Reactions of 2,2-Dimethyl-1,1-diphenylpropan-1-ol with Acidic Reagents: a Reinvestigation of the Dehydration Products and Isolation of a Sulphonation Product

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Dehydration of 2,2-dimethyl-1,1-diphenylpropan-1-ol (1) with acidic reagents has been reinvestigated and shown to give 2-methyl-3,3-diphenylbut-1-ene (2), which rearranges rapidly under acidic conditions to give 3-methyl-2,3-diphenylbut-1-ene (3). Some earlier claims to have prepared the olefin (2) are shown to be erroneous. Prolonged treatment of the alcohol (1) with concentrated sulphuric acid gives a compound which appears to be a sultone.

PREVIOUS investigations [1-5] of the dehydration of 2,2-dimethyl-1,1-diphenylpropan-1-ol (1) have given contradictory results. Ramart-Lucas,[1] using acetic anhydride–

acetyl chloride as dehydrating agent, obtained a hydrocarbon which she suggested was a cyclopropane derivative. Bateman and Marvel,[2] using toluene-*p*-sulphonic

[1] Mme. Ramart-Lucas, *Ann. Chim. Phys.*, 1913, [8] **30**, 349.
[2] D. E. Bateman and C. S. Marvell, *J. Amer. Chem. Soc.*, 1927, **49**, 2914.
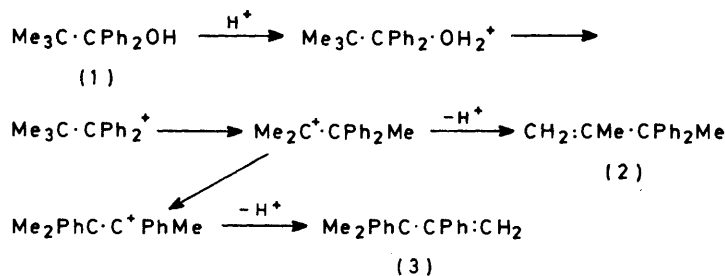[3] E. J. Skerrett and D. Woodcock, *J. Chem. Soc.*, 1952, 2804.
[4] G. E. M. Moussa and N. F. Eweiss, *J. Appl. Chem. Biotech.*, 1971, **21**, 93.
[5] J. Bertram, *Archiv. Pharm.*, 1975, **308**, 195.

acid (TsOH), concluded that the product was the olefin (2). Skerrett and Woodcock [3] appear to have accepted this conclusion without comment. More recently Moussa and Eweiss [4] have synthesised not only the olefins (2) and (3) but also several cyclopropane derivatives suggested by Ramart-Lucas, and have shown that (2) gives all the oxidation products found by her, including several formed by rearrangement. I.r. and n.m.r. spectroscopy were not available to the earlier investigators, but it is perhaps surprising that most of the later ones do not appear to have used them.

In our hands preliminary experiments with either TsOH or concentrated sulphuric acid as the dehydrating agent gave products which appeared, from their i.r. and n.m.r. spectra, to be mixtures in most cases, with the major product, sometimes the only one, showing only one signal assignable to the methyl protons, as expected for structure (3) rather than (2). When sulphuric acid was used, the olefin (3) appeared to be the only product, but when TsOH was used the n.m.r. spectrum showed two additional signals in the methyl region and also in the vinyl region, as expected for a mixture of (2) and (3). When portions of the alcohol (1) were heated with TsOH for times varying from 1 to 17 min, examination of the partially dehydrated products showed that the ratio of the signals attributed to (3) to those attributed to (2) increased with time of heating. Thus it appeared that (3) was formed by acid-catalysed rearrangement of (2). The rearrangements can be rationalised as in the Scheme involving a migration of methyl followed by

synthesis of the alcohol (4) by the reaction between dimethyldeoxybenzoin (PhCOCMe$_2$Ph) and methyl-magnesium iodide. In our hands this gave only unchanged starting material, but the reaction between dimethyldeoxybenzoin and methyl-lithium in ether gave the alcohol (4) in high yield as a white solid, in contrast to the liquid obtained by the previous authors,[4] having the expected spectral characteristics. Dehydration with TsOH regenerated the alkene (3). On treatment with dry hydrogen chloride in ether this alkene formed a hydrochloride which, on dehydrochlorination, regenerated the alkene (3). Ozonolysis gave the expected dimethyldeoxybenzoin. Hence we claim that the alkene (3) has now for the first time been fully characterised, and that previous authors had been handling, at best, a mixture of (2) and (3). If Bateman and Marvel [2] obtained a mixture of (2) and (3) ozonolysis would have given a mixture of ketones MePh$_2$CCOMe and PhCOCMe$_2$Ph, but the elemental analysis on which they relied as a criterion of purity would not distinguish between these separately and a mixture of the two. They oxidised the ketone with sodium hypobromite, which would oxidise only 3,3-diphenylbutan-2-one. At a later stage they extracted an alkaline solution with ether to remove unchanged ketone: this would remove dimethyldeoxybenzoin, leaving the product they isolated, viz. 2,2-diphenylpropionic acid. In fact our experiments showed that ozonolysis of the dehydration product of (1) gave a product which was, from i.r. and n.m.r. data, a mixture of two ketones.

$$Me_3C \cdot CPh_2OH \xrightarrow{H^+} Me_3C \cdot CPh_2 \cdot OH_2^+ \longrightarrow$$

(1)

$$Me_3C \cdot CPh_2^+ \longrightarrow Me_2C^+ \cdot CPh_2Me \xrightarrow{-H^+} CH_2:CMe \cdot CPh_2Me$$

(2)

$$Me_2PhC \cdot C^+PhMe \xrightarrow{-H^+} Me_2PhC \cdot CPh:CH_2$$

(3)

SCHEME

either formation of (2) or a migration of phenyl giving, after loss of a proton, (3). Similar mixtures were obtained when potassium hydrogen sulphate, oxalic acid, or acetic anhydride–acetyl chloride was used as dehydrating agent.

While this work was in progress a paper by Bertram [5] reported, on the basis of n.m.r. evidence, that dehydration of the alcohol (1) by phosphoric acid gave exclusively the olefin (3), but no reference was made to any other product or to the work of previous authors on the reaction.

MeCPh(OH)·CMe$_2$Ph   MeCPh$_2$·CMe$_2$·OH

(4)   (5)
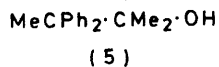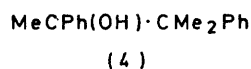
It seemed desirable to synthesise the olefins (2) and (3) unambiguously. Moussa and Eweiss [4] reported the

We were unable to prepare an authentic specimen of the alkene (2). In our hands, methyl 2,2-diphenyl-propionate and methylmagnesium iodide did not give the 100% yield of alcohol reported [3] even when left for 3 days,[4] but gave a product shown by the presence of an i.r. band at 1 715 cm^{-1} to contain a ketone, presumably 3,3-diphenylbutan-2-one. Distillation at reduced pressure did not separate this from the desired alcohol (5). Use of methyl-lithium in place of methyl-magnesium iodide also gave a product containing both ketone and alcohol, as reported for the reaction of free acids with alkyl-lithiums.[6a,b]
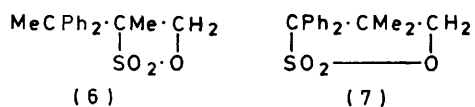
The reaction of 3,3-diphenylbutan-2-one with methyl-lithium also gave a mixture of alcohol and ketone.

[6] (a) R. Levine, M. J. Karten, and W. M. Kadunce, J. Org. Chem., 1975, 40, 1770; (b) C. Tegnor, Acta Chem. Scand., 1952, 6, 782.

Dehydration of this mixture with either TsOH or iodine gave mixtures of the alkenes (2) and (3). An attempted Wittig reaction was no more successful.

A mixture of the alkenes (2) and (3) was converted completely into (3) by heating with TsOH. We conclude that dehydration of the alcohol (1) with acidic reagents gives the alkene (2), which then rearranges rapidly to the alkene (3).

Isolation of a Sultone.—Treatment of the alcohol (1) with concentrated sulphuric acid at room temperature for a few days gave a white solid, $C_{17}H_{18}O_3S$. The mass spectrum showed no peaks between m/e 302 and 222, apart from the expected isotope peak, thus indicating the loss of SO_3 in one step. The n.m.r. spectrum at 100 MHz showed, besides other features, an AB quartet, with chemical shifts of the protons computed to be τ 5.57 and 6.45. Decoupling experiments showed the lower field component to be weakly coupled to a methyl group. The most likely formula to accommodate such a large chemical shift difference between A and B protons appears to be (6). Addition of a shift reagent moved the lower field components of the quartet further downfield than the higher field components, and increased the chemical shift difference. The ^{13}C n.m.r. signals indicated the presence of a methylene group in the region expected for carbon attached to oxygen, two methyl groups in slightly different environments, and a signal at 53.13 p.p.m. (quaternary carbon), close to that shown by methanesulphonyl chloride (52.74 p.p.m.). The i.r. spectrum showed very strong bands at 1 360 and 1 175 cm^{-1}, suggesting a sulphone or sulphonate. An S-benzylthiouronium salt could be isolated from the saponification product. The most likely route to (6) is dehydration of the alcohol to the alkene (2) followed by addition of the elements of sulphur trioxide. There is precedent for addition of complexes of sulphur trioxide

$$\underset{(6)}{\overset{\displaystyle MeCPh_2 \cdot \overset{|}{C}Me \cdot \overset{|}{C}H_2}{\underset{\displaystyle SO_2 \cdot O}{\rule{0pt}{0pt}}}} \qquad \underset{(7)}{\overset{\displaystyle \overset{|}{C}Ph_2 \cdot CMe_2 \cdot \overset{|}{C}H_2}{\underset{\displaystyle SO_2 \rule[0.5ex]{4em}{0.4pt} O}{\rule{0pt}{0pt}}}}$$

to a double bond,[7] but we know of none for such a reaction with sulphuric acid. β-Sultones are usually easily hydrolysed, often with rearrangement,[7] but we consider the alternative formula (7) to be inconsistent with the difference in proton chemical shifts (0.24 p.p.m.) of the two methyl groups.

EXPERIMENTAL

M.p.s were taken with a hot-stage apparatus or for samples in heated capillaries. ^1H N.m.r. spectra were measured for solutions in deuteriochloroform (tetramethylsilane as internal standard) with a Perkin-Elmer R12A or HA 100D spectrometer, ^{13}C n.m.r. spectra with a CFT-20 instrument, and i.r. spectra with a Perkin-Elmer 275 or 177 spectrometer (Nujol mulls or solutions in carbon tetrachloride).

[7] E. E. Gilbert, ' Sulfonation and Related Reactions,' Interscience, New York, London and Sydney, 1965, pp. 42—47 and references cited therein.

2,2-Dimethyl-1,1-diphenylpropan-1-ol (1) was prepared by the reaction between ethyl pivalate and phenylmagnesium bromide; b.p. 120° at 0.1 mmHg, n_D^{21} 1.5721 (lit.,[2] b.p. 148—150° at 2.5 mmHg, n_D^{20} 1.5748) (Found: C, 84.8; H, 8.4. Calc. for $C_{17}H_{20}O$: C, 85.0; H, 8.4%).

3-Methyl-2,3-diphenylbutan-2-ol (4).—To αα-dimethyldeoxybenzoin [8] (4.6 g, 0.020 mol) was added 2M-methyl-lithium in ether (10 ml), under nitrogen with stirring. After 5 min under reflux, the excess of methyl-lithium was destroyed by addition of isopropyl alcohol, followed by water. Extraction with ether gave a white solid, m.p. 70—71° (from ethanol–water) (Found: C, 84.5; H, 8.35. Calc. for $C_{17}H_{20}O$: C, 85.0; H, 8.4%), τ 2.75—2.79, (10 H, m), 8.33 (1 H, s, removed by D_2O), 8.53 (3 H, s), and 8.67 (6 H, d) (lit.,[4] liquid, b.p. 158—160° at 10 mmHg, n_D^{26} 1.5161).

3-Methyl-2,3-diphenylbut-1-ene (3).—3-Methyl-2,3-diphenylbutan-2-ol (6.5 g) was dissolved in benzene and refluxed with TsOH (0.6 g) for 15 min. The product was washed successively with water, sodium carbonate solution, and water, then dried (MgSO$_4$), and evaporated. Distillation gave the olefin (3), b.p. 96—98° at 0.1 mmHg, n_D^{21} 1.5729 (lit.,[4] b.p. 121° at 2 mmHg, $n_D^{29.5}$ 1.5478) (Found: C, 91.8; H, 8.3. Calc. for $C_{17}H_{18}$: C, 91.9; H, 8.1%). Treatment of this compound in ether–ethanol with dry hydrogen chloride, followed by evaporation, gave the hydrochloride, m.p. 105—109° (from ethanol–ether) (lit.,[2] 102—106°), τ 2.82 (10 H, m), 8.05 (3 H, s), 8.42 (3 H, s), and 8.54 (3 H, s). The hydrochloride (6 g) was refluxed for 1.5 h with NN-dimethylaniline (10 g). After acidification with dilute hydrochloric acid an oily layer separated, which was taken up in light petroleum (b.p. 60—80 °C); the solution was washed with dilute hydrochloric acid, water, sodium hydrogen carbonate solution, and water, then dried (Na$_2$SO$_4$). The regenerated 3-methyl-2,3-diphenylbut-1-ene was distilled (b.p. 146—150° at 8 mmHg); $\nu_{max.}$ 1 625 cm^{-1} (C:C), τ 2.5—3.4, (10 H, complex), 4.65 and 4.80 (2 H, ABq, J 2.5 Hz), and 8.55 (6 H, s). This alkene reacted only slowly (i) with bromine in carbon tetrachloride and (ii) with ethanolic potassium permanganate and sodium carbonate.

Ozonolysis of the Alkene (3).—The alkene (1.02 g) was dissolved in carbon tetrachloride and ozone was passed through to the extent of 30% excess. A little dilute hydrochloric acid was added, and the mixture left overnight. After separation, the organic layer was dried (MgSO$_4$) then evaporated to dryness. The oil formed crystallised on scratching and seeding to give αα-dimethyldeoxybenzoin (0.233 g, 23%), m.p. and mixed m.p. 42—44°. Both this solid and the unsolidified material gave the same oxime, m.p. and mixed m.p. 189—192°.

Reaction of 3,3-Diphenylbutan-2-one with Methyl-lithium.—3,3-Diphenylbutan-2-one (prepared [9] from acetophenone; m.p. 39—40°) (10 g) was treated with ethereal methyl-lithium [from lithium (2.5 g) and methyl iodide (11 ml)]. Work-up gave a product, b.p. 154—156° at 0.6 mmHg, which i.r. and n.m.r. data showed to be a mixture of ketone and alcohol. In a repetition, the reaction mixture was refluxed for 5 h then stirred overnight, but the product was still a mixture. T.l.c. on silica gel GF (50 : 50 v/v chloroform–light petroleum) separated the alcohol, 3,3-diphenyl-2-methylbutan-2-ol, τ 2.4—2.9, (10 H, complex), 8.21 (1 H, s), 8.37 (1 H, s, removable by D_2O), and 8.67 (6 H, s). Dehydration of this with TsOH gave the alkene (3).

Rearrangement of the Alkene (2).—A mixture of alkenes (2)

[8] D. W. Grant and R. Shilton, *J.C.S. Perkin I*, 1974, 135.
[9] K. Sisido and H. Nozaki, *J. Amer. Chem. Soc.*, 1948, 70, 776.

and (3) was prepared by dehydrating 1,1-diphenyl-2,2-dimethylpropan-1-ol with TsOH in benzene, and was judged by the relative intensities of the n.m.r. signals in the vinyl region to contain about 65% (2) and 35% (3). This was heated at 110 °C for 30 min with a small amount of TsOH. The product was extracted into ether and the extract was washed with water, dried (MgSO₄) and evaporated. The product was shown by its n.m.r. spectrum to be entirely the alkene (3).

Ozonolysis of the Mixture of Alkenes (2) *and* (3).—A mixture of the alkenes was dissolved in carbon tetrachloride and a 20% excess of ozone was passed through. Water was added and the mixture left overnight. The carbon tetrachloride layer was washed twice with water, then dried (MgSO₄) and evaporated. The product showed two carbonyl i.r. bands but no olefinic absorption. T.l.c. on silica gel [30 : 70 chloroform–light petroleum (b.p. 30—40 °C)] showed two main products, both showing strong carbonyl absorption (1 682 and 1 718 cm⁻¹; dimethyldeoxybenzoin and 3,3-diphenylbutan-2-one have bands at 1 680 and 1 715 cm⁻¹, respectively).

1-(1,1-*Diphenylethyl*)-1-*methylethane*-1,2-*sultone* (6).—2,2-Dimethyl-1,1-diphenylpropan-1-ol (19.65 g) was shaken with concentrated sulphuric acid (20 ml) for 5 min, whereupon it became blood-red. After 5 days the mixture had deposited a pale solid and become viscous. Water (50 ml) was added, followed by sodium hydroxide solution until the mixture was alkaline. The liquid was decanted and light petroleum added, forming a white solid (23.66 g, 95.7%). Crystallisation from ethanol gave white *crystals*, m.p. 130—131° (Found: C, 67.2; H, 6.2; S, 10.7. $C_{17}H_{18}O_3S$ requires C, 67.5; H, 6.01; S, 10.6%), saponification value 308, m/e 302, 222, 118 (base peak) and other high intensity peaks, τ (100 MHz) 8.54 (3 H, s), 8.30 (3 H, s), 6.53, 6.38, 5.63, and 5.50, (2 H, ABq, CH₂), and 2.52—2.95, (10 H, complex) [on addition of Eu(fod)₃ the AB quartet was moved considerably downfield, the methyl signals somewhat less], δ_C 24.78 and 25.08 (quartets in off-resonance spectra), 52.13, 57.44 (triplet in off-resonance spectra), 97.04, 126.09, 127.16, 128.47, 137.30, and 138.30, $\nu_{max.}$ 1 360vs, 1 278s, 1 225s, and 1 175vs cm⁻¹.