 molar ratio) (method D) (Table 1).

The reactivity of the intermediates (2) with electrophiles at low temperature was investigated. Thus, when (2) was treated with deuterium oxide at –78 °C followed by further hydrolysis with aqueous hydrochloric acid, the 2-deuterioalcohols (3; X = D) were obtained. Treatment of (2) at –78 °C with a pre-cooled current of dry oxygen at the same temperature followed by acid hydrolysis afforded the corresponding 1,2-diols (3; X = OH). When the β -substituted organolithium compounds (2) were allowed to react with solid carbon dioxide at –78 °C, and the reaction then hydrolysed with hydrochloric acid, β -hydroxy-acids were obtained (3; X = CO₂H). Since the direct isolation and purification of these products were tedious they were purified by esterification of the acid group with diazomethane¹¹ to give β -hydroxy-esters (3; X = CO₂Me) (see footnote *f* in Table 2). The reaction of the dianion (2f) with benzyl bromide led to the corresponding alcohol (3f; X = PhCH₂) after acid hydrolysis. The β -hydroxythioethers (3; X = SMe) were obtained by reaction of the intermediates (2) with dimethyl disulphide at –78 °C and further acid hydrolysis. Finally, treatment of the dianions (2) with different aliphatic or aromatic aldehydes and ketones at –78 °C led to the corresponding 1,3-diols [3; X = R³R⁴C(OH)] after acid hydrolysis. We should point out that in the reactions with carbonyl compounds, side reactions induced by the alkoxide group, such as condensation processes, were never observed¹⁵ (Scheme 3 and Table 2).

The preparation of the intermediates (2) can, alternatively, be carried out starting from the commercially available α -chlorocarbonyl compounds (1') by addition of an organolithium compound in the first step of the reaction. Thus, the reaction of the compounds (1'j) or (1'k) with *n*-butyl-lithium at –78 °C and further lithiation with lithium naphthalenide afforded respectively the intermediates (2j) and (2k); reaction

**Scheme 5.** Reagents and conditions: i, BuⁿLi, –78 °C; ii, Li⁺-C₁₀H₈²⁻, –78 °C; iii, E⁺ = D₂O or Me₂CO, –78 to 20 °C; iv, HCl-H₂O**Scheme 6.** Reagents and conditions: i, BuⁿLi, –78 °C; ii, Li⁺-C₁₀H₈²⁻, –100 °C

of these with deuterium oxide and acetone led to the products (3j; X = D), (3k; X = D), and [3k; X = C(OH)Me₂] (Scheme 5). This method for the preparation of the dianions (2) does not work very satisfactorily and the yields are poor (entries 33–35, Table 2).

When the lithium atom is linked to a secondary carbon atom the corresponding organolithium intermediates (2l)* and (2m) are very unstable and decompose even at –100 °C by a β -elimination process yielding the corresponding olefins, respectively 3-methylbutene and 1-butylcyclohexene (47%) (see Scheme 6). 3-Methylbutene was isolated as its hydroxy derivative (38) (54%) after successive treatment of the olefin solution obtained with water and mercury(II) acetate, and further reduction with sodium borohydride in alkaline media (oxymercuration–demercuration).¹⁶

It can be concluded that the dianion derivatives (2) described here are highly reactive intermediates which act as synthons for the regioselective introduction of the HO–C–C group in reactions with electrophiles.

Experimental

General.—M.p.s are uncorrected and were measured on a Büchi-Tottoli capillary melting point apparatus. I.r. spectra were determined with a Pye-Unicam SP-1000 spectrometer. ¹H and ¹³C N.m.r. spectra were recorded on a Varian FT-80 spectrometer, with SiMe₄ as internal standard; when carbon tetrachloride was used as solvent a D₂O capillary was employed as lock reference. The purity of volatile distilled products was determined with a g.l.c. Varian Aerograph 2800 instrument equipped with a OV-101 Chromosorb column. Elemental analyses were carried out with a Perkin-Elmer 240 elemental analyser. Ether refers to diethyl ether. Starting chloroketones (1') [chloroacetone (1'j), chloroacetophenone (1'k), and α -chlorocyclohexanone (1'm)], chloroacetyl chloride, the other carboxylic acid chlorides, and the other reactants

* The starting chlorohydrin (1l) was prepared by reduction, with sodium borohydride, of 2-chloro-3-methylbutanal⁸ (method A).

Table 2. Reaction of intermediates (2) with electrophiles (E⁺)

Entry	Starting compound	Organo-lithium intermediate	E ⁺	Product		
				Yield (%) ^a	B.p. (°C/mmHg) or m.p. (°C) (solvent)	
1	(1a)	(2a)	Me ₂ S ₂	(3a; X = MeS)	35	56—59/15 ^b
2	(1a)	(2a)	PhCHO	(3a; X = CH(OH)Ph)	74	93—95/0.001
3	(1a)	(2a)	PhCH ₂ COMe	[3a; X = C(OH)MeCH ₂ Ph]	72	70—72/0.001
4	(1b)	(2b)	D ₂ O	(3b; X = D)	40	110—114/760
5	(1c)	(2c)	D ₂ O	(3c; X = D)	51	39—42/15
6	(1c)	(2c)	PhCHO	[3c; X = CH(OH)Ph]	68	89—91/0.001
7 ^c	(1d)	(2d)	D ₂ O	(3d; X = D)	88	51—53/0.1 ^d
8	(1d)	(2d)	O ₂	(3d; X = OH)	77	67—69 (hexane) ^e
9	(1d)	(2d)	CO ₂	(3d; X = CO ₂ H) ^f	22	141—143/12 ^{f,g}
10	(1d)	(2d)	Me ₂ S ₂	(3d; X = MeS)	85	69—73/0.001 ^h
11	(1d)	(2d)	PhCHO	[3d; X = CH(OH)Ph]	79	126—128 (hexane-ether) ⁱ
12	(1e)	(2e)	O ₂	(3e; X = OH)	72	83—85/0.001
13	(1e)	(2e)	Me ₂ S ₂	(3e; X = MeS)	73	69—71/0.001
14	(1f)	(2f)	D ₂ O	(3f; X = D)	55	118—121/760
15	(1f)	(2f)	O ₂	(3f; X = OH)	ca. 50	^j
16	(1f)	(2f)	CO ₂	(3f; X = CO ₂ H) ^f	46	31—33/0.1 ^f
17	(1f)	(2f)	PhCH ₂ Br	(3f; X = PhCH ₂)	37	51—53/0.001
18	(1f)	(2f)	Me ₂ S ₂	(3f; X = MeS)	56	81—83/15
19	(1f)	(2f)	Pr ⁱ CHO	[3f; X = CH(OH)Pr ⁱ]	55	57—59/0.001
20	(1f)	(2f)	PhCHO	[3f; X = CH(OH)Ph]	85	105—107/0.001
21	(1f)	(2f)	PhCH ₂ COMe	[3f; X = C(OH)MeCH ₂ Ph]	52	99—101/0.001
22 ^c	(1g)	(2g)	D ₂ O	(3g; X = D)	55	60—62/15
23	(1g)	(2g)	O ₂	(3g; X = OH)	ca. 50	35—37/0.001
24	(1g)	(2g)	CO ₂	(3g; X = CO ₂ H) ^f	64	48—50/0.1 ^f
25 ^c	(1h)	(2h)	D ₂ O	(3h; X = D)	57	116—119/15
26	(1h)	(2h)	O ₂	(3h; X = OH)	90	89—91/0.001
27	(1h)	(2h)	CO ₂	(3h; X = CO ₂ H)	72	39—41 (hexane)
28	(1h)	(2h)	Me ₂ S ₂	(3h; X = MeS)	96	83—85/0.001
29	(1h)	(2h)	Pr ⁱ CHO	[3h; X = CH(OH)Pr ⁱ]	78	97—99/0.001
30	(1h)	(2h)	[CH ₂] ₅ CO	{3h; X = C(OH)[CH ₂] ₅ }	77	109—111/0.001
31	(1i)	(2i)	D ₂ O	(3i; X = D)	57	89—91/0.001
32	(1i)	(2i)	CO ₂	(3i; X = CO ₂ H) ^f	ca. 60	96—100 (hexane-ether) ^f
33	(1'j)	(2j)	D ₂ O	(3j; X = D)	35 ^k	52—55/15
34	(1'k)	(2k)	D ₂ O	(3k; X = D)	46 ^k	54—59/0.001
35	(1'k)	(2k)	Me ₂ CO	[3k; X = C(OH)Me ₂]	23 ^k	80—84/0.001

^a Based on compound (1). Yields of isolated product. ^b Lit.,¹² b.p. 67 °C/20 mmHg. ^c Lithium 1-dimethylaminonaphthalenide ⁶ was used instead of lithium naphthalenide. ^d Lit.,¹³ b.p. 86—88 °C/10 mmHg. ^e Lit.,^{4a} m.p. 68—69 °C. ^f Isolated as its methyl ester by treatment of the hydroxy acid with diazomethane. ^g Lit.,^{4a} b.p. 140—143 °C/12 mmHg. ^h Lit.,^{4b} b.p. 76—77 °C/0.001 mmHg. ⁱ Lit.,¹⁴ m.p. 128—130 °C. ^j Isolated and purified by preparative chromatography on silica gel with dichloromethane as eluant. ^k Based on compound (1').

(electrophiles E⁺) were of the best commercial grade available (Aldrich, Fluka, and Merck) and were used without further purification. 2-Chloro-3-methylbutanal was obtained from the corresponding aldehyde (Merck) by the literature method.¹⁷ Grignard reagents and n-butyl-lithium were prepared in ether by treating the corresponding alkyl bromide with magnesium (turnings, Merck) or lithium (powder, <20 μ, Koch Light) according to the standard methods¹⁸ and used as *ca.* 1M-solutions. Lithium naphthalenide⁵ and lithium 1-dimethylaminonaphthalenide⁶ were prepared as already described. Ether was dried prior to use successively with anhydrous calcium chloride, sodium sulphate, sodium, and finally a K-Na (K₃Na) liquid alloy¹⁹ under reflux, and was then distilled and stored under argon. Tetrahydrofuran (THF) was dried successively with anhydrous calcium chloride and sodium sulphate; it was then refluxed with potassium, distilled, and stored under argon. All reactions were carried out under argon and all glassware was dried before use.

Preparation of Chlorohydrins (1).—Method A. A solution of sodium borohydride (50 mmol) in water (50 ml) was added to a stirred suspension of the corresponding α-chlorocarbonyl compound (1') (100 mmol) and sodium hydrogen carbonate

(10 g) in ethanol (100 ml). After being stirred for 1 h the reaction mixture was hydrolysed with water, neutralized with sulphuric acid, and extracted with dichloromethane. The extract was washed with water and dried (Na₂SO₄). The solvents were removed (15 mmHg) and the residue was distilled or trap-to-trap condensed under reduced pressure to give the compounds (1a), (1d), and (1i) (see Table 1). 1-Chloropropan-2-ol (1a),¹⁰ *v*_{max.} (neat) 3 350 cm⁻¹ (OH); ²⁰ δ_H (CCl₄) 1.2 (3 H, d, *J* 6 Hz, Me), 3.45 (2 H, d, *J* 6 Hz, CH₂), 3.7—4.1 (1 H, m, CH), and 4.4 (1 H, s, OH); ²¹ δ_C (CCl₄) 20.0, 50.2, and 67.4 p.p.m.

2-Chloro-1-phenylethanol (1d),¹⁰ *v*_{max.} (neat) 3 400 (OH), 3 020, 1 600, 1 490, 760, and 710 cm⁻¹ (Ph); δ_H (CCl₄) 3.5 (2 H, d, *J* 6 Hz, CH₂), 3.8 (1 H, s, OH), 4.65 (1 H, t, *J* 6 Hz, CH), and 7.2 (5 H, s, Ph); δ_C (CCl₄) 49.6, 73.5, 125.9, 127.8, 128.1, and 140.2 p.p.m.

2-Chloro-3-methylbutanol (1i) (Found: C, 49.0; H, 9.0. C₅H₁₁ClO requires C, 48.99; H, 9.04%); *v*_{max.} (neat) 3 400 cm⁻¹ (OH); δ_H (CCl₄) 1.0, 1.1 (6 H, 2 d, *J* 6 Hz, 2 × Me), 1.7—2.3 (1 H, m, CHMe), 3.6—4.0 (3 H, m, CHCl and CH₂), and 4.2 (1 H, br s, OH); δ_C (CCl₄) 16.8, 20.0, 30.5, 64.7, and 70.0 p.p.m.

Method B. The corresponding carboxylic acid chloride was

added to a stirred solution of diazomethane (200 mmol) at -20°C (bath temperature) under argon. The reaction mixture was stirred and the temperature allowed to rise to 0°C for 2 h. The resulting solution was cooled to -20°C and then hydrolysed with a solution of hydrogen chloride in ether (150 mmol); the reaction mixture was stirred overnight and the temperature allowed to rise to 20°C . Solvents were removed (15 mmHg) and the residue was worked up as described in method A. Thus, compounds (1b), (1c), and (1e) were isolated.

1-Chloro-3-methylbutan-2-ol (1b) (Found: C, 48.8; H, 9.0. $\text{C}_5\text{H}_{11}\text{ClO}$ requires C, 48.99; H, 9.04%; ν_{max} (neat) 3450 cm^{-1} (OH); δ_{H} (CCl_4) 0.95 (6 H, 2 d, J 6 Hz, $2 \times \text{Me}$), 1.65—2.05 (1 H, m, CHMe), 3.4—3.75 (3 H, m, CHO and CH_2), and 4.0 (1 H, s, OH); δ_{C} (CCl_4) 17.2, 18.7, 31.2, 47.9, and 76.05 p.p.m.

1-Chloro-4-methylpentan-2-ol (1c) (Found: C, 52.8; H, 9.5. $\text{C}_6\text{H}_{13}\text{ClO}$ requires C, 52.75; H, 9.59%; ν_{max} (neat) 3360 cm^{-1} (OH); δ_{H} (CCl_4) 0.9, 0.95 (6 H, 2 d, J 6 Hz, $2 \times \text{Me}$), 1.2—1.45 (2 H, m, CH_2Pr^1), 1.6—1.9 (1 H, m, CHMe), 3.3—3.5 (3 H, m with s at 3.4, CH_2Cl and OH), and 3.6—3.9 (1 H, m, CHO); δ_{C} (CCl_4) 21.75, 23.2, 24.3, 43.1, 49.7, and 69.4 p.p.m.

1-Chloro-3-phenylpropan-2-ol (1e) (Found: C, 63.2; H, 6.5. $\text{C}_9\text{H}_{11}\text{ClO}$ requires C, 63.35; H, 6.50%; ν_{max} (neat) 3460 cm^{-1} (OH), 3 040, 1 615, 1 510, 760, and 720 cm^{-1} (Ph); δ_{H} (CCl_4) 2.8 (2 H, d, J 6 Hz, CH_2Ph), 3.1 (1 H, s, OH), 3.25—3.5 (2 H, m, CH_2Cl), 3.7—4.1 (1 H, m, CH), and 6.9—7.25 (5 H, m, Ph); δ_{C} (CCl_4) 40.2, 48.7, 72.0, 126.4, 128.3, 149.3, and 137.4 p.p.m.

Method C. A solution of allylmagnesium bromide (120 mmol) in ether was added to a stirred solution of the corresponding α -chloroketone (100 mmol) in ether (125 ml) at -50°C under argon. The reaction mixture was stirred for 6 h and the temperature allowed to rise to 20°C . The resulting suspension was hydrolysed with water, neutralized with hydrochloric acid, and extracted with dichloromethane. The extract was washed with water and dried (Na_2SO_4). The solvents were removed (15 mmHg) and the residue was distilled under reduced pressure (see Table 1). Compounds (1f) and (1h) were prepared by this method. 1-Chloro-2-methylpent-4-en-2-ol (1f) (Found: C, 53.7; H, 8.3. $\text{C}_6\text{H}_{11}\text{ClO}$ requires C, 53.54; H, 8.24%; ν_{max} (neat) 3410 cm^{-1} (OH), 3 060, and 1645 cm^{-1} ($\text{HC}=\text{C}$); δ_{H} (CCl_4) 1.2 (3 H, s, Me), 2.3 (2 H, d, J 8 Hz, $\text{CH}_2\text{C}=\text{C}$), 3.4 (2 H, s, CH_2Cl), 4.4 (1 H, s, OH), 4.9—5.3 (2 H, m, $\text{CH}_2=\text{C}$), and 5.5—6.1 (1 H, m, CH); δ_{C} (CCl_4) 24.1, 43.3, 52.6, 71.5, 118.3, and 132.8 p.p.m.

1-Chloro-2-phenylpent-4-en-2-ol (1h) (Found: C, 67.3; H, 6.7. $\text{C}_{11}\text{H}_{13}\text{ClO}$ requires C, 67.18; H, 6.66%; ν_{max} (neat) 3500 cm^{-1} (OH), 3 070, 3 020, 1 650, 1 600, 1 500, 730, and 700 cm^{-1} ($\text{HC}=\text{C}$ and Ph); δ_{H} (CCl_4) 2.5 (2 H, d, J 8 Hz, $\text{CH}_2\text{C}=\text{C}$), 2.7 (1 H, s, OH), 3.5 (2 H, s, CH_2Cl), 4.7—5.1 (2 H, m, $\text{CH}_2=\text{C}$), 5.2—5.8 (1 H, m, CH), and 6.9—7.4 (5 H, m, Ph); δ_{C} (CCl_4) 44.1, 53.5, 75.2, 119.0, 125.5, 127.2, 128.05, 132.55, and 142.7 p.p.m.

Method D. A solution of chloroacetyl chloride (11.3 g, 100 mmol) in ether (100 ml) was added to a stirred solution of the corresponding Grignard reagent (210 mmol) in ether at -50°C under argon. The reaction mixture was stirred overnight and the temperature allowed to rise to 20°C . The resulting suspension was hydrolysed with water, neutralized with hydrochloric acid, and extracted with dichloromethane. The extract was washed with water and dried (Na_2SO_4), the solvents were removed (15 mmHg), and the residue was distilled under reduced pressure or recrystallized (see Table 1) to afford compounds (1g) and (1i). 4-Chloromethylhepta-1,6-dien-4-ol (1g) (Found: C, 59.7; H, 8.1. $\text{C}_8\text{H}_{13}\text{ClO}$ requires C, 59.81; H, 8.16%; ν_{max} (neat) 3500 cm^{-1} (OH), 3 100, and 1660 cm^{-1} ($\text{HC}=\text{C}$); δ_{H} (CCl_4) 2.3 (4 H, d, J 8 Hz, $2 \times \text{CH}_2\text{C}=\text{C}$), 2.8 (1 H, s, OH), 3.45 (2 H, s, CH_2Cl), 4.9—5.3 (4 H, m,

$2 \times \text{CH}_2=\text{C}$), and 5.5—6.15 (2 H, m, $2 \times \text{CH}$); δ_{C} (CCl_4) 41.4, 50.8, 73.1, 118.8, and 132.7 p.p.m.

2-Chloro-1,1-diphenylethanol (1i) (Found: C, 72.3; H, 5.7. $\text{C}_{14}\text{H}_{13}\text{ClO}$ requires C, 72.26; H, 5.63%; ν_{max} (CCl_4) 3 560, 3 480 (OH), 3 050, 3 020, 1 605, 1 500, 730, and 705 cm^{-1} (Ph); δ_{H} (CCl_4) 3.1 (1 H, s, OH), 4.0 (2 H, s, CH_2), and 6.8—7.5 (10 H, m, $2 \times \text{Ph}$); δ_{C} (CCl_4) 52.7, 77.5, 126.3, 127.3, 128.0, and 143.3 p.p.m.

Preparation of the Intermediates (2) from the Chlorohydrins (1) and Further Deuterolysis. Isolation of the 2-Deuterioalcohols. General Procedure.—An ether solution of n-butyllithium (22 mmol) was added to a stirred solution of the chlorohydrin (1) (20 mmol) in THF (25 ml) at -78°C under argon. After 15 min a THF solution of lithium naphthalenide (42 mmol) was added and the mixture stirred for 5 h at -78°C . Deuterium oxide (2.5 ml) was then added, the mixture stirred for 1 h at -78°C , and the temperature allowed to rise to 20°C overnight. The mixture was hydrolysed with water, neutralized with hydrochloric acid, and then extracted with dichloromethane, and the organic layer was washed with water and dried (Na_2SO_4). The solvents were removed (15 mmHg) and naphthalene was removed by sublimation (0.001 mmHg). The residue was distilled (0.001 mmHg) to give compound (3i; X = D). In the case of compounds (3b; X = D), (3c; X = D), and (3f; X = D) the product was distilled off before sublimation of the naphthalene (Table 2, entries 4, 5, and 14). When lithium 1-dimethylaminonaphthalenide was used (footnote c in Table 2) the corresponding 1-dimethylaminonaphthalene was readily removed by extraction with aqueous hydrochloric acid; thus, compounds (3d; X = D), (3g; X = D), and (3h; X = D) were isolated. 1-Deuterio-3-methylbutan-2-ol (3b; X = D) (Found: C, 67.5; H/D, 14.7. $\text{C}_5\text{H}_{11}\text{DO}$ requires C, 67.36; H/D, 14.70%; ν_{max} (CCl_4) 3400 cm^{-1} (OH); δ_{H} (CCl_4) 0.8—1.1 (8 H, m, $2 \times \text{Me}$ and CH_2D), 1.25—1.65 (1 H, m, CHMe), 3.0 (1 H, s, OH), and 3.5 (1 H, m, CHO); δ_{C} (CCl_4) 17.8, 18.1, 19.6 (t, J_{CD} 19.1 Hz, CH_2D), 34.8, and 71.8 p.p.m.

1-Deuterio-4-methylpentan-2-ol (3c; X = D) (Found: C, 69.8; H/D, 14.7. $\text{C}_6\text{H}_{13}\text{DO}$ requires C, 69.84; H/D, 14.65%; ν_{max} (CCl_4) 3340 cm^{-1} (OH); δ_{H} (CCl_4) 0.9 (6 H, d, J 6 Hz, $2 \times \text{Me}$), 1.05—1.9 (5 H, m, CH_2D , CH_2 , and CHMe), 3.6—3.9 (1 H, m, CHO), and 3.95 (1 H, s, OH); δ_{C} (CCl_4) 22.3, 23.1, 23.4 (t, J_{CD} 19.5 Hz, CH_2D), 24.5, 48.9, and 65.0 p.p.m.

2-Deuterio-1-phenylethanol (3d; X = D),¹³ ν_{max} (neat) 3400 cm^{-1} (OH), 3 020, 3 000, 1 605, 1 490, 755, and 700 cm^{-1} (Ph); δ_{H} (CCl_4) 1.3 (2 H, d, J 6 Hz, CH_2D), 4.05 (1 H, s, OH), 4.6 (1 H, t, J 6 Hz, CHO), and 7.15 (5 H, m, Ph); δ_{C} (CCl_4) 24.7 (t, J_{CD} 19.5 Hz, CH_2D), 69.5, 125.3, 126.8, 128.0, and 146.0 p.p.m.

1-Deuterio-2-methylpent-4-en-2-ol (3f; X = D) (Found: C, 71.4; H/D, 13.0. $\text{C}_6\text{H}_{11}\text{DO}$ requires C, 71.23; H/D, 12.95%; ν_{max} (neat) 3350 cm^{-1} (OH), 3 020, and 1640 cm^{-1} ($\text{HC}=\text{C}$); δ_{H} (CCl_4) 1.15 (5 H, s, Me and CH_2D), 2.15 (2 H, d, J 7.5 Hz, $\text{CH}_2\text{C}=\text{C}$), 3.05 (1 H, s, OH), 4.85—5.1 (2 H, m, $\text{CH}_2=\text{C}$), and 5.55—6.1 (1 H, m, CH); δ_{C} (CCl_4) 28.6 (t, J_{CD} 19.15 Hz, CH_2D), 28.9, 48.65, 69.9, 117.0, and 135.3.

4-Deuteriomethylhepta-1,6-dien-4-ol (3g; X = D) (Found: C, 75.4; H/D, 11.9. $\text{C}_8\text{H}_{13}\text{DO}$ requires C, 75.54; H/D, 11.88%; ν_{max} (neat) 3450 cm^{-1} (OH), 3 080, and 1650 cm^{-1} ($\text{HC}=\text{C}$); δ_{H} (CCl_4) 1.1 (2 H, s, CH_2D), 2.2 (4 H, d, J 8 Hz, $2 \times \text{CH}_2\text{C}=\text{C}$), 2.4 (1 H, s, OH), 4.9—5.3 (4 H, m, $2 \times \text{CH}_2=\text{C}$), and 5.5—6.15 (2 H, m, $2 \times \text{CH}$); δ_{C} (CCl_4) 26.15 (t, J_{CD} 19.2 Hz, CH_2D), 46.2, 71.6, 117.6, and 134.3 p.p.m.

1-Deuterio-2-phenylpent-4-en-2-ol (3h; X = D) (Found: C, 80.7; H/D, 9.3. $\text{C}_{11}\text{H}_{13}\text{DO}$ requires C, 80.94; H/D, 9.26%; ν_{max} (neat) 3460 cm^{-1} (OH), 3 080, 3 020, 1 650, 1 610, 1 500, 770, and 710 cm^{-1} ($\text{HC}=\text{C}$ and Ph); δ_{H} (CCl_4) 1.5 (2 H, s, CH_2D),

2.4—2.7 (2 H, m, $\text{CH}_2\text{C}=\text{C}$), 3.15 (1 H, s, OH), 4.8—5.2 (2 H, m, $\text{CH}_2=\text{C}$), 5.3—5.9 (1 H, m, CH), and 7.0—7.5 (5 H, m, Ph); δ_{C} (CCl_4) 28.8 (t, J_{CD} 20.2 Hz, CH_2D), 48.5, 73.6, 118.3, 124.8, 126.3, 127.8, 133.9, and 147.7 p.p.m.

2-Deuterio-1,1-diphenylethanol (3i; X = D) (Found: C, 84.4; H/D, 7.5. $\text{C}_{14}\text{H}_{13}\text{DO}$ requires C, 84.38; H/D, 7.59%); ν_{max} (neat) 3 440 (OH), 3 060, 3 020, 1 605, 1 585, 1 500, 770, and 700 cm^{-1} (Ph); δ_{H} (CCl_4) 1.8 (2 H, s, CH_2D), 2.4 (1 H, s, OH), and 6.9—7.4 (10 H, m, $2 \times$ Ph); δ_{C} (CCl_4) 30.3 (t, J_{CD} 19.2 Hz, CH_2D), 75.6, 125.75, 126.4, 127.7, 128.2, and 148.0 p.p.m.

Preparation of the Intermediates (2) from the α -Chloro-ketones (1') and Further Deuterolysis. Isolation of 2-Deuterio-alcohols. General Procedure.—A solution of n-butyl-lithium (22 mmol) in ether was added to a solution of the corresponding α -chloroketone (1') (20 mmol) in THF (25 ml) at -78°C under argon for 20 min. The mixture was stirred for 3 h and the temperature was allowed to rise to -50°C . The resulting solution was cooled at -78°C and then a solution of lithium naphthalenide (42 mmol) in THF was added. The reaction mixture was stirred at -78°C for 5 h and then deuterium oxide (3 ml) was added to the resulting solution. The mixture was stirred for 1 h at -78°C , and the temperature allowed to rise to 20°C overnight. After that the reaction was worked up as described above for the preparation of compound (3i; X = D), and the product (3k; X = D) was isolated. In the case of the product (3j; X = D) the work-up was similar to that described above e.g., for compound (3b; X = D). *1-Deuterio-2-methylhexan-2-ol* (3j; X = D) (Found: C, 71.8; H/D, 14.6. $\text{C}_7\text{H}_{15}\text{DO}$ requires C, 71.73; H/D, 14.62%); ν_{max} (neat) $3\ 420\text{ cm}^{-1}$ (OH); δ_{H} (CCl_4) 0.9 (3 H, deformed t, MeCH_2), 1.1 (5 H, s, MeCO and CH_2D), 1.3 (6 H, br s, $3 \times \text{CH}_2$), and 3.5—4.4 (1 H, br signal, OH); δ_{C} (CCl_4) 13.9, 23.1, 26.4, 28.55 (t, J_{CD} 19.1 Hz, CH_2D), 28.8, 43.5, and 70.35 p.p.m.

1-Deuterio-2-phenylhexan-2-ol (3k; X = D) (Found: C, 80.2; H/D, 10.6. $\text{C}_{12}\text{H}_{17}\text{DO}$ requires C, 80.39; H/D, 10.68%); ν_{max} (CCl_4) 3 440 (OH), 3 040, 3 010, 1 610, 1 500, and 715 cm^{-1} (Ph); δ_{H} (CCl_4) 0.85 (3 H, deformed t, Me), 1.15 (4 H, m, $\text{CH}_2\text{CH}_2\text{Me}$), 1.45 (2 H, s, CH_2D), 1.7 (2 H, m, CH_2CO), 2.7 (1 H, s, OH), and 7.25 (5 H, m, Ph); δ_{C} (CCl_4) 13.9, 22.85, 25.9, 29.6 (t, J_{CD} 19.3 Hz, CH_2D), 43.8, 73.9, 124.6, 125.95, 127.6, and 148.1 p.p.m.

Oxidation of the Intermediates (2). Obtention of 1,2-Diols. General Procedure.—Through a solution of the intermediate (2) (20 mmol) in ether-THF (obtained as described above) was bubbled dry oxygen (purity $>99\%$), pre-cooled to -78°C , for 3 h at -78°C . The resulting mixture was hydrolysed with water, neutralized with hydrochloric acid, and extracted with dichloromethane, and the organic layer was washed with water and dried (Na_2SO_4). The solvents were removed (15 mmHg) and the naphthalene was removed by sublimation (0.001 mmHg). The residue was distilled (0.001 mmHg) or recrystallized to afford compounds (3d; X = OH), (3e; X = OH), and (3h; X = OH). In the case of the diols (3f; X = OH) and (3g; X = OH) the residue was chromatographed on silica gel with dichloromethane as eluant to give, in order of elution, naphthalene and the product (see Table 2). *1-Phenylethane-1,2-diol* (3d; X = OH),^{4a} ν_{max} (Nujol) 3 300 (OH), 3 010, 1 610, 1 505, 770, and 720 cm^{-1} (Ph); δ_{H} (CDCl_3) 3.6 (2 H, m, CH_2), 4.7 (1 H, t, J 6 Hz, CH), 5.0 (2 H, s, $2 \times$ OH), and 7.3 (5 H, m, Ph); δ_{C} (CDCl_3) 67.75, 74.5, 125.9, 127.65, 128.3, and 140.3 p.p.m.

3-Phenylpropane-1,2-diol (3e; X = OH) (Found: C, 71.1; H, 8.0. $\text{C}_9\text{H}_{12}\text{O}_2$ requires C, 71.03; H, 7.95%); ν_{max} (neat) 3 340 (OH), 3 020, 3 000, 1 600, 1 490, 745, and 700 cm^{-1}

(Ph); δ_{H} (CCl_4) 2.6 (2 H, d, J 6 Hz, CH_2Ph), 3.2—3.4 (2 H, m, CH_2O), 3.6—3.9 (1 H, m, CH), 4.3 (2 H, s, $2 \times$ OH), and 7.1 (5 H, s, Ph); δ_{C} (CCl_4) 39.5, 65.4, 73.0, 126.0, 128.1, 129.2, and 138.2 p.p.m.

2-Methylpent-4-ene-1,2-diol (3f; X = OH) (Found: C, 62.0; H, 10.3. $\text{C}_6\text{H}_{12}\text{O}_2$ requires C, 62.04; H, 10.41%); ν_{max} (neat) 3 380 (OH), 3 040, and $1\ 645\text{ cm}^{-1}$ ($\text{HC}=\text{C}$); δ_{H} (CCl_4) 1.1 (3 H, s, Me), 2.25 (2 H, d, J 6 Hz, $\text{CH}_2\text{C}=\text{C}$), 3.4 (2 H, s, CH_2O), 4.1—4.6 (2 H, br s, $2 \times$ OH), 4.9—5.2 (2 H, m, $\text{CH}_2=\text{C}$), and 5.5—6.0 (1 H, m, CH); δ_{C} (CCl_4) 22.9, 43.0, 68.8, 72.55, 117.75, and 133.8 p.p.m.

2-Allylpent-4-ene-1,2-diol (3g; X = OH) (Found: C, 67.3; H, 9.9. $\text{C}_8\text{H}_{14}\text{O}_2$ requires C, 67.67; H, 9.92%); ν_{max} (neat) 3 420 (OH), 3 080, and $1\ 650\text{ cm}^{-1}$ ($\text{HC}=\text{C}$); δ_{H} (CCl_4) 2.2 (4 H, d, J 8 Hz, $2 \times \text{CH}_2\text{C}=\text{C}$), 3.4 (2 H, s, CH_2O), 4.1 (2 H, s, $2 \times$ OH), 4.9—5.2 (4 H, m, $2 \times \text{CH}_2=\text{C}$), and 5.5—6.1 (2 H, m, $2 \times$ CH); δ_{C} (CCl_4) 40.35, 67.1, 74.1, 118.0, and 133.4 p.p.m.

2-Phenylpent-4-ene-1,2-diol (3h; X = OH) (Found: C, 74.0; H, 7.9. $\text{C}_{11}\text{H}_{14}\text{O}_2$ requires C, 74.13; H, 7.92%); ν_{max} (neat) 3 420 (OH), 3 050, 3 000, 1 645, 1 605, 1 500, 765, and 705 cm^{-1} ($\text{HC}=\text{C}$ and Ph); δ_{H} (CCl_4) 2.6 (2 H, d, J 8 Hz, $\text{CH}_2\text{C}=\text{C}$), 3.3 (2 H, s, $2 \times$ OH), 3.6 (2 H, s, CH_2O), 4.8—5.1 (2 H, m, $\text{CH}_2=\text{C}$), 5.3—5.8 (1 H, m, CH), and 7.1—7.6 (5 H, m, Ph); δ_{C} (CCl_4) 43.1, 69.1, 76.3, 118.2, 125.5, 126.6, 127.9, 133.2, and 143.5 p.p.m.

Carbonation of Intermediates (2) and Further Esterification with Diazomethane. Isolation of β -Hydroxyesters. General Procedure.—An excess of anhydrous solid carbon dioxide was added to a solution of the intermediate (2) (20 mmol) in ether-THF and the temperature was allowed to rise to 20°C overnight. The resulting mixture was hydrolysed with water and naphthalene was extracted with dichloromethane. The aqueous layer was acidified with hydrochloric acid and extracted with dichloromethane. The organic layer was washed with water and dried (Na_2SO_4), and the solvents were removed (15 mmHg). An ether solution of diazomethane (25 mmol) was added to a solution of the resulting residue in ether (20 ml). The ether was removed (15 mmHg) and the residue was distilled under reduced pressure or recrystallized to give the β -hydroxyesters of the acids (3d; X = CO_2H), (3f; X = CO_2H), (3g; X = CO_2H), (3h; X = CO_2H), and (3i; X = CO_2H) (see Table 2). *Methyl 3-hydroxy-3-phenylpropanoate* (3d; X = CO_2H),^{4a} ν_{max} (neat) 3 480 (OH), 3 020, 1 610, 1 505, 775, 715 (Ph), and $1\ 750\text{ cm}^{-1}$ ($\text{C}=\text{O}$); δ_{H} (CCl_4) 2.55 (2 H, m, CH_2), 3.45 (4 H, s, Me and OH), 4.95 (1 H, t, J 6 Hz, CH), and 7.2 (5 H, m, Ph); δ_{C} (CCl_4) 43.5, 51.2, 69.9, 125.55, 127.2, 128.1, 143.4, and 171.7 p.p.m.

Methyl 3-hydroxy-3-methylhex-5-enoate (3f; X = CO_2H) (Found: C, 60.8; H, 8.9. $\text{C}_8\text{H}_{14}\text{O}_3$ requires C, 60.74; H, 8.92%); ν_{max} (neat) 3 520 (OH), 3 080, 1 660 ($\text{HC}=\text{C}$), and $1\ 760\text{ cm}^{-1}$ ($\text{C}=\text{O}$); δ_{H} (CCl_4) 1.1 (3 H, s, MeC), 2.25 (2 H, d, J 8 Hz, $\text{CH}_2\text{C}=\text{C}$), 2.4 (2 H, s, $\text{CH}_2\text{C}=\text{O}$), 3.3 (1 H, s, OH), 3.6 (3 H, s, MeO), 4.75—5.2 (2 H, m, $\text{CH}_2=\text{C}$), and 5.5—6.1 (1 H, m, CH); δ_{C} (CCl_4) 26.7, 44.3, 46.4, 51.0, 70.3, 117.75, 134.05, and 172.2 p.p.m.

Methyl 3-allyl-3-hydroxyhex-5-enoate (3g; X = CO_2H) (Found: C, 65.1; H, 8.8. $\text{C}_{10}\text{H}_{16}\text{O}_3$ requires C, 65.19; H, 8.75%); ν_{max} (neat) 3 500 (OH), 3 050, 1 650 ($\text{HC}=\text{C}$), and $1\ 740\text{ cm}^{-1}$ ($\text{C}=\text{O}$); δ_{H} (CCl_4) 2.3 (4 H, d, J 8 Hz, $2 \times \text{CH}_2\text{C}=\text{C}$), 2.4 (2 H, s, $\text{CH}_2\text{C}=\text{O}$), 3.4 (1 H, s, OH), 3.7 (3 H, s, Me), 4.8—5.2 (4 H, m, $2 \times \text{CH}_2=\text{C}$), and 5.5—6.2 (2 H, m, $2 \times$ CH); δ_{C} (CCl_4) 41.7, 43.6, 50.8, 71.8, 117.6, 133.5, and 172.2 p.p.m.

Methyl 2-hydroxy-3-phenylhex-5-enoate (3h; X = CO_2H) (Found: C, 71.0; H, 7.3. $\text{C}_{13}\text{H}_{16}\text{O}_3$ requires C, 70.89; H, 7.32%); ν_{max} (Nujol) 3 510 (OH), 3 050, 3 000, 1 650, 1 605, 1 500, 750, 705 ($\text{HC}=\text{C}$ and Ph), and $1\ 730\text{ cm}^{-1}$ ($\text{C}=\text{O}$); δ_{H}

(CCl₄) 2.5 (2 H, d, *J* 6 Hz, CH₂C=C), 2.8 (2 H, s, CH₂C=O), 3.5 (3 H, s, Me), 3.9 (1 H, br s, OH), 4.7–5.2 (2 H, m, CH₂C=C), 5.4–5.9 (1 H, m, CH), and 6.9–7.5 (5 H, m, Ph); δ_c (CCl₄) 43.7, 47.7, 51.1, 74.1, 117.9, 124.8, 126.5, 127.8, 133.4, 145.55, and 172.4 p.p.m.

Methyl 3-hydroxy-3,3-diphenylpropanoate (3i; X = CO₂H) (Found: C, 75.1; H, 6.2. C₁₆H₁₆O₃ requires C, 74.98; H, 6.29%); ν_{max.} (Nujol) 3 470 (OH), 3 040, 3 020, 1 605, 1 500, 760, 705 (Ph), and 1 725 cm⁻¹ (C=O); δ_H (CDCl₃) 3.3 (2 H, s, CH₂), 3.6 (3 H, s, Me), 4.5–5.5 (1 H, br signal, OH), and 7.0–7.6 (10 H, m, 2 × Ph); δ_c (CDCl₃) 45.2, 51.8, 76.2, 125.5, 126.95, 128.1, 145.8, and 173.0 p.p.m.

Reaction of the Intermediate (2f) with Benzyl Bromide. 3-Methyl-1-phenylhex-5-en-3-ol (3f; X = PhCH₂).—Benzyl bromide (25 mmol) was added to a stirred solution of the intermediate (2f) in ether–THF at –78 °C. The reaction mixture was stirred at –78 °C for 1 h and then the temperature was allowed to rise to 20 °C overnight. The mixture was hydrolysed with water, neutralized with hydrochloric acid, and extracted with ether. The extract was washed with water, dried (Na₂SO₄), and the solvents were removed (15 mmHg). Naphthalene was removed by sublimation (0.001 mmHg) and the residue was distilled (0.001 mmHg) to give *compound* (3f; X = PhCH₂) (Found: C, 81.9; H, 9.6. C₁₃H₁₈O requires C, 82.06; H, 9.53%); ν_{max.} (neat) 3 420 (OH), 3 050, 3 010, 1 645, 1 610, 1 500, 755, and 705 cm⁻¹ (HC=C and Ph); δ_H (CCl₄) 1.2 (3 H, s, Me), 1.4–1.8 (3 H, m, CH₂CO and OH), 2.25 (2 H, d, *J* 8 Hz, CH₂C=C), 2.5–2.8 (2 H, m, CH₂Ph), 4.9–5.2 (2 H, m, CH₂=C), 5.4–6.2 (1 H, m, CH), and 7.1 (5 H, s, Ph); δ_c (CCl₄) 26.7, 30.1, 37.8, 43.6, 46.5, 71.5, 118.0, 125.4, 125.6, 128.05, 134.1, and 142.2 p.p.m.

Reaction of the Intermediates (2) with Dimethyl Disulphide. Obtention of 2-Methylthioalcohols. General Procedure.—Dimethyl disulphide (25 mmol) was added to a stirred solution of the intermediate (2) (20 mmol) in ether–THF at –78 °C under argon. The mixture was stirred at –78 °C for 1 h and then the temperature was allowed to rise to 20 °C overnight. The reaction mixture was hydrolysed with water, neutralized with hydrochloric acid and extracted with dichloromethane. The extract was washed with water, dried (Na₂SO₄) and the solvents were removed (15 mmHg). Naphthalene was removed by sublimation (0.001 mmHg) and the residue was distilled (0.001 mmHg) to give compounds (3d; X = MeS), (3e; X = MeS), and (3h; X = MeS). In the case of compounds (3a; X = MeS) and (3f; X = MeS) the product was distilled off (15 mmHg) before the sublimation of the naphthalene (see Table 2). 1-Methylthioprop-2-ol (3a; X = MeS),¹² ν_{max.} (neat) 3 380 cm⁻¹ (OH); δ_H (CCl₄) 1.2 (3 H, d, *J* 6 Hz, MeC), 2.05 (3 H, s, MeS), 2.3–2.6 (2 H, m, CH₂), 3.7 (1 H, s, OH), and 3.8 (1 H, m, CH); δ_c (CCl₄) 15.7, 22.0, 43.1, and 65.6 p.p.m.

2-Methylthio-1-phenylethanol (3d; X = MeS),^{4b} ν_{max.} (neat) 3 400 (OH), 3 040, 3 010, 1 610, 1 500, 755, and 710 cm⁻¹ (Ph); δ_H (CCl₄) 1.95 (3 H, s, Me), 2.6 (2 H, m, CH₂), 3.55 (1 H, s, OH), 4.6 (1 H, t, *J* 6 Hz, CH), and 7.25 (5 H, m, Ph); δ_c (CCl₄) 15.6, 43.2, 72.2, 125.9, 127.35, 128.1, and 143.05 p.p.m.

1-Methylthio-3-phenylpropan-2-ol (3e; X = MeS) (Found: C, 65.8; H, 7.8. C₁₀H₁₄OS requires C, 65.89; H, 7.74%); ν_{max.} (neat) 3 450 (OH), 3 060, 3 020, 1 610, 1 505, 760, and 715 cm⁻¹ (Ph); δ_H (CCl₄) 2.0 (3 H, s, Me), 2.3–2.5 (2 H, m, CH₂S), 2.8 (2 H, d, *J* 6 Hz, CH₂Ph), 2.8 (1 H, s, OH), 3.8 (1 H, quintet, *J* 6 Hz, CH), and 7.2 (5 H, s, Ph); δ_c (CCl₄) 15.7, 40.8, 42.3, 70.7, 126.1, 128.1, 129.4, and 138.2 p.p.m.

2-Methyl-1-methylthiopent-4-en-2-ol (3f; X = MeS) (Found: C, 57.3; H, 9.5. C₇H₁₄OS requires C, 57.49; H, 9.65%); ν_{max.}

(neat) 3 420 (OH), 3 050, and 1 645 cm⁻¹ (HC=C); δ_H (CCl₄) 1.1 (3 H, s, MeC), 2.1 (3 H, s, MeS), 2.25 (2 H, d, *J* 8 Hz, CH₂C=C), 2.3 (1 H, s, OH), 2.5 (2 H, s, CH₂S), 4.9–5.2 (2 H, m, CH₂=C), and 5.5–6.1 (1 H, m, CH); δ_c (CCl₄) 17.6, 26.15, 45.5, 46.8, 72.4, 117.8, and 134.1 p.p.m.

1-Methylthio-2-phenylpent-4-en-2-ol (3h; X = MeS) (Found: C, 69.0; H, 7.7. C₁₂H₁₆OS requires C, 69.19; H, 7.74%); ν_{max.} (neat) 3 460 (OH), 3 060, 3 000, 1 645, 1 600, 1 495, 760, and 700 cm⁻¹ (Ph); δ_H (CCl₄) 1.7 (3 H, s, Me), 2.5 (2 H, d, *J* 8 Hz, CH₂C=C), 2.75, 2.8 (2 H, 2 s, CH₂S), 2.95 (1 H, s, OH), 4.7–5.05 (2 H, m, CH₂=C), 5.2–5.9 (1 H, m, CH), and 7.0–7.4 (5 H, m, Ph); δ_c (CCl₄) 17.1, 46.0, 47.4, 75.4, 118.3, 125.4, 126.6, 127.8, 133.4, and 145.2 p.p.m.

Reaction of the Intermediates (2) with Carbonyl Compounds. Obtention of 1,3-Diols. General Procedure.—The corresponding carbonyl compound (25 mmol) was added to a stirred solution of the intermediate (2) (20 mmol) in ether–THF at –78 °C under argon. The reaction mixture was stirred at –78 °C for 1 h and then the temperature was allowed to rise to 20 °C overnight. The mixture was hydrolysed with water, neutralized with hydrochloric acid and extracted with dichloromethane. The organic layer was washed with water, dried (Na₂SO₄) and the solvents were removed (15 mmHg). Naphthalene was removed by sublimation (0.001 mmHg) and the residue was distilled or recrystallized to give the following 1,3-diols. 1-Phenylbutane-1,3-diol [3a; X = CH(OH)Ph] (Found: C, 72.3; H, 8.5. C₁₀H₁₄O₂ requires C, 72.26; H, 8.49%); ν_{max.} (neat) 3 400 (OH), 3 040, 1 610, 1 590, 1 500, 755, and 710 cm⁻¹ (Ph); δ_H (CCl₄) 1.1 (3 H, d, *J* 6 Hz, Me), 1.5–1.8 (2 H, m, CH₂), 3.7–4.1 (1 H, m, CHMe), 4.6–5.0 (1 H, m, CHPh), 5.6 (2 H, s, 2 × OH), and 7.1 (5 H, s, Ph); δ_c (CCl₄) 23.2, 46.9, 64.6, 67.6, 70.7, 73.9, 125.6, 126.8, 128.0, and 144.6 p.p.m.

2-Methyl-1-phenylpentane-2,4-diol [3a; X = C(OH)Me-CH₂Ph] (Found: C, 74.2; H, 9.4. C₁₂H₁₈O₂ requires C, 74.19; H, 9.34%); ν_{max.} (neat) 3 400 (OH), 3 040, 3 010, 1 600, 1 585, 1 495, 735, and 700 cm⁻¹ (Ph); δ_H (CCl₄) 0.75–1.3 (6 H, m, 2 × Me), 1.4 (2 H, br s, CH₂CH), 2.6 and 2.7 (2 H, 2 s, CH₂Ph), 3.3 (2 H, br s, 2 × OH), 4.0–4.6 (1 H, br signal, CH), and 7.0–7.4 (5 H, m, Ph); δ_c (CCl₄) 14.0, 23.1, 26.0, 26.2, 41.3, 48.1, 72.3, 125.9, 127.7, 130.4, and 137.9 p.p.m.

5-Methyl-1-phenylhexane-1,3-diol [3c; X = CH(OH)Ph] (Found: C, 75.1; H, 9.6. C₁₃H₂₀O₂ requires C, 74.96; H, 9.68%); ν_{max.} (neat) 3 400 (OH), 3 060, 3 020, 1 610, 1 590, 1 500, 760, and 710 cm⁻¹ (Ph); δ_H (CCl₄) 0.8 (6 H, d, *J* 6 Hz, 2 × Me), 1.1–1.4 (2 H, m, CH₂Pr¹), 1.5–1.9 (3 H, m, CH₂CHPh and CHMe), 3.65–4.0 (1 H, m, CHBu¹), 4.6–5.1 (1 H, m, CHPh), 5.1 (2 H, s, 2 × OH), and 7.2 (5 H, s, Ph); δ_c (CCl₄) 22.2, 23.1, 24.3, 45.7, 46.3, 66.5, 70.6, 125.5, 126.7, 128.0, and 144.8 p.p.m.

1,3-Diphenylpropane-1,3-diol [3d; X = CH(OH)Ph],¹⁴ ν_{max.} (Nujol) 3 440 (OH), 3 030, 3 000, 1 610, 1 500, 765, and 710 cm⁻¹ (Ph); δ_H (CDCl₃) 2.15 (2 H, t, *J* 6 Hz, CH₂), 2.85 (2 H, s, 2 × OH), 4.95 (2 H, t, *J* 6 Hz, 2 × CH), and 7.3 (10 H, m, 2 × Ph); δ_c (CDCl₃) 46.4, 71.6, 125.5, 127.35, 128.4, and 144.1 p.p.m.

2,5-Dimethyloct-7-ene-3,5-diol [3f; X = CH(OH)Pr¹] (Found: C, 69.6; H, 11.7. C₁₀H₂₀O₂ requires C, 69.72; H, 11.70%); ν_{max.} (neat) 3 460 (OH), 3 050, and 1 650 cm⁻¹ (HC=C); δ_H (CCl₄) 1.2 (6 H, 2 overlapping d, *J* 6 Hz, 2 × MeCH), 1.45, 1.5 (3 H, 2 s, MeCO), 1.6–2.1 (3 H, m, CH₂-CO and CHMe), 2.5–2.6 (2 H, 2 d, *J* 8 Hz, CH₂C=C), 3.8–4.1 (1 H, m, CHO), 4.8 (2 H, br s, 2 × OH), 5.1–5.5 (2 H, m, CH₂=C), and 5.7–6.4 (1 H, m, CH=C); δ_c (CCl₄) 17.7, 17.8, 18.1, 18.2, 25.4, 28.7, 34.2, 41.5, 41.7, 44.9, 49.1, 72.7, 72.8, 73.3, 73.5, 117.55, 117.7, 134.0, and 134.4 p.p.m.

3-Methyl-1-phenylhex-5-ene-1,3-diol [3f; X = CH(OH)Ph]

(Found: C, 75.7; H, 8.8. $C_{13}H_{18}O_2$ requires C, 75.69; H, 8.79%); ν_{\max} . (neat) 3 350 (OH), 3 050, 3 000, 1 650, 1 610, 1 500, 760, and 710 cm^{-1} (HC=C and Ph); δ_H (CCl_4) 1.05, 1.25 (3 H, 2 s, Me), 1.45—1.85 (2 H, m, CH_2CO), 2.1—2.35 (2 H, 2 d, J 8 Hz, $CH_2C=C$), 4.6—5.25 (5 H, m with s at 4.8, $CH_2=C$, $CHPh$, and $2 \times OH$), 5.5—6.0 (1 H, m, $CH=C$), and 7.2 (5 H, s, Ph); δ_C (CCl_4) 25.3, 28.1, 45.0, 48.0, 48.1, 71.2, 71.5, 73.0, 116.8, 117.9, 125.4, 125.6, 127.8, 128.1, 133.75, 134.4, 144.8, and 144.9 p.p.m.

2,4-Dimethyl-1-phenylhept-6-ene-2,4-diol [3f; X = C(OH)-Me CH_2 Ph] (Found: C, 76.7; H, 9.5. $C_{15}H_{22}O_2$ requires C, 76.88; H, 9.46%); ν_{\max} . (neat) 3 380 (OH), 3 060, 3 010, 1 650, 1 610, 1 500, 750, and 710 cm^{-1} (HC=C and Ph), δ_H (CCl_4) 1.0—1.4 (6 H, m, $2 \times Me$), 1.5—1.75 (2 H, m, CH_2CO), 2.1—2.4 (2 H, m, $CH_2C=C$), 2.5—2.9 (2 H, m, CH_2Ph), 3.7 (2 H, br s, $2 \times OH$), 4.85—5.2 (2 H, m, $CH_2=C$), 5.5—6.05 (1 H, m, CH), and 7.15 (5 H, s, Ph); δ_C (CCl_4) 28.1, 28.4, 28.8, 29.4, 48.4, 50.1, 50.4, 51.5, 73.25, 73.4, 73.8, 117.7, 126.0, 127.7, 130.6, 134.3, 134.5, 137.4, and 137.6 p.p.m.

2-Methyl-5-phenyloct-7-ene-3,5-diol [3h; X = CH(OH)Pr'] (Found: C, 76.8; H, 9.5. $C_{15}H_{22}O_2$ requires C, 76.88; H, 9.46%); ν_{\max} . (neat) 3 400 (OH), 3 060, 3 020, 1 650, 1 610, 1 500, 770, and 710 cm^{-1} (HC=C and Ph); δ_H (CCl_4) 0.55—1.0 (6 H, m, $2 \times Me$), 1.1—1.9 (3 H, m, CH_2CO and $CHMe$), 2.44, 2.65 (2 H, 2 d, J 8 Hz, $CH_2C=C$), 2.9—3.25 (1 H, m, CHO), 3.45—3.95 (2 H, br s, $2 \times OH$), 4.7—5.15 (2 H, m, $CH_2=C$), 5.25—5.75 (1 H, m, $CH=C$), and 6.95—7.45 (5 H, m, Ph); δ_C (CCl_4) 17.7, 18.1, 34.0, 43.4, 45.0, 45.4, 49.3, 73.2, 73.75, 76.1, 77.1, 117.9, 118.1, 124.95, 125.3, 126.2, 126.3, 127.85, 133.5, 133.8, 145.9, and 147.1 p.p.m.

1-(1-Hydroxycyclohexyl)-2-phenylpent-4-en-2-ol [3h; X = C(OH)(CH_2) $_5$] (Found: C, 78.5; H, 9.2. $C_{17}H_{24}O_2$ requires C, 78.42; H, 9.29%); ν_{\max} . (CCl_4) 3 400 (OH), 3 060, 3 000, 1 645, 1 605, 1 495, 770, and 705 cm^{-1} (HC=C and Ph); δ_H (CCl_4) 0.5—1.75 (10 H, m, $5 \times CH_2$ ring), 2.05 and 2.1 [2 H, 2 s, $CH_2(CO)_2$], 2.5 (2 H, d, J 8 Hz, $CH_2C=C$), 4.25 (2 H, br s, $2 \times OH$), 4.75—5.15 (2 H, m, $CH_2=C$), 5.3—5.75 (1 H, m, CH), and 7.0—7.65 (5 H, m, Ph); δ_C (CCl_4) 21.85, 25.5, 36.9, 40.9, 49.8, 51.0, 73.5, 76.7, 118.05, 125.2, 125.9, 127.6, 133.5, and 147.4 p.p.m.

2-Methyl-4-phenyloctane-2,4-diol [3k; X = C(OH)Me $_2$] (Found: C, 76.2; H, 10.2. $C_{15}H_{24}O_2$ requires C, 76.23; H, 10.23%); ν_{\max} . (neat) 3 400 (OH), 3 040, 3 000, 1 605, 1 495, 765, and 705 cm^{-1} (Ph); δ_H (CCl_4) 0.85 (3 H, deformed t, Me CH_2), 0.95 (4 H, m, CH_2CH_2Me), 1.3 (6 H, s, $2 \times MeCO$), 1.7 (2 H, m, CH_2Pr^a), 2.2 [2 H, s, $CH_2(CO)_2$], 4.55 (2 H, s, $2 \times OH$), and 7.2—7.65 (5 H, m, Ph); δ_C (CCl_4) 14.0, 22.9, 24.7, 29.1, 33.3, 46.2, 51.7, 72.6, 77.2, 125.4, 125.7, 127.6, and 147.3 p.p.m.

Attempted Preparation of the Intermediate (2l). 3-Methylbutan-3-ol (4).—An ether solution of n-butyl-lithium (22 mmol) was added to a stirred solution of 2-chloro-3-methylbutanol (1l) (2.45 g, 20 mmol) in THF (25 ml) at $-78^\circ C$ under argon. The mixture was stirred for 15 min and then cooled at $-100^\circ C$. A solution of lithium naphthalenide (42 mmol) in THF was added to the resulting solution and the reaction mixture was stirred at $-100^\circ C$ for 5 h. The mixture was hydrolysed with water (10 ml) and the temperature allowed to rise to $20^\circ C$ overnight. The resulting suspension was neutralized with hydrochloric acid and extracted with ether. The organic layer was washed with water, dried (Na_2SO_4), and condensed trap-to-trap (0.1 mmHg). The resulting condensate was oxymethylated by addition of mercury(II) acetate (6.36 g, 20 mmol) and water (30 ml). The reaction mixture was stirred overnight and the resulting suspension was made alkaline with 2.5M-sodium hydroxide.

Then, a solution of sodium borohydride (0.38 g, 10 mmol) in 2.5M-sodium hydroxide (10 ml) was added to the resulting mixture and stirred for 30 min. The mercury(0) which precipitated was filtered off and the resulting solution was extracted with ether. The organic layer was washed with water, dried (Na_2SO_4), and the solvents were removed (760 mmHg). The resulting residue was distilled to give the title compound (4) (0.95 g, 54%), b.p. 110—113 $^\circ C$ (760 mmHg) [lit.,¹⁰ b.p. 112.9 $^\circ C$ (760 mmHg)]; ν_{\max} . (CCl_4) 3 400 cm^{-1} (OH); δ_H (CCl_4) 0.8 (6 H, 2 d, J 6 Hz, $2 \times MeCH$), 1.0 (3 H, d, J 6 Hz, MeCO), 1.2—1.65 (1 H, m, $CHMe_2$), and 3.2—3.7 (2 H, m with s at 3.4, CHO and OH); δ_C (CCl_4) 17.9, 18.0, 19.6, 34.8, and 71.9 p.p.m.

Attempted Preparation of the Intermediate (2m). 1-Butylcyclohexene.—An ether solution of n-butyl-lithium (22 mmol) was added to a stirred solution of α -chlorocyclohexanone (2.6 g, 20 mmol) in THF (25 ml) at $-78^\circ C$ under argon. The mixture was stirred for 2 h and the temperature was allowed to rise to $-60^\circ C$. The resulting mixture was cooled to $-100^\circ C$, a solution of lithium naphthalenide (42 mmol) in THF was added and the mixture was stirred at $-100^\circ C$ for 5 h. The mixture was hydrolysed with water (10 ml) and the temperature allowed to rise to $20^\circ C$ overnight. The resulting suspension was neutralized with hydrochloric acid and extracted with ether. The organic layer was washed with water, dried (Na_2SO_4), and condensed trap-to-trap (0.1 mmHg). The resulting condensate was distilled to give the title compound (1.3 g, 47%), b.p. 67—69 $^\circ C$ (15 mmHg) [lit.,²² b.p. 180.8—182.9 $^\circ C$ (760 mmHg)]; ν_{\max} . (neat) 3 040 and 1 605 cm^{-1} (HC=C); δ_H (CCl_4) 0.65—1.05 (3 H, m, Me), 1.15—1.5 (4 H, m, CH_2CH_2Me), 1.5—1.75 (4 H, m, $2 \times CH_2CH_2C=C$ ring), 1.75—2.1 (6 H, m, $3 \times CH_2C=C$), and 5.3 (1 H, m, CH); δ_C (CCl_4) 13.15, 21.8, 22.1, 25.55, 24.6, 27.7, 29.4, 37.2, 119.95, and 136.75 p.p.m.

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