

685. *Reduced Cyclic Compounds. Part V.* The Preparation of 5 : 6-Dihydro-3-methyl-4H-pyran and its Conversion into 4-Methylhex-trans-4-en-1-ol.†*

By M. F. ANSELL and B. GADSBY.

The preparation of 5 : 6-dihydro-3-methyl-4H-pyran and its conversion, involving ring scission of 3-chlorotetrahydro-2 : 3-dimethylpyran by sodium, into 4-methylhex-trans-4-en-1-ol ‡ are described. The configuration of the alcohol is deduced by comparison of its derivatives with those of the 4-methylhept-4-en-1-ols obtained from tiglic and angelic acid, methyl 3-methylpent-trans-3-enoate, and *cis*- and *trans*-2-bromobut-2-ene. The mechanism of the ring scission of 3-chlorotetrahydropyrans is discussed.

THE use of 2 : 3-dichlorotetrahydropyran in the preparation of the ω -arylolefinic alcohol (I; R = R' = H) and its cyclodehydration to the hydrocarbon (II; R = R' = H) has been described.¹ To extend this synthesis to compounds containing an angular methyl group, 5 : 6-dihydro-2- and -3-methyl-4H-pyran are required: only the former has been previously reported.²

A convenient and unambiguous route to 2 : 3-dihydro-4H-pyran is the Diels-Alder reaction of acraldehyde with a vinyl ether,³ followed by hydrogenation to the 2-alkoxy-tetrahydropyran and pyrolysis to yield the dihydropyran (III \rightarrow VII; R = H). This route is adaptable; 2 : 3-dihydro-4-methyl- and 2 : 3-dihydro-2-methoxy-5-methyl-4H-pyran have been prepared from crotonaldehyde and 2-methylacraldehyde respectively.^{4, 5} We have utilised it for the preparation of 5 : 6-dihydro-3-methyl-4H-pyran (VII; R = Me) from acraldehyde (III) and ethyl propenyl ether (IV; R = Me).

* Part IV, *J.*, 1958, 2955.

† Presented in part at the XVIth Internat. Congr. Pure Appl. Chem., Paris, 1957.

‡ The prefix *cis* or *trans* refers to the main chain in accordance with I.U.P.A.C. recommendations (cf. *J.*, 1952, 5059).

¹ Ansell and Selleck, *J.*, 1956, 1238.

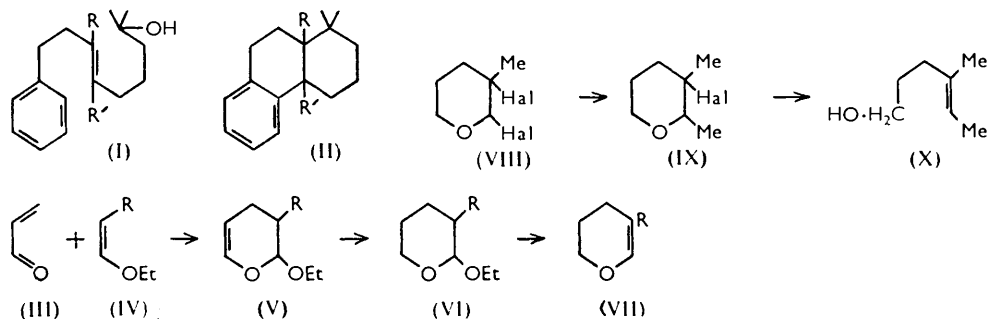
² Perkin, *J.*, 1887, **51**, 702.

³ Longley and Emerson, *J. Amer. Chem. Soc.*, 1950, **72**, 3079.

⁴ Smith, Norton, and Ballard, *ibid.*, 1951, **73**, 5267.

⁵ Parham and Holmquist, *ibid.*, p. 913.

For the catalytic pyrolysis of 1:1-diethoxypropane (obtained from ethyl orthoformate and excess of ethylmagnesium bromide ⁶ rather than excess of orthoformate ⁷) into ethyl propenyl ether, both acid ⁸ and kaolin ⁹ have been used. We found the latter more convenient. Alumina was unsuitable. Condensation of the propenyl ether with acrolein at 180° yields 2-ethoxy-2:3-dihydro-3-methyl-4*H*-pyran (V; R = Me) smoothly,



whose structure was confirmed by hydrolysis to 2-methylglutaraldehyde, identified by conversion into 2-methylglutaric acid. Hydrogenation of the ether (V; R = Me) gave 2-ethoxytetrahydro-3-methylpyran (VI) which was pyrolysed over a kaolin catalyst (cf. the preparation of ethyl propenyl ether above) to yield 5:6-dihydro-3-methyl-4*H*-pyran (VII; R = Me). Previous workers ^{4,5} have used an acid catalyst at this stage.

Addition of chlorine or bromine to 5:6-dihydro-3-methyl-4*H*-pyran (VII; R = Me), and coupling of the resultant compound (VIII) with methylmagnesium bromide readily yielded the 3-halogenotetrahydro-2:3-dimethylpyran (IX) (presumably as a *cis-trans*-mixture). The bromide (IX) lost hydrogen bromide on distillation under reduced pressure giving a dihydro-2:3-dimethylpyran isolated in the subsequent stage, but the chloride was stable. Both halogeno-compounds readily underwent ring scission with sodium to yield as the sole product 4-methylhex-*trans*-4-en-1-ol (X) whose structure was confirmed by the formation of acetaldehyde on ozonolysis and the known 4-methylhexan-1-ol ¹⁰ on hydrogenation. The evidence for the allocation of the *trans*-configuration to this alcohol is discussed below.

4-Methylhex-4-en-1-ols

Source of alcohol	B. p.°/ mm.	n_D^{20}	α -Naphthyl- urethane, m. p.*	4-Diphenyl- urethane, m. p.*
Ring scission	82/16	1.4512	76.5—77°	97—98°
Tiglic acid	82/16	1.4512	76.5—77	97—98
Methyl 3-methylpent- <i>trans</i> -3-enoate .	79/16	1.4520	75.5—76	—
Angelic acid	80/16	1.4504	73.5—74.5	94—95
2-Bromobut- <i>trans</i> -2-ene	78/15	1.4498—1.4506	61—65 †	93—95 †
2-Bromobut- <i>cis</i> -2-ene	78.5/15.5	1.4499—1.4507	65—67 †	99.5—101 †

* M. p.s after two recrystallisations except those marked † which are after six recrystallisations.

A possible route to pure *cis*- and *trans*-4-methylhex-4-en-1-ols starts from methyl 3-methylpent-3-enoate which is obtainable ¹¹ stereochemically pure by the Favorski rearrangement of 3:4-dibromo-3-methylpentan-2-one. Unfortunately the configuration of this ester, although accepted as *trans* by Wagner ¹¹ and by Loftfield,¹² is not firmly

⁶ Wood and Comley, *J. Soc. Chem. Ind.*, 1923, **42**, 430 T.

⁷ Kranzfelder and Vogt, *J. Amer. Chem. Soc.*, 1938, **60**, 1714.

⁸ Voronkov, *J. Gen. Chem. (U.S.S.R.)*, 1950, **20**, 2060.

⁹ Deschamps, Paty, and Pineau, *Compt. rend.*, 1954, **238**, 2006.

¹⁰ Huston and Agett, *J. Org. Chem.*, 1941, **6**, 123.

¹¹ Wagner, *J. Amer. Chem. Soc.*, 1949, **71**, 3214.

¹² Loftfield, *ibid.*, 1951, **73**, 4707.

established. The parent acid was assigned the *trans*-configuration by Kon, Linstead, and Wright¹³ on the basis of its non-identity with a stereoisomeric acid "provisionally called *cis*." However, the allocation of a *trans*-configuration to this acid is consistent with our own results (see below).

Methyl 3-methylpent-*trans*-3-enoate was reduced to 3-methylpent-*trans*-3-en-1-ol. Conversion of the latter into the *cis*-isomer¹⁴ by the addition of chlorine (*trans*), elimination (*trans*) of hydrogen chloride with propanolic potassium hydroxide, and removal of the resulting vinyl halogen atom with sodium in liquid ammonia, gave 3-methylpent-*cis*-3-en-1-ol as expected, but in low yield. Both these alcohols gave acetaldehyde on ozonolysis, and 3-methylpentan-1-ol¹⁰ on hydrogenation. An attempt to convert the *trans*-alkenol into 1-chloro-3-methylpent-*trans*-2-ene with thionyl chloride and pyridine was unsuccessful,¹⁵ but the toluene-*p*-sulphonate was readily formed and with sodium iodide in acetone yielded 1-iodo-3-methylpent-*trans*-2-ene. The Grignard reagent from this iodide reacted with formaldehyde to give 4-methylhex-*trans*-4-en-1-ol, whose α -naphthylurethane was identical with that obtained from the alcohol prepared in the ring scission, thus establishing the stereochemical homogeneity of the latter. In view of the low yields obtained in the above sequence of reactions the conversion of 3-methylpent-*cis*-3-en-1-ol into the homologous alcohol was not attempted.

An alternative route to *cis*- and *trans*-4-methylhex-4-en-1-ol is from the readily available¹⁶ stereochemically pure tiglic (XII) and angelic acid (XIII) whose configurations are well established.¹⁷ This route necessitates the use of allylic halides as intermediates, and although such compounds have been used successfully in the preparation of authentic *cis*- and *trans*-isomers¹⁸ stereoisomerisation or rearrangement may occur. Tiglic (XII) and angelic acid (XIII) were reduced to the allylic alcohols (XI and XIV) which were then treated with phosphorus tribromide. From both alcohols it is conceivable¹⁹ that essentially the same equilibrium mixture of pentenyl bromides (XV, XVI, and XVII) could be obtained in which, by analogy with the preferential stability of tiglic acid,²⁰ the primary halide present would be predominantly (XV). While primary allylic halides react with ethyl sodiomalonate by an S_N2 mechanism with retention of configuration, rearrangement may occur by an S_N2' mechanism.²¹ Further the secondary halide (XVI) may react by an S_N2' mechanism to yield structurally the same product as is obtained from the primary halide by a S_N2 mechanism. However, this route yields the more thermodynamically stable product²² which would be expected to be the *trans*-isomer (XVIII). Thus treatment of the pentenyl halides, from either source, with ethyl sodiomalonate followed by hydrolysis, decarboxylation, and reduction, would be expected to give a mixture of the alcohols (XVIII, XIX, and XX) in which the *trans*-isomer (XVIII) would predominate. This result was achieved experimentally. The heptenol mixture derived from tiglic acid yielded 2 : 3-dimethylpent-1-en-5-ol (XIX) [detected by infrared bands at 887 and 1650 cm^{-1} ($=\text{CH}_2$)] and 4-methylhex-4-en-1-ol (ozonolysis gave acetaldehyde and hydrogenation gave 4-methylhexan-1-ol), the latter identical with the alcohol obtained in the ring scission which has already been shown to be stereochemically pure and which we therefore consider from the above discussion to be *trans*. Fractional distillation of the heptenol mixture derived from angelic acid afforded 2 : 3-dimethylpent-1-en-5-ol (XIX) and 4-methylhex-4-en-1-ol (ozonolysis gave acetaldehyde, and hydrogenation gave 4-methylhexan-1-ol)

¹³ Kon, Linstead, and Wright, *J.*, 1934, 599.

¹⁴ Cf. Hoff, Greenlee, and Boord, *J. Amer. Chem. Soc.*, 1951, **73**, 3329.

¹⁵ Cf. Ansell and Brown, *J.*, 1957, 1788.

¹⁶ Buckles and Mock, *J. Org. Chem.*, 1950, **15**, 680.

¹⁷ Korte and Behner, *Chem. Ber.*, 1956, **89**, 2675; Titov, *Zhur. obshchei Khim.*, 1948, **18**, 1467; *Chem. Abs.*, 1949, **43**, 2166.

¹⁸ Birch and McAllan, *J.*, 1951, 2556.

¹⁹ Cf. Hatch and Journey, *J. Amer. Chem. Soc.*, 1953, **75**, 3712.

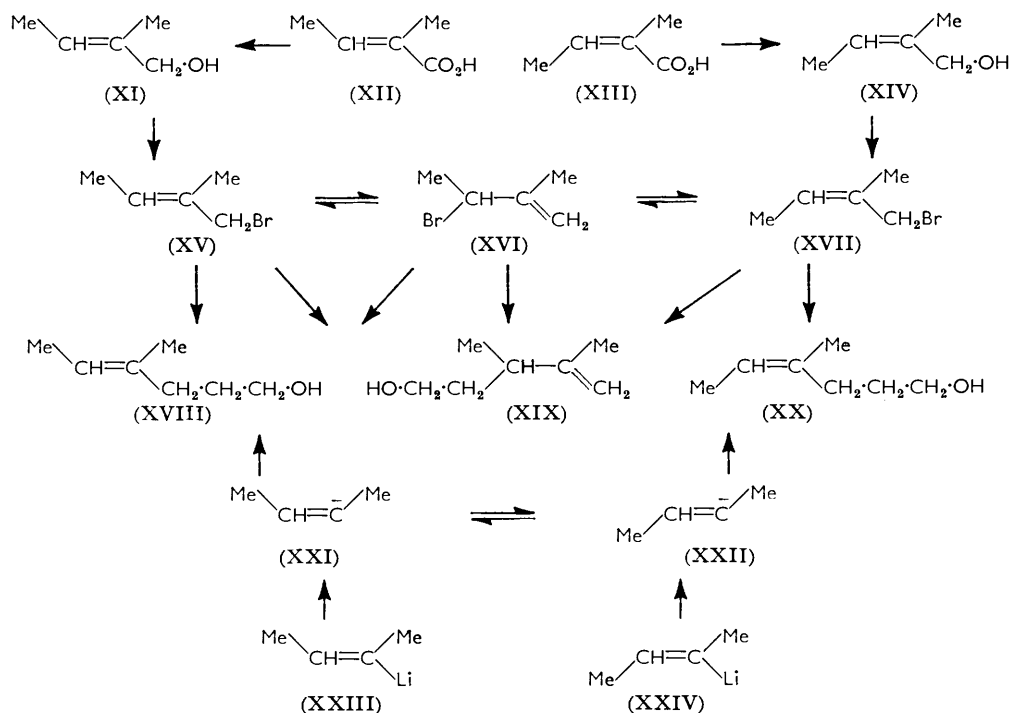
²⁰ Buckles, Mock, and Locatell, *Chem. Rev.*, 1955, **55**, 659.

²¹ De Wolfe and Young, *ibid.*, 1956, **56**, 753.

²² Prévost, *Ann. Chim. (France)*, 1928, **10**, 113; Valette, *ibid.*, 1946, **3**, 644.

which, as judged from the melting points of its derivatives (see Table), was predominantly the *trans*-isomer.

A third route to 4-methylhex-4-en-1-ol is the reaction of 2-lithiobut-2-ene with trimethylene oxide. This chain extension procedure, which has been used with alkyl- and aryl-lithiums and Grignard reagents,²³ has not previously been used with an alkenyl-lithium. Reaction of the lithio-derivatives (XXIII and XXIV) of *cis*- and *trans*-but-2-ene



with carbon dioxide has been shown to be predominantly stereospecific,²⁴ although the retention of configuration is greater with the *trans*-isomer (the *cis*-isomer yields angelic and tiglic acid in the ratio of approximately 3 : 7 whereas with the *trans*-isomer the ratio is approximately 9 : 1). We have found that when either of these alkenyl-lithiums reacts with trimethylene oxide a mixture of *cis*- and *trans*-4-methylhex-4-en-1-ols is obtained, from which can be isolated, by repeated recrystallisation, derivatives whose melting points were depressed in admixture with those of the 4-methylhex-4-en-1-ols obtained from other sources, and are therefore considered to be derived from 4-methylhex-*cis*-4-en-1-ol, which must be predominant in the product. We attribute this result to the use in the trimethylene oxide reaction of a higher reaction temperature than in the carbonation; this accentuates the tendency shown in the latter reaction for the formation of compounds derived from the *trans*-bromide. A similar thermal effect is shown in the carbonation of 2-lithio-octane²⁵ (from (–)-2-iodo-octane) which proceeds with partial retention of configuration at –70° but with complete racemisation if the intermediate organometallic compound is allowed to warm to 0°. If it is accepted²⁶ that retention of configuration normally occurs in both the formation and the reaction of the alkenyl-lithiums, and that the reaction proceeds *via* a carbanion intermediate, then the retention of configuration by the latter

²³ Searles, *J. Amer. Chem. Soc.*, 1951, **73**, 124.

²⁴ Dreiding and Pratt, *ibid.*, 1954, **76**, 1902.

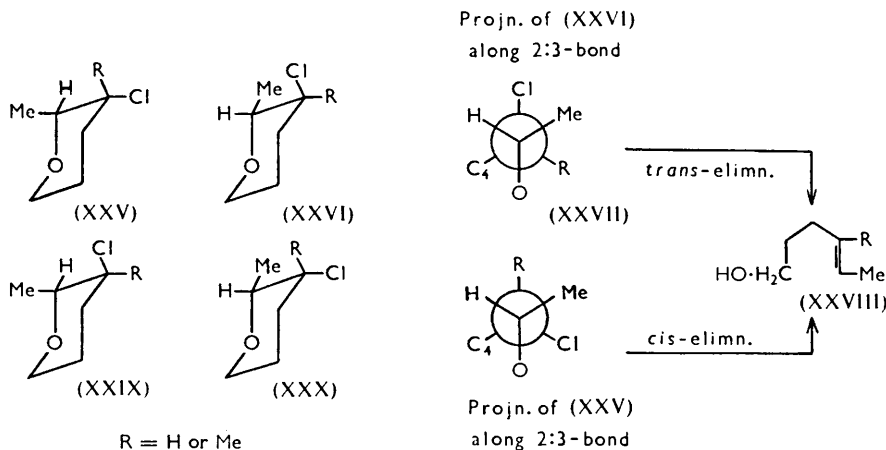
²⁵ Letsinger, *ibid.*, 1950, **72**, 4842.

²⁶ Braude, "Progress in Organic Chemistry, Vol. III," Butterworths, London, 1955, p. 193.

must be temperature-dependent. Thus 2-lithiobut-*cis*- and -*trans*-2-ene (XXIII and XXIV) can give rise to the carbanions (XXI and XXII) which would be in equilibrium, with the more stable *trans*-form (XXII) predominating at the higher temperature, which would give rise to 4-methylhex-*cis*-4-en-1-ol (XX).

On the basis of the above results, although no rigid proof is available of the configuration of the 4-methylhex-4-en-1-ol obtained by the ring fission of 3-chlorotetrahydro-2:3-dimethylpyran (IX), the results are consistent with its being the pure *trans*-isomer.

The infrared spectra of *cis*- and *trans*-isomers containing a trisubstituted double bond have not been extensively studied²⁷ and the infrared spectra of our compounds have not been sufficiently distinct for this method to be useful for the allocation of configurations or for differentiation between the isomers.



Various mechanisms have been suggested^{28,29} for the ring fission of 3-halogenotetrahydropyrans. Any mechanism proposed must account for the fact that both *cis*- and *trans*-2-alkyl-3-chlorotetrahydropyran and, as we have shown, 3-chlorotetrahydro-2:3-dimethylpyran yield *trans*-alk-4-en-1-ols. Crombie and Harper²⁹ have put forward such a mechanism, but a better insight into a possible mechanism is obtained by a study of the conformations of the reactants.

If it is accepted that the tetrahydropyran ring exists in a chair form,³⁰ then in the substituted 3-chlorotetrahydropyran in which the 3-chlorine and the 2-hydrogen atom are *cis* to each other the two possible conformations are (XXV) and (XXVI). Models show that in (XXV) there is interaction between the 2-methyl group and the axial 6-hydrogen atom and that (XXVI) is therefore the preferred conformation. In the latter, the equatorial 3-chlorine atom, C₍₃₎, C₍₂₎, and the oxygen atom are coplanar (see XXVII). This arrangement meets the steric requirements³¹ for a concerted *trans*-elimination of chlorine and alkoxy. This would be initiated by nucleophilic attack of the surface electrons of the sodium on the chlorine atom followed by electron-recession to C₍₂₎, then fission of the C₍₂₎-oxygen bond with release of two sodium ions. The resultant alk-4-en-1-ol (XXVIII) would have a *trans*-configuration. This mechanism is an elaboration of that suggested by Crombie and Harper.²⁹ For ring fission of the stereoisomeric substituted 3-chlorotetrahydropyran (2-hydrogen and 3-chlorine *trans*) to yield the *trans*-alk-4-en-1-ol (XXVIII), *cis*-elimination must occur. A study of models of the

²⁷ Bellamy, "Infra-red Spectra of Complex Molecules," Methuen, London, 1954.

²⁸ Paul, *Bull. Soc. chim. France*, 1933, **53**, 421; 1935, **2**, 745; Robinson and Smith, *J.*, 1936, 195; Amstutz, *J. Org. Chem.*, 1944, **9**, 310.

²⁹ Crombie and Harper, *J.*, 1950, 1707, 1714.

³⁰ Reeves, *J. Amer. Chem. Soc.*, 1949, **71**, 215, 2116.

³¹ Ingold, "Structure and Mechanism in Organic Chemistry," Cornell Univ. Press, 1953, p. 465.

possible conformations (XXIX) and (XXX) shows that in the former there is steric interference between the 2-methyl group, the 3-chlorine atom, and the axial 6-hydrogen atom, and the latter is therefore the preferred conformation. In (XXX) the 3-chlorine, C₍₃₎, C₍₂₎, and the oxygen atom are not coplanar (see XXXI) and a concerted *trans*-elimination is not sterically probable. The reaction might therefore proceed non-concertedly as proposed by Crombie and Harper²⁹ whereby C₍₂₎ becomes a carbonium ion and steric factors promote the formation of the *trans*-alk-4-en-1-ol (XXVIII) rather than a *cis-trans*-mixture of alkenols. An alternative mechanism is that owing to the close proximity of the axial 3-chlorine atom and the oxygen atom in conformation (XXX) (cf. XXXI), these atoms may make contact simultaneously with the surface of the sodium and a direct *cis*-elimination reaction, *via* a cyclic transition state (cf. ref. 32), may take place to yield the *trans*-alkenol (XXVIII). The above considerations account satisfactorily for the stereospecificity of the ring scission of substituted 3-halogenotetrahydropyrans by sodium.

Models show that when the 2-alkyl group in the above compounds is larger than methyl the same considerations apply and the ring scission by sodium of 2-alkyl-3-chlorotetrahydro-3-methylpyrans therefore constitutes a route to *trans*-alkenols of the type R·CH:CMc·CH₂·CH₂·CH₂·OH.

EXPERIMENTAL

(S) denotes distillation through a 30-plate spinning band column (Haage, Mulheim).

Petroleum denotes light petroleum (b. p. 60–80°).

Ethyl Propenyl Ether.—A mixture of heavy kaolin, Gooch asbestos, and water glass (10 : 2 : 4 by wt.), mixed with just sufficient water to bind it together, was spread on a sheet of asbestos paper and dried at 150° for 1 hr. The resulting semi-solid was broken into pieces (8/16 mesh) and loosely packed, together with a thermometer, into a 30 × 2 cm. Pyrex tube, arranged vertically in an electrically heated furnace. This packed tube was then heated at 300° for 2 hr. in a stream of dry nitrogen to complete drying of the catalyst. 1 : 1-Diethoxypropane (400 g.) was passed through the tube (340–350° int. temp.) at the rate of 2 small drops per sec. The product, collected over anhydrous potassium carbonate, was washed with ice-cold saturated sodium carbonate solution (2 × 200 ml.), dried (K₂CO₃), and distilled through a 30 × 2 cm. column packed with Dixon gauze; it yielded ethyl propenyl ether (144 g., 67·7% on acetal consumed), b. p. 66–72°, n_D^{20} 1·3965 (Deschamps *et al.*⁹ record b. p. 68–70°, n_D^{20} 1·3965), together with 1 : 1-diethoxypropane (72 g.), b. p. 122–124°.

2-Ethoxy-2 : 3-dihydro-3-methyl-4H-pyran.—A mixture of redistilled acraldehyde (28 g., 0·5 mole), ethyl propenyl ether (60 g., 0·7 mole), and quinol (1·0 g.) was heated in an autoclave to 180°/11 atm. and kept at that temperature for 2 hr. The product was distilled under reduced pressure and the distillate fractionated through a 30 × 1 cm. column (as above) to give, after a forerun (6·0 g.), *2-ethoxy-2 : 3-dihydro-3-methyl-4H-pyran* (41 g., 57·5%), b. p. 149–152°, n_D^{20} 1·4356 (Found: C, 67·6; H, 9·95. C₈H₁₄O₂ requires C, 67·6; H, 9·8%).

2-Methylglutaraldehyde.—*2-Ethoxy-2 : 3-dihydro-3-methyl-4H-pyran* (12 g.) and 0·6N-hydrochloric acid (42·5 ml.) were stirred at 60° for 3 hr., then at room temperature for 3 hr., neutralised with sodium hydrogen carbonate solution, saturated with sodium chloride, and extracted with ether. Distillation of the dried (MgSO₄) extract gave *2-methylglutaraldehyde* (3·4 g., 36%), b. p. 86–88°/17 mm., n_D^{20} 1·4345 [bis-*p*-nitrophenylhydrazone, orange plates (from ethanol), m. p. 162–164°; bis-2 : 4-dinitrophenylhydrazone, insoluble orange crystals (washed with ethanol, benzene, and chloroform), m. p. 194° (Found: C, 45·0; H, 4·1; N, 23·3. C₁₈H₁₈O₈N₈ requires C, 45·4; H, 3·8; N, 23·6%)]. Longley and Emerson³ record b. p. 86–88°/17 mm., n_D^{25} 1·4330 (*p*-nitrophenylhydrazone, m. p. 167–169°).

Oxidation of *2-methylglutaraldehyde* (cf. ref. 3) gave *2-methylglutaric acid*, m. p. 75–77° undepressed on admixture with an authentic specimen.³³

2-Ethoxytetrahydro-3-methylpyran.—*2-Ethoxy-2 : 3-dihydro-3-methyl-4H-pyran* (60 g.) in ethanol (60 ml.) was hydrogenated at 31°/20 atm. in the presence of 5% of Raney nickel. Removal of the catalyst and fractionation through a 30 × 2 cm. column (as above) gave

²⁹ Barton, *J.*, 1949, 2174.

³³ Ansell and Hey, *J.*, 1950, 1683.

2-ethoxytetrahydro-3-methylpyran (54.5 g., 90%), b. p. 152—153°/760 mm., 46°/12 mm., n_D^{20} 1.4244 (Found: C, 66.6; H, 11.3. $C_8H_{16}O_2$ requires C, 66.7; H, 11.1%). With Brady's reagent it gave the 2:4-dinitrophenylhydrazone of 5-hydroxy-2-methylpentanal as orange plates (from aqueous alcohol), m. p. 121—122° (Found: C, 48.45; H, 5.25. $C_{12}H_{16}O_6N_4$ requires C, 48.65; H, 5.4%).

5:6-Dihydro-3-methyl-4H-pyran.—2-Ethoxytetrahydro-3-methylpyran (95 g.) was pyrolysed at the rate of 1 drop/2 sec. as in the preparation of ethyl propenyl ether; on fractionation through a 30 × 2 cm. column (as above), and distillation from sodium, it gave 5:6-dihydro-3-methyl-4H-pyran (38 g., 59%), b. p. 111—113°, n_D^{20} 1.4456 (Found: C, 73.2; H, 10.3. $C_6H_{10}O$ requires C, 73.5; H, 10.2%). A fractionated (S) sample had b. p. 113.5°, n_D^{20} 1.4458. With Brady's reagent it gave the same derivative (m. p. 122—123°) as its precursor.

3-Bromotetrahydro-2:3-dimethylpyran.—Dry bromine (ca. 11.5 ml.) was added to a stirred solution of 5:6-dihydro-3-methyl-4H-pyran (20 g.) in dry ether (40 ml.) at -60° until a permanent yellow colour was obtained. This was removed by addition of a few drops of the dihydropyran. The ethereal solution of the crude dibromide was added to a stirred solution of methylmagnesium bromide (from magnesium, 7.3 g.) in ether (765 ml.) at such a rate that gentle refluxing was maintained. After being stirred for another 15 min. the mixture was poured on an excess of ice and ammonium chloride (12 g.). The ethereal layer was separated and the aqueous layer extracted with ether (2 × 50 ml.). Distillation of the dried ($MgSO_4$) combined extracts gave 3-bromotetrahydro-3-methylpyran (23.5 g., 64%), b. p. 78—82°/20 mm., n_D^{20} 1.4843. This material partially decomposed on attempted fractional (S) distillation (Found: C, 43.7; H, 7.2; Br, 40.3. Calc. for $C_7H_{13}OBr$: C, 43.5; H, 6.7; Br, 41.5%).

3-Chlorotetrahydro-2:3-dimethylpyran.—Dry chlorine was passed into a stirred solution of 5:6-dihydro-3-methyl-4H-pyran (20 g.) in dry ether (40 ml.) at -20° until a permanent green colour was obtained which was removed by the addition of a little of the dihydropyran. The subsequent procedure was as for the 3-bromo-analogue. The final distillation gave 3-chlorotetrahydro-2:3-dimethylpyran (28.7 g., 84%), b. p. 55—58°/12 mm., n_D^{20} 1.4571. Fractional (S) distillation gave material of b. p. 54—56°/17 mm., n_D^{20} 1.4580—1.4569 (Found: C, 56.8; H, 8.7. $C_7H_{13}OCl$ requires C, 56.6; H, 8.75%).

Ring Scission of 3-Halogenotetrahydro-2:3-dimethylpyran.—The 3-halogenotetrahydro-2:3-dimethylpyran (0.12 mole) was added to a stirred suspension of sodium sand (11 g.) in ether (30 ml.) at such a rate that steady refluxing was maintained. After a further 1 hour's stirring, water was cautiously added, the ethereal layer separated, and the aqueous layer extracted with ether. Distillation of the dried ($MgSO_4$) combined extracts gave 4-methylhex-trans-4-en-1-ol (5.2 g., 39% from 3-bromo-, 10 g., 74% from 3-chloro-compound), b. p. 75—78°/10 mm., n_D^{20} 1.4512. Fractional (S) distillation gave only material of b. p. 82°/16 mm., n_D^{20} 1.4512 (Found: C, 73.4; H, 12.7. $C_7H_{14}O$ requires C, 73.7; H, 12.3%). The derived α -naphthylurethane (plates from petroleum) had m. p. 76.5—77° (Found: C, 75.9; H, 7.7; N, 5.0. $C_{18}H_{21}O_2N$ requires C, 76.3; H, 7.5; N, 4.9%), and the 4-diphenylurethane (laths from petroleum) had m. p. 97—98° (Found: C, 77.6; H, 7.3; N, 4.5. $C_{20}H_{23}O_2N$ requires C, 77.7; H, 7.4; N, 4.5%). Ozonolysis of the alcohol gave acetaldehyde, identified as the dimedone derivative, m. p. and mixed m. p. 140—141°. Hydrogenation (of 0.5 g.) in the presence of Adams catalyst gave 4-methylhexan-1-ol, n_D^{20} 1.4249 (α -naphthylurethane, m. p. 48.5—49°). Huston and Agett¹⁰ record n_D^{23} 1.4233 (α -naphthylurethane, m. p. 50°).

The forerun, obtained only in the distillation of the alcohol from 3-bromotetrahydro-2:3-dimethylpyran, was redistilled from sodium to yield a dihydro-2:3-dimethylpyran (1.6 g.), b. p. 132—135°, n_D^{20} 1.4416 (Found: C, 75.3; H, 10.9. Calc. for $C_7H_{12}O$: C, 75.0; H, 10.8%). Sachs³⁴ records b. p. 131° for 5:6-dihydro-2:3-dimethyl-4H-pyran.

3-Methylpent-trans-3-en-1-ol.—Methyl 3-methylpent-trans-3-enoate¹¹ (100 g.) was added during 20 min. to a stirred suspension of lithium aluminium hydride (45 g.) in ether (1200 ml.) at 5°. After being boiled and stirred for 2½ hr. the mixture was cooled, and water added. The ethereal layer was decanted, and the residue washed by decantation with ether (3 × 200 ml.). The combined ethereal solutions were washed with saturated sodium chloride solution (100 ml.), dried (K_2CO_3), and distilled to yield 3-methylpent-trans-3-en-1-ol (70 g., 90%), b. p. 63—65°/15 mm., n_D^{20} 1.4466. A fractionated (S) sample had b. p. 155°, n_D^{20} 1.4467 (Found: C, 71.5; H, 12.15. $C_8H_{12}O$ requires C, 71.9; H, 12.1%). The derived α -naphthylurethane (laths from petroleum) had m. p. 78—78.5° (Found: C, 75.1; H, 7.0. $C_{17}H_{19}O_2N$ requires C, 75.8; H, 7.1%).

³⁴ Sachs, *Bcr.*, 1899, 32, 62.

Ozonolysis of the alcohol gave acetaldehyde, identified as the dimedone derivative, m. p. and mixed m. p. 140—141°. Hydrogenation in the presence of Adams catalyst gave 3-methylpentan-1-ol (α -naphthylurethane, m. p. 56°). Huston and Agett¹⁹ record α -naphthylurethane, m. p. 58°.

3-Methylpent-cis-3-en-1-ol.—Dry chlorine (14 g.) was added to a stirred solution of 3-methylpent-*trans*-3-en-1-ol (20 g.) and antimony pentachloride (1.5 ml.) in chloroform (40 ml.) at -60°. The solution was stirred for 15 min., allowed to warm to room temperature, poured into water, and extracted with ether (2 \times 50 ml.). The combined extracts were dried (MgSO₄) and distilled, to give 3:4-dichloro-3-methylpentan-1-ol (15 g., 44%), b. p. 90—102°/0.1 mm., n_D^{18} 1.4840. The above dichloride (15 g.) was added to a stirred solution of potassium hydroxide (9.5 g.) in propanol (60 ml.), and the mixture stirred at 90° for 15 hr. Water (100 ml.) was added, and the mixture extracted with ether (2 \times 150 ml.), and dried (MgSO₄). The ethereal extracts were distilled to give 4-chloro-3-methylpent-*cis*-3-en-1-ol (3 g., 27%), b. p. 84—96°/12 mm., n_D^{19} 1.4660. The above chloroalkenol (3 g.) was added, during 15 min., to a stirred solution of sodium (3.5 g.) in redistilled liquid ammonia (50 g.). Excess of sodium was destroyed by solid ammonium chloride, and the solution obtained by addition of water was extracted with ether (2 \times 20 ml.). The dried (MgSO₄) extracts were distilled, to give 3-methylpent-*cis*-3-en-1-ol (1.2 g., 54%), b. p. 64—65°/18 mm., n_D^{20} 1.4452 (Found: C, 71.4; H, 12.05. C₈H₁₂O requires C, 71.9; H, 12.1%). The derived α -naphthylurethane (plates from petroleum) had m. p. 105° (Found: N, 5.4. C₁₇H₁₈O₂N requires N, 5.2%). Ozonolysis of the alcohol gave acetaldehyde, identified as the dimedone derivative, m. p. and mixed m. p. 140—141°. Hydrogenation in the presence of Adams catalyst gave 3-methylpentan-1-ol (α -naphthylurethane, m. p. 56—56.5°).

1-Iodo-3-methylpent-trans-3-ene.—A mixture of toluene-*p*-sulphonyl chloride (21 g.) and pyridine (10 g.) was warmed to 40°, then cooled rapidly to 0° with stirring and allowed to warm to room temperature. 3-Methylpent-*trans*-3-en-1-ol (10 g.) was added to the stirred suspension at 5—25°. After being stirred for a further 1 hr. the mixture was poured into water and extracted with ether (2 \times 100 ml.), and the extract washed with 25% sulphuric acid (100 ml.), then saturated sodium hydrogen carbonate solution (100 ml.), and dried (MgSO₄). The residue left on removal of the solvent was heated at 100°/10⁻² mm. for 30 min., to yield the derived toluene-*p*-sulphonate (22 g.). The latter was added to a stirred solution of sodium iodide (15 g.) in dry acetone (150 ml.), and the mixture heated under reflux for 3½ hr., then left overnight at room temperature. The ice-cold suspension was filtered and the residue washed with ether. After removal of solvent, the residue was washed with 10% aqueous sodium thiosulphate solution (2 \times 30 ml.), dried (MgSO₄), and distilled, to yield 1-iodo-3-methylpent-*trans*-3-ene (11.5 g., 65%), 61—62°/16 mm., n_D^{20} 1.5236 (Found: C, 34.7; H, 5.7. C₈H₁₁I requires C, 34.5; H, 5.3%).

4-Methylhex-trans-4-en-1-ol.—Formaldehyde [from dry paraformaldehyde (15 g.) heated at 180°] was carried in a stream of dry nitrogen into a stirred solution of the Grignard reagent from the above iodide (34.5 g.) and magnesium (4 g.) in ether (100 ml.). After 30 min. the mixture solidified. Ice and ammonium chloride solution were added, the ethereal layer was separated, and the aqueous layer was extracted with ether (3 \times 50 ml.). Fractional distillation (S) of the dried (MgSO₄) combined extracts gave 4-methylhex-*trans*-4-en-1-ol (2.5 g., 15%), b. p. 80°/17 mm., n_D^{20} 1.4520 (Found: C, 73.5; H, 12.2. Calc. for C₇H₁₄O: C, 73.7; H, 12.3%). The derived α -naphthylurethane (plates from petroleum) had m. p. 75.5—76.5° alone or on admixture with the derivative of the alcohol obtained in the ring fission experiment (Found: N, 5.0. Calc. for C₁₈H₂₁O₂N: N, 4.9%). Ozonolysis of the alcohol gave acetaldehyde, identified as the dimedone derivative, m. p. and mixed m. p. 140—141°. Hydrogenation in the presence of Adams catalyst gave 4-methylhexan-1-ol, n_D^{23} 1.4237 (α -naphthylurethane, m. p. 48—49°).

4-Methylhex-4-en-1-ol from Tiglic Acid.—3-Methylbut-*trans*-3-en-1-ol,³⁵ prepared by reduction of tiglic acid,¹⁷ was treated with phosphorus tribromide and pyridine,³⁶ and the resulting pentenyl bromide (90 g.) was added slowly to a stirred solution of sodiomalonic ester from ethyl malonate (95 g.) and sodium (13.7 g.) in alcohol (150 ml.), and the solution then stirred and boiled for 24 hr. Water was added to the cold solution, to dissolve the precipitated sodium bromide, and the mixture was extracted with ether (3 \times 100 ml.). Distillation of the dried (MgSO₄) extracts gave a C₁₂-alkenyl-malonic ester (84 g., 60.5%), b. p. 129—132°/14 mm.,

³⁵ Hatch and Noyes, *J. Amer. Chem. Soc.*, 1957, **79**, 345.

³⁶ Cf. Lauchenaer and Schinz, *Helv. Chim. Acta*, 1951, **34**, 1514.

n_D^{20} 1.4404 (Found: C, 63.7; H, 8.75. Calc. for $C_{12}H_{20}O_4$: C, 63.2; H, 8.8%). This ester (75 g.) was added, with stirring, to a cold solution of potassium hydroxide (67 g.) in water (100 ml.), followed by sufficient alcohol to produce homogeneity. After 15 hr. at room temperature, the solution was concentrated to half bulk under reduced pressure, cooled to 0° , made just acid to Congo-red with concentrated hydrochloric acid, and extracted with ether (4×50 ml.). The crude dicarboxylic acid obtained on evaporation of the dried ($MgSO_4$) extracts was decarboxylated at $150^\circ \pm 5^\circ$ for 2 hr. The product was dissolved in saturated sodium hydrogen carbonate solution and, after re-extraction with ether (3×100 ml.), the solution was acidified at 0° by stirring it with an equal volume of hexane and cautiously adding concentrated hydrochloric acid. The hexane layer was separated, and the aqueous layer extracted with hexane. Distillation of the dried ($MgSO_4$) extracts gave a C_7 -alkenoic acid (21.5 g., 51%), b. p. $112-114^\circ/12$ mm., n_D^{20} 1.4472 (Found: C, 65.7; H, 9.7. Calc. for $C_7H_{12}O_2$: C, 65.6; H, 9.4%). The acid (20 g.) in ether (40 ml.) was added to a stirred suspension of lithium aluminium hydride (8.5 g.) in ether (200 ml.) at such a rate that vigorous refluxing occurred. After being boiled and stirred for a further $\frac{1}{2}$ hr. the mixture was cooled, water added, and the ethereal solution decanted. The residue was washed by decantation with ether (2×25 ml.), and the dried ($MgSO_4$) combined extracts when distilled gave 14 g. of material, b. p. $84-86^\circ/18$ mm. The latter on fractional distillation (S) gave:

Fraction	B. p./14.5 mm.	Wt. (g.)	n_D^{20}	Infrared absorption at 887 and 1650 cm^{-1}
1	72—75°	1.2	1.4419	Strong
2	75—79.5	3.4	1.4450	Medium
3	79.5—80.5	2.3	1.4490	Absent
4	80.5	4.2	1.4512 *	Absent

* Constant for 6 fractions.

Fraction 4 was accepted as 4-methylhex-*trans*-4-en-1-ol (Found: C, 73.55; H, 12.1. Calc. for $C_7H_{14}O$: C, 73.7; H, 12.3%). The derived α -naphthylurethane (plates from petroleum) had m. p. $76.5-77^\circ$ (Found: N, 4.6. Calc. for $C_{18}H_{21}O_2N$: N, 4.9%), and the 4-diphenylurethane (laths from petroleum) had m. p. $97-98^\circ$ (Found: C, 77.5; H, 7.5; N, 4.6. Calc. for $C_{20}H_{23}O_2N$: C, 77.7; H, 7.4; N, 4.5%). The m. p.s of these derivatives were not depressed on admixture with the corresponding derivatives of the alcohol obtained by ring scission. Ozonolysis of the alcohol gave acetaldehyde (dimedone derivative, m. p. and mixed m. p. $140-141^\circ$). Hydrogenation in the presence of Adams catalyst gave 4-methylhexan-1-ol, n_D^{23} 1.4237 (α -naphthylurethane, m. p. $48-49^\circ$) (see above for previously recorded constants).

4-Methylhex-4-en-1-ol from *Angelic Acid*.—2-Methylbut-*cis*-2-en-1-ol (35 g.) obtained (by reduction³⁵ of angelic acid¹⁷) and pyridine (7 g.) were added to redistilled phosphorus tribromide (44 g.) at 0° during 30 min. and the mixture stirred at 0° for 1 hr., left overnight, and distilled at 15 mm. The crude distillate was dissolved in ether (50 ml.), washed with 10% aqueous sodium hydrogen carbonate (100 ml.) and water (50 ml.), dried ($MgSO_4$), and distilled, to give a pentenyl bromide (42 g., 70%), b. p. $124-130^\circ$, n_D^{20} 1.4794. The bromide was added to a stirred solution of sodiomalonic ester [from ethyl malonate (48 g.) and sodium (6.9 g.) in alcohol (90 ml.)], and the solution treated as above. Distillation of the product gave a C_{12} -alkenyl-malonic ester (41 g., 59%), b. p. $132-140^\circ/23$ mm., n_D^{20} 1.4400. This ester (41 g.) was stirred into a cold solution of potassium hydroxide (37 g.) in water (50 ml.) and ethanol (10 ml.), and after 7 days at room temperature was treated as above, to yield a crude oily dicarboxylic acid. The acid was decarboxylated at $150^\circ \pm 5^\circ$ for 2 hr. and the product purified as before, to yield on distillation a C_7 -alkenoic acid (9 g., 40%), b. p. $128-132^\circ/45$ mm., n_D^{20} 1.4468. This acid (9 g.) was dissolved in ether (20 ml.), added to a stirred suspension of lithium aluminium hydride (3.5 g.), and the mixture was boiled and stirred for $\frac{1}{2}$ hr. The residue was purified as before and distilled, to give 4 g. of material, b. p. $90-94^\circ/34$ mm. The latter on fractional distillation (S) gave:

Fraction	B. p./15.5 mm.	Wt. (g.)	n_D^{20}	Infrared absorption at 887 and 1650 cm^{-1}
1	71—75°	0.4	1.4420	Strong
2	75—79	0.5	1.4448	Medium
3	79—79.5	1.1	1.4480	Weak
4	79.5	1.7	1.4504	Absent

Fraction 4 was accepted as predominantly 4-methylhex-*trans*-4-en-1-ol (Found: C, 75.3; H, 12.5. Calc. for $C_7H_{14}O$: C, 73.7; H, 12.3%), The derived α -naphthylurethane (plates from petroleum) had m. p. 73.5—74.5° (Found: C, 76.3; H, 7.55; N, 5.0. Calc. for $C_{18}H_{21}O_2N$: C, 76.3; H, 7.5; N, 4.9%), and the 4-diphenylurethane (laths from petroleum) had m. p. 94—95°. Mixed m. p.s of these derivatives with those of the alcohol from the ring fission were 76—77° and 95—96° respectively. Ozonolysis of the alcohol gave acetaldehyde (dimedone derivative, m. p. and mixed m. p. 140—141°). Hydrogenation in the presence of Adams catalyst gave 4-methylhexan-1-ol, n_D^{20} 1.4240 (α -naphthylurethane, m. p. 48.5—49.5°).

4-Methylhex-4-en-1-ols from *cis*- and *trans*-2-Bromobut-2-ene.—Freshly distilled 2-bromobut-2-ene (80 g., 0.59 mole) was added during 1 hr. to a stirred suspension of lithium (9 g., 1.3 mole) in ether (1000 ml.) at -20° to -15° under nitrogen, and the mixture then stirred for a further 15 min. at -10° . A solution of trimethylene oxide³⁷ (37.8 g.) in ether (100 ml.) was added at this temperature and the mixture was then boiled and stirred under reflux for 1 hr. Benzene (750 ml.) was then added slowly while ether (ca. 1000 ml.) was distilled off, and the solution then boiled and stirred for a further 2½ hr., left overnight, then hydrolysed by the addition of a saturated solution of ammonium chloride (200 ml.). The organic layer was separated, and the aqueous layer extracted with ether (3 × 100 ml.). Distillation of the dried ($MgSO_4$) combined organic material gave, from 2-bromobut-*trans*-2-ene, 4-methylhex-4-en-1-ol (51 g., 73%), b. p. 73—78°/14 mm., n_D^{20} 1.4500, a portion of which on fractional distillation (S) gave material, b. p. 78°/15 mm., n_D^{20} 1.4498—1.4506 (Found: C, 73.2; H, 12.4. Calc. for $C_7H_{14}O$: C, 73.7; H, 12.3%), which yielded acetaldehyde (dimedone derivative, m. p. and mixed m. p. 140—141°) on ozonolysis. The derived α -naphthylurethane (from petroleum) had m. p. 54.5—55.5°, raised to 61—65° after six recrystallisations (Found: C, 76.5; H, 7.4; N, 4.8. Calc. for $C_{18}H_{21}O_2N$: C, 76.3; H, 7.5; N, 4.9%), and the 4-diphenylurethane (laths from petroleum) had m. p. 86—91°, raised to 93—95° after six recrystallisations (Found: C, 77.5; H, 7.3; N, 4.8. Calc. for $C_{20}H_{23}O_2N$: C, 77.7; H, 7.4; N, 4.5%). The organic material from 2-bromobut-*cis*-2-ene gave 4-methylhex-4-en-1-ol (39 g., 57.5%), b. p. 80—81°/17 mm., n_D^{20} 1.4506, a portion of which on fractional distillation (S) gave material, b. p. 78—78.5°/15.5 mm., n_D^{20} 1.4499—1.4507 (Found: C, 73.55; H, 12.6. Calc. for $C_7H_{14}O$: C, 73.7; H, 12.3%). The derived α -naphthylurethane (from petroleum) had m. p. 47—49.5°, raised to 65—67° after six recrystallisations (Found: C, 76.5; H, 7.8%), and the 4-diphenylurethane (laths from petroleum) had m. p. 94—95° raised to 99.5—101° after six recrystallisations (Found: C, 77.4; H, 7.6; N, 4.8%). These derivatives depressed the m. p. to about 60° and 90° respectively on admixture with those of 4-methylhex-*trans*-4-en-1-ol.

The authors are indebted to Professor M. J. S. Dewar for helpful advice and encouragement, to the D.S.I.R. for a maintenance award (to B. G.), to the University of London Central Research Fund for financial assistance, and to May and Baker Ltd. for help with hydrogenations.

CHEMISTRY DEPARTMENT, QUEEN MARY COLLEGE, UNIVERSITY OF LONDON,
MILE END ROAD, LONDON, E.1.

[Received, October 10th, 1957.]

³⁷ Noller, *Org. Synth.*, Coll. Vol. III, p. 835.