Oxidation Products of Diïsobutylene. Part III. Products from Ring-opening of* 1 : 2-*Epoxy*-2 : 4 : 4-*trimethylpentane.*

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The interaction of 1 : 2-epoxy-2 : 4 : 4-trimethylpentane with water, alcohols, amines, acids, and various other reagents has been examined. Ring-opening reactions in presence of acidic catalysts take place under mild conditions, but are accompanied by rearrangement to 2 : 4 : 4-trimethylpentanal and other side-reactions. On the other hand, interaction of the epoxide with basic reagents or under alkaline conditions usually gives good yields of the expected product, but high temperatures are necessary in order to attain reasonable rates of reaction.

The structures of the majority of the adducts have been proved by synthesis or otherwise, and accord with the general rule that with a reagent HX, the epoxide under acid conditions gives $CH_2Bu^t{\cdot}CMeX{\cdot}CH_2{\cdot}OH$, and under basic conditions (and also with hydrogen chloride in dry ether) gives $CH_2Bu^t{\cdot}CMe(OH){\cdot}CH_2X$. From reaction with various alcohols, a series of isomeric derivatives has thus been prepared by varying the catalyst.

The epoxide is hydrated to 2 : 4 : 4-trimethylpentane-1 : 2-diol in either dilute acid or alkali. Alkaline hydration has been successfully applied to some other epoxides that are sensitive to acids. The 1 : 2-diol is easily converted by acids into 2 : 4 : 4-trimethylpentanal or its cyclic acetal with the diol.

This paper describes the products obtained from 1 : 2-epoxy-2 : 4 : 4-trimethylpentane by reactions involving ring-opening without pinacolic rearrangement. We find that 1 : 2-epoxy-2 : 4 : 4-trimethylpentane (I) undergoes the conventional reactions of epoxides, but that the great ease of rearrangement to trimethylpentanal is a complicating factor. This has already been noted by Hickinbottom (*J.*, 1948, 1332). Ring-opening with acidic reagents or acid catalysts is rapid and exothermic, but is always accompanied by formation of 2 : 4 : 4-trimethylpentanal or its " dimer," and sometimes 2-*neo*pentylprop-2-en-1-ol as well. With basic reagents and alkaline catalysts, on the other hand, the epoxide reacts very sluggishly, and temperatures of 150° or higher are frequently necessary for reaction at a reasonable rate. An exception is the case of thiols, which react exothermally at room temperature in presence of alkalis. A summary of the reactions carried out is given in Table 1.

Hydration.—Hickinbottom (*loc. cit.*) expressed surprise at the preponderance of side-reactions during attempted hydration of the epoxide with aqueous sulphuric acid, although he quoted some other epoxides which behaved similarly. Prileschajev (*J. Russ. Phys. Chem. Soc.*, 1910, **42**, 1404) hydrated mixed 1 : 2- and 2 : 3-epoxy-2 : 4 : 4-trimethylpentane with water at room temperature, but found that the reaction was very slow. Danilow and Venus-Danilowa (*Ber.*, 1927, **60**, 1061) reduced isomerisation of 1 : 2-epoxy-2-phenylpropane by hydrating it with very dilute acid, in this case hydrochloric. Application of this technique was successful with 1 : 2- and 2 : 3-epoxytrimethylpentane; by agitation with 0·1N-sulphuric or -nitric acid at room temperature, a gently exothermic reaction ensued, and the diols were obtained after some hours in about 70% yields. This concentration of acid was the optimum; 0·1N-hydrochloric acid, however, gave very poor yields. All attempts to accelerate the reaction by warming only led to an increase of isomerisation; even when refluxed with water, the product was mainly aldehyde. Boiling aqueous alcohol gave some diol, but in this case the mixture was probably sufficiently acid (pH 3) to catalyse hydration.

The occurrence of some rearrangement, even under optimum conditions, during acid hydration suggested the possibility of hydration by aqueous alkali. Alkaline hydration of epoxides has in the past been neglected in favour of acidic catalysis, which is normally much more effective. Indeed, the existence of alkaline catalysis at all was demonstrated

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* Part II, preceding paper.

only recently (Lichtenstein and Twigg, *Trans. Faraday Soc.*, 1948, **44**, 905), although alkaline hydration had been employed in a few cases previously (Porret, *Helv. Chim. Acta*, 1944, **27**, 1321; Levene and Walti, *J. Biol. Chem.*, 1927, **73**, 263; Leroux, *Ann. Chim.*, 1910, **21**, 500; Bamberger and Lodter, *Annalen*, 1895, **288**, 100).

1 : 2-Epoxy-2 : 4 : 4-trimethylpentane was very stable to aqueous alkali of any strength at the atmospheric boiling point, and could in fact be steam-distilled unchanged from alkaline media. Hydration took place at a reasonable rate only above 150°, and preferably at 175—200°, with N-sodium hydroxide. No increase in ease of reaction could be found when more concentrated sodium hydroxide was used, but sodium carbonate less concentrated than 2N gave appreciable amounts of by-product. The catalytic power of the alkali is thus negligible, but its effect is to suppress side-reactions arising from rearrangement. The yield of diol under optimum conditions was 76%; as only 7% of high- and no low-boiling products were formed, the comparatively low yield may be due to difficulties of isolation.

The successful use of alkaline hydration to suppress side-reactions suggested its application to some other easily rearranged epoxides. This met with varying success. 2 : 3-Epoxy-2 : 4 : 4-trimethylpentane was almost entirely unchanged after 2 hr. with N-sodium hydroxide at 175°; increasing the time and temperature to 12 hr. at 200° gave 14% conversion into diol, but the rest of the epoxide was converted into 2 : 2 : 3 : 3-tetramethylbutanal and intermediate fractions. Increasing the concentration of the alkali to 5N under otherwise the same conditions partly suppressed the side-reactions but did not increase the amount of diol formed, and it was evident that alkaline hydration was of no value here. Styrene oxide was successfully hydrated to styrene glycol under similar conditions to those used for 1 : 2-epoxytrimethylpentane; this conversion has apparently not previously been achieved directly. The epoxide from α-methylstyrene, in the form of a purified oxidation product, was also converted into 2-phenylpropane-1 : 2-diol by this means.

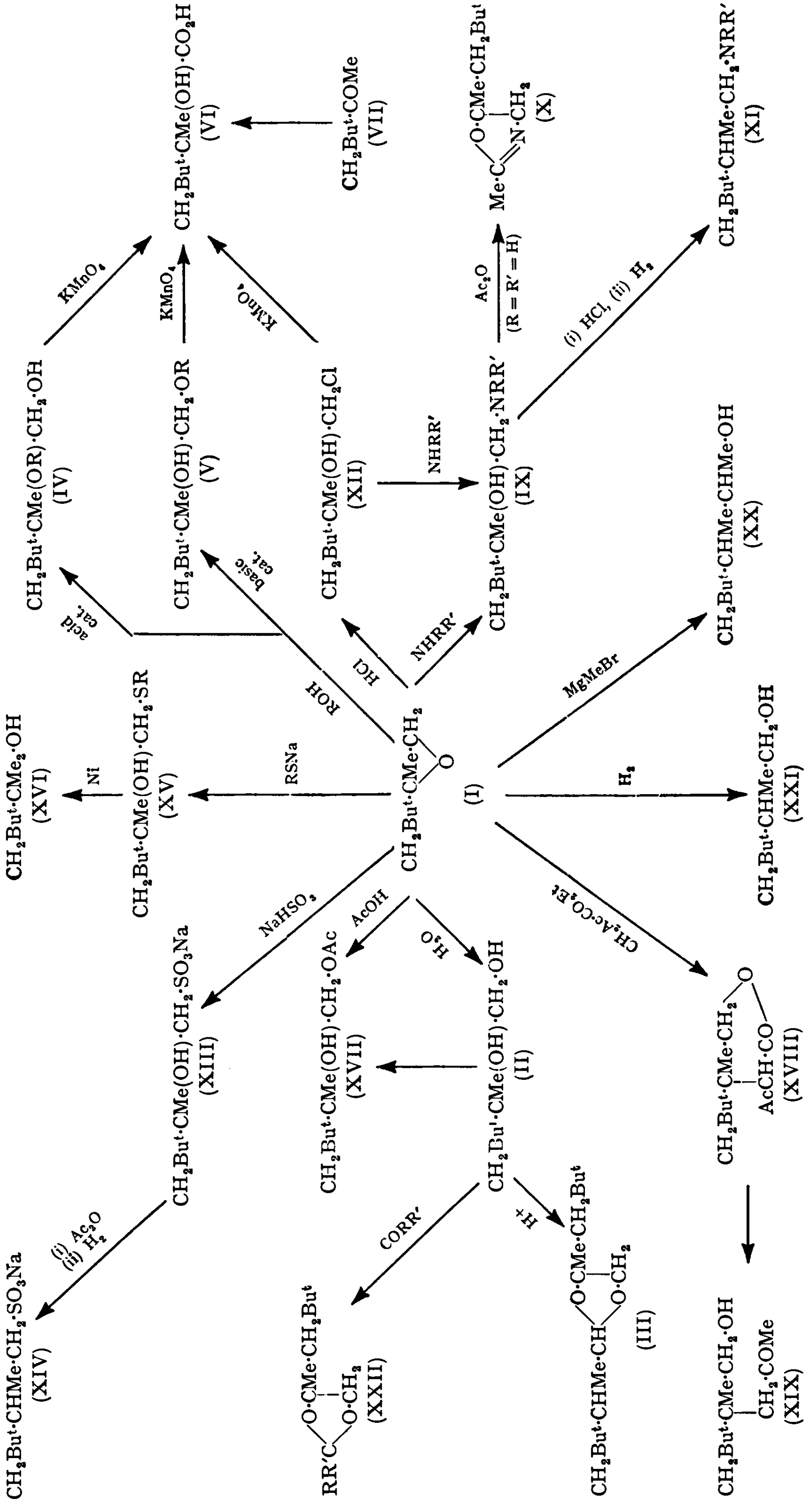
The 1 : 2-diol (II) is very sensitive to acids; water is eliminated on distillation at 15 mm. pressure, or simply on boiling in benzene solution, in either case with a trace of mineral acid, and it is quantitatively converted into an oil of somewhat higher b. p. This is without functional groups, and proved to be spectrographically identical with the "cyclic ether" obtained as a by-product from hydroxylation of 2 : 4 : 4-trimethylpent-1-ene (Byers and Hickinbottom, *J.*, 1948, 1328). Mugdan and Young (*J.*, 1949, 2995) showed this to be dihydro-4-methyl-4-*neo*pentyl-2-1′ : 3′ : 3′-trimethylbutyldioxole (III). Their method of synthesis, from the 1 : 2-diol (II) and trimethylpentanal (XXIV) in presence of a trace of mineral acid, was carried out on a very small scale, and is open to the criticism that the diol alone forms the same product under the same conditions. However, repetition with larger quantities, now easily available, gave a yield of 94% on diol plus aldehyde, so that there is no doubt that the aldehyde enters into the compound. Hence the structure postulated seems more reasonable than the dioxan structure advanced by Byers and Hickinbottom. The same cyclic acetal (III) is rapidly obtained if the glycol (II) is shaken with cold concentrated hydrochloric acid. Boiling the glycol with 6N-sulphuric acid gives a mixture of the cyclic acetal (III) and trimethylpentanal (XXIV).

In view of their ready formation from the diol, it seems that at least a part of the aldehyde and acetal formed as by-products during the acid hydration of the epoxide, except under the mildest possible conditions, and during hydroxylation of trimethylpentane, may have arisen from diol initially formed. The initial effect of acids on the diol (II) would presumably be to facilitate ionisation of the tertiary hydroxyl group, forming the ion (XXIII). This is also probably the intermediate in acid-catalysed ring opening of the epoxide, and evidently rearranges with considerable ease, by pinacolic change, to the aldehyde (XXIV):

$$\underset{\text{(II)}}{\mathrm{CH_2Bu^t{\cdot}CMe(OH){\cdot}CH_2{\cdot}OH}} \xrightarrow{H^+} \underset{\text{(XXIII)}}{\mathrm{CH_2Bu^t{\cdot}\overset{+}{C}Me{\cdot}CH_2{\cdot}OH}} \longrightarrow$$

$$\mathrm{CH_2Bu^t{\cdot}CHMe{\cdot}\overset{+}{C}H{\cdot}OH} \longrightarrow \underset{\text{(XXIV)}}{\mathrm{CH_2Bu^t{\cdot}CHMe{\cdot}CHO}} + H^+$$

TABLE 1.


CH₂Buᵗ·CMe·CH₂ (O) (I)
CH₂Buᵗ·CMe(OH)·CH₂·OH (II)
(III)
CH₂Buᵗ·CMe(OR)·CH₂·OH (IV)
CH₂Buᵗ·CMe(OH)·CH₂·OR (V)
CH₂Buᵗ·CMe(OH)·CO₂H (VI)
CH₂Buᵗ·COMe (VII)
CH₂Buᵗ·CMe(OH)·CH₂·NRR′ (IX)
Me·C(=N·CH₂)·O·CMe·CH₂Buᵗ (X)
CH₂Buᵗ·CHMe·CH₂·NRR′ (XI)
CH₂Buᵗ·CMe(OH)·CH₂Cl (XII)
CH₂Buᵗ·CMe(OH)·CH₂·SO₃Na (XIII)
CH₂Buᵗ·CHMe·CH₂·SO₃Na (XIV)
CH₂Buᵗ·CMe(OH)·CH₂·SR (XV)
CH₂Buᵗ·CMe₂·OH (XVI)
CH₂Buᵗ·CMe(OH)·CH₂·OAc (XVII)
(XVIII)
CH₂Buᵗ·CMe·CH₂·OH CH₂·COMe (XIX)
CH₂Buᵗ·CHMe·CHMe·OH (XX)
CH₂Buᵗ·CHMe·CH₂·OH (XXI)
RR′C (XXII)
acid cat.
basic cat.
ROH
HCl
NHRR′
KMnO₄
Ac₂O (R = R′ = H)
(i) HCl, (ii) H₂
MgMeBr
H₂
CH₂Ac·CO₂Et
H₂O
AcOH
NaHSO₃
RSNa
Ni
(i) Ac₂O (ii) H₂
CORR′
H⁺

This may then react, also under catalysis by acids, with unchanged diol to form the acetal (III).

Cyclic acetals (XXII) were also obtained from the glycol (II) with *cyclo*hexanone and benzaldehyde.

2 : 4 : 4-Trimethylpentane-2 : 3-diol is dehydrated much less readily by acids, and gives a complex product in which 2 : 4 : 4-trimethylpent-1-en-3-ol, 2 : 4 : 4-trimethylpentan-3-one, another aldehyde or ketone, and an unidentified cyclic ether or acetal were detected spectrographically.

Reaction with Alcohols.—From epoxide (I) and alcohols, either possible reaction product (IV) or (V) can be obtained according to whether acidic or basic catalysts are used. The isomeric products from any one alcohol could be distinguished by their physical and chemical properties. Comparison of their rates of esterification with acetyl chloride in pyridine–toluene showed that the adduct from acidic medium had the " abnormal " structure (IV), and that from basic medium the " normal " structure (V). Similar alteration in the character of the product by the nature of the catalyst has been observed and discussed before (cf. Swern, Billen, and Knight, *J. Amer. Chem. Soc.*, 1949, **71**, 1152, and refs. therein; Reeve and Sadle, *ibid.*, 1950, **72**, 1251), but this appears to be the first recorded case where either product could be obtained to the complete exclusion of the other.

The epoxide reacted rapidly and exothermally with an excess of lower primary alcohols in presence of a trace of sulphuric acid. The product was fairly complex, and besides about 30% of (IV) it contained unsaturated alcohol, aldehyde, acetal, and cylic acetal (III). It was clear that acid-catalysed rearrangement was a competing reaction, as in the case of acid hydration. None of the isomer (V) was detected in the product, and since (V; R = Et) was found to be quite stable to dilute alcoholic sulphuric acid, even at the b. p., it was certain that no appreciable amounts are formed.

Some search was made for a better yield of compounds of type (IV), which as primary alcohols were of some interest for esterification purposes. Various other catalysts were tried but only boron trifluoride, in the form of its ethyl ether complex, was better than sulphuric acid, giving a higher yield of a cleaner product. The highest yield (62%) was obtained with methanol; ethanol and *n*-butanol gave lower yields, but *iso*propanol gave, with sulphuric acid catalyst, none of the desired product (IV; R = Pr^i). Adducts were also prepared from various glycols and glycerol, which when employed in excess only reacted at one hydroxyl group—the more nucleophilic one in cases where they differed.

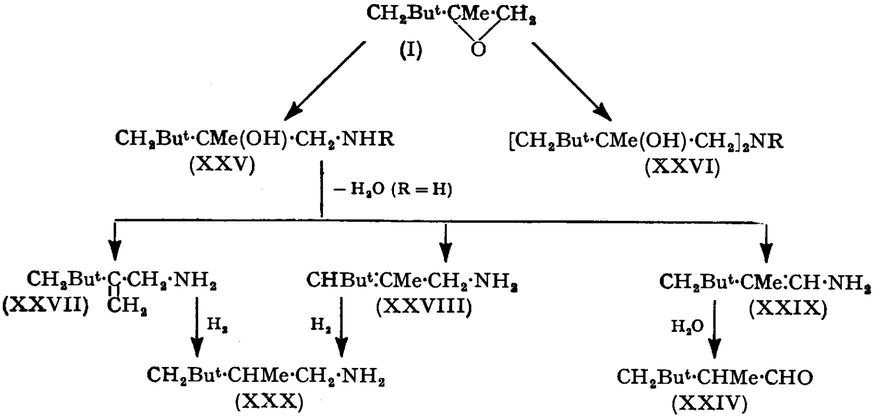
The epoxide did not react with an excess of ethanol and catalytic quantities of sodium ethoxide or sodium hydroxide at the atmospheric b. p. The reaction could be achieved smoothly either by increasing the temperature to 150° (autoclave) or by using a larger amount—1 mol.—of alkali at reflux temperature. Alcohols such as *n*-butanol with a higher b. p. could, however, be brought into reaction under reflux in presence of only small quantities of alkali. The necessary conditions can be generalised as 0·1—0·25 mol. of alkali at 150°, or an equimolar amount at 70—80°. The product was less complex than that from acid medium, and about 70% yields of various alkoxytrimethylpentanols (V) were obtained. *iso*Propanol, however, gave a very poor yield. Small yields of adducts were also obtained from phenol and 2-naphthol.

The " abnormal " adducts (IV) have higher b. p., density, and refractive index than their " normal " isomers (V). The lower members are oily liquids with the somewhat peppermint-like odour common to most di*iso*butylene derivatives. The glycol adducts are viscous liquids with an unpleasant acrid taste, sparingly soluble or insoluble in water, although the glycerol adduct is freely soluble. The compounds gave solid nitro- or dinitrobenzoates by which they could be characterised, although the tertiary alcohols were esterified with some difficulty. As already mentioned, this property was used to distinguish the " normal " adducts (V). However, after long boiling with acetic anhydride, (V; R = Et) gave an acetate in fairly good yield. Ineffective attempts were made to obtain an unsaturated ether by elimination of water from (V; R = Et). Distillation with iodine, etc., gave mainly trimethylpentanal; as just mentioned, boiling with acetic anhydride esterified the hydroxyl group, and heating with phthalic anhydride gave no recognisable product except ethyl hydrogen phthalate. Treatment with concentrated hydrochloric acid gave an inseparable mixture of aldehyde and, apparently, unsaturated ether, but no chloro-compound.

Permanganate oxidation of (V; R = Et) gave the solid hydroxy-acid (VI), first described by Butlerov (*J. Russ. Phys. Chem. Soc.*, 1882, **14**, 201). The same acid was isolated from oxidation of (IV; R = Et). The structure of this acid was proved by synthesis from the cyanohydrin of 4 : 4-dimethylpentan-2-one (VII).

Attempts to combine ethanol with the epoxide without catalyst showed that no reaction took place below 200°, and above this temperature rearrangement to 2-*neo*pentylprop-2-en-1-ol took place (Part II, p. 2171). With methanol a small fraction, possibly (IV; R = Me), was obtained, but was not certainly identified.

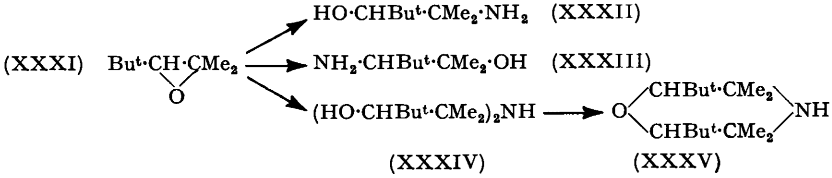
Reaction with Ammonia and Amines.—1 : 2-Epoxy-2 : 4 : 4-trimethylpentane (I) combined with ammonia in concentrated aqueous or alcoholic solution at *ca.* 160° for 5 hr.; under less drastic conditions reaction was incomplete. Only two products were formed, 2-hydroxy-2 : 4 : 4-trimethylpentylamine (XXV; R = H) and di-(2-hydroxy-2 : 4 : 4-trimethylpentyl)amine (XXVI; R = H), in proportions varying with those of the reactants. None of the tertiary amine appeared to be formed; attempts to obtain this compound from (XXVI; R = H) and the epoxide failed, the starting materials being recovered unchanged after prolonged heating. Attempts to make the epoxide combine with ammonia in the gas phase were unsuccessful, the major products at above 290° being rearrangement products.



In early experiments on the reaction with ammonia a small fraction intermediate between the mono- and the di-hydroxy-amine was obtained. The existence of a separate compound was inferred from the refractive index, which was lower than those of the main products. Elementary analysis indicated a formula of approximately $C_{12}H_{27}ON$, but analysis of the 3 : 5-dinitrobenzoyl derivative showed it to be that of an amine $C_{16}H_{33}ON$. In later, larger-scale preparations this fraction did not appear; it may have originated from an impurity in the early batches of epoxide.

The structure of the monohydroxy-amine was expected, by analogy with similar cases described in the literature, to be 1-amino-2 : 4 : 4-trimethylpentan-2-ol (XXV; R = H). This was confirmed in two ways: (*a*) On refluxing amino-trimethylpentanol with concentrated hydrochloric acid, a poor yield of an unsaturated amine was obtained, together with a rather larger amount of 2 : 4 : 4-trimethylpentanal (XXIV). Spectroscopic evidence indicated that this unsaturated amine was a mixture of roughly equal parts of (XXVII) and (XXVIII). When it was hydrogenated, hydrogen equivalent to 1·0 double bond per molecule was absorbed, and the picrate of 2 : 4 : 4-trimethylpentylamine (XXX) was isolated from the product. The structure of (XXX) has been proved (see Part II, p. 2172). Further, dehydration to an unsaturated amine would not be possible if the monohydroxy-amine were 2-amino-2 : 4 : 4-trimethylpentan-1-ol. Trimethylpentanal may be supposed to have arisen through a vinylamine (XXIX). (*b*) As described below, the monohydroxy-amine was prepared by interaction of 1-chloro-2 : 4 : 4-trimethylpentan-2-ol (XII) with methanolic ammonia.

The reaction of (XXV; $R = H$) with acetic anhydride did not afford the expected *N*-acetyl derivative. On distillation of the neutral portion of the product, some dehydration must have taken place, since one fraction was strongly basic. Analyses of this and its picrate left little doubt that it was substantially 4 : 5-dihydro-2 : 5-dimethyl-5-*neo*pentyloxazole (X), obtained by cyclic dehydration of the expected *N*-acetyl-hydroxy-amine.



Although 2 : 3-epoxy-2 : 4 : 4-trimethylpentane (XXXI) failed to react with ethanolic diethylamine, interaction with methanolic ammonia took place at 190° in 3—5 hr. A large excess of ammonia afforded a product corresponding to the monohydroxy-amine, probably a mixture of 2-amino-2 : 4 : 4-trimethylpentan-3-ol (XXXII) and 3-amino-2 : 4 : 4-trimethylpentan-2-ol (XXXIII). Since only one picrate and one hydrochloride were obtained it was assumed that one of these two components predominated. With restricted quantities of ammonia, a number of products was obtained. The lower-boiling fractions contained unchanged epoxide, a carbonyl compound (2 : 2 : 4-trimethylpentan-3-one, 2 : 2 : 3 : 3-tetramethylbutanal, or both), some (XXXII) or (XXXIII), and 2 : 4 : 4-trimethylpentane-2 : 3-diol. From the largest and highest-boiling fraction was obtained a homogeneous liquid, which elementary and functional-group analysis indicated to be, not the expected dihydroxy-amine (XXXIV), but a dehydration product thereof. All the evidence pointed to a morpholine structure, either (XXXV) or the isomeric structure with O and NH groups interchanged. Its infra-red spectrum confirmed the absence of hydroxyl groups and indicated the probable presence of an imino-group and an ether link. No fine structure characteristic of unsubstituted morpholine was displayed. This may be due to the heavy substitution about the ring. The yield of this material was 36% of theory.

In view of the failure of 1 : 2-epoxy-2 : 4 : 4-trimethylpentane (I) to form a triadduct with ammonia, it was of interest to find out whether a di- as well as a mono-adduct could be obtained from interaction with primary amines. Reaction products of both one and two molecules of epoxide (I) with methylamine were obtained; aniline, on the other hand, gave only a single product, the monoadduct. The epoxide (I) was allowed to react with both aqueous and alcoholic methylamine at *ca.* 180° in an autoclave. Two products, *N*-methyl-mono- (XXV; $R = Me$) and -di-(2-hydroxy-2 : 4 : 4-trimethyl-*n*-pentyl)amine (XXVI; $R = Me$) were produced in proportions which varied with those of the reactants. The second product solidified to a waxy solid, and all attempts to recrystallise it failed. Purification was eventually achieved by conversion into the hydrochloride or hydrobromide, and reconversion of the recrystallised salt into the amine. In this way, samples of base, m. p. 42—43° and 66°, respectively, were obtained. These differed little in their equivalent on titration. Examination of the infra-red spectrum showed the material of m. p. 66° to be the purest, but no trace of (XXVI; $R = H$) could be found to account for the impurity in specimens of lower m. p. This impurity is evidently a base of similar equivalent weight, but its exact nature has not been elucidated.

All attempts to quaternise the tertiary base (XXVI; $R = Me$) with methyl bromide or iodide failed; under drastic conditions some hydrobromide or hydriodide was formed. This behaviour is in contrast to the successful quaternisation of *N*-methyldi-(2 : 4 : 4-trimethylpentyl)amine (see Part II, p. 2173). The epoxide (I) failed to react with triethylamine.

Interaction of the epoxide (I) with ethanolic diethylamine and aqueous dimethylamine at 180° for several hours afforded high yields of *NN*-diethyl- (IX; R = R′ = Et) and *NN*-dimethyl-2-hydroxy-2 : 4 : 4-trimethylpentylamine (IX; R = R′ = Me), respectively; both readily formed methiodides. The structure of the product with diethylamine as (IX) and not the isomeric 2-diethylamino-1-hydroxy-compound follows from its synthesis from 1-chloro-2 : 4 : 4-trimethylpentan-2-ol (XII) (see below). The structures of the other products of addition of amines to the epoxide have not been rigidly proved. They are based on analogy with the above instances and with similar reactions of unsymmetrical epoxides reported in the literature.

The epoxide (I) reacted in the expected manner with aniline, methylaniline, and morpholine, each in methanolic solution, giving *N*-(2-hydroxy-2 : 4 : 4-trimethylpentyl)-aniline (XXV; R = Ph), -*N*-methylaniline (IX; R = Ph, R′ = Me), and -morpholine, respectively. No evidence of a diadduct (XXVI; R = Ph) with aniline was observed. The morpholine adduct quaternised readily with methyl bromide or iodide.

The non-formation of more highly substituted amines and quaternary salts is attributed to steric hindrance. An examination of molecular models suggests that, whereas the compounds described above have unstrained molecules, the *NN*-di-(2-hydroxy-2 : 4 : 4-trimethylpentyl)-*NN*-dimethylammonium cation would be too strained to exist. The molecules of *NN*-di-(2-hydroxy-2 : 4 : 4-trimethylpentyl)aniline and tri-(2-hydroxy-2 : 4 : 4-trimethylpentyl)amine, and the *N*-2-hydroxy-2 : 4 : 4-trimethylpentyl-*NNN*-trimethylammonium cation, although they could exist without or with only slight strain, would be extremely cramped and rigid; they are doubtless very difficult to form, especially as the reaction transition states may be strained.

Reaction with Acids, Salts, etc.—The epoxide (I) did not appear to react with acetic acid in the absence of a catalyst. In the presence of a trace of sulphuric acid, a rapid and exothermic reaction took place, but only a poor yield of impure product was obtained; this did, however, appear to be the expected glycol monoacetate. In presence of sodium acetate (1 mole) in acetic acid at the b. p., the glycol monoacetate was formed very slowly but with less side-reaction, and was obtained pure; it was identical with the ester formed by treating the diol (II) with 1 mole of acetic anhydride, and so was identified as 2-hydroxy-2 : 4 : 4-trimethylpentyl acetate (XVII). Surprisingly, in presence of boron trifluoride the product was mainly the aldehyde (XXIV).

The epoxide reacted readily with formic acid without catalyst. The product appeared to be the glycol monoformate, but was not obtained pure. The product from interaction with acetyl chloride in boiling carbon tetrachloride was very complex, but appeared to include trimethylpentenyl acetate, chlorotrimethylpentane, and chlorotrimethylpentyl acetate. As mentioned in Part II (p. 2170), with acetic anhydride and a trace of sulphuric acid, (I) gave almost exclusively 2 : 4 : 4-trimethylpentylidene diacetate.

The quantitative aspects of the reaction between the epoxide and ethereal hydrogen chloride are discussed in Part I (p. 2163). On the preparative scale, a very vigorous reaction set in when the epoxide (I) was added to a small excess of hydrogen chloride in ether. About 60—70% of the theoretical amount of hydrogen chloride was absorbed, but the conversion into chlorohydrin was poor and seldom exceeded 25%. A second chlorine-containing compound was also formed, together with large quantities of 2 : 4 : 4-trimethylpentanal (XXIV). These two products had boiling points very close to one another and were not readily separable by distillation. The yield of chlorohydrin was very much reduced when the epoxide was treated with concentrated hydrochloric acid. Correspondingly greater quantities of aldehyde (XXIV) were formed.

Only one of the two possible chlorohydrin isomers was isolated. This may be due either to instability of the second isomer or to the absence of any addition to the epoxide in that direction. The chlorohydrin was homogeneous on distillation, and its reactions gave rise to only one series of products. The chlorohydrin was somewhat unstable and tended to lose hydrogen chloride rather readily except in presence of weak bases. The chlorine atom could be replaced by hydroxy-, amino-, and diethylamino-groups by reaction in Carius tubes with methanolic potassium acetate, ammonia, and diethylamine, respectively. The product in each case was identified with the material produced from epoxide (I) by hydration and interaction with ammonia and diethylamine respectively (see above). In the last two cases, no indications of the presence of any 2-amino-1-hydroxy-compounds, derived from the isomeric chlorohydrin, were noted. This establishes the fact that additions of ammonia, diethylamine, and hydrogen chloride to the ring of the epoxide (I) all take place in the same direction.

The chlorohydrin was readily dehydrated with anhydrous oxalic acid. An unsaturated chloro-compound, presumably 1-chloro-2 : 4 : 4-trimethylpent-2-ene or an isomer thereof, was obtained. The fact that dehydration could be brought about easily to give an unsaturated chloro-compound constitutes strong evidence that the chlorohydrin is correctly formulated as the 1-chloro-2-hydroxy-compound (XII) and not the 2-chloro-1-hydroxy-isomer. In the latter case, dehydration could only have been accomplished if extensive degradation of the molecule had taken place. This in turn affords further proof of the correctness of the structures of the reaction products of the epoxide (I) with ammonia and diethylamine. An unsaturated chloro-compound obtained by the reaction of chlorine or hypochlorous acid with di*iso*butylene has been described by Umnowa (*J. Russ. Phys. Chem. Soc.*, 1910, **42**, 1536), and this might be expected to have the same or a similar constitution.

The chlorine atom in the unsaturated chloro-compound was unaffected by cold 0·1N-sodium hydroxide. Hydrogenation in the presence of Adams's catalyst caused simultaneous removal of the chlorine atom. On the other hand, all attempts to remove the chlorine atom in the original chlorohydrin by similar means failed. By oxidation of the chlorohydrin with hot alkaline permanganate, α-hydroxy-αγγ-trimethylvaleric acid (VI) was obtained.

It did not appear possible to obtain sulphuric esters from the epoxide (I) and sulphuric acid of any concentration, since the very dilute acid gives diol (II) (see above) and higher concentrations cause rearrangement to the aldehyde (XXIV) (Part II, p. 2170). Similarly, it was found that phosphoric acid of concentrations from 85% to 100%, or containing dissolved phosphoric oxide, and even phosphoric oxide alone, acted entirely as rearrangement catalysts, and no phosphorus-containing product could be obtained.

A reaction took place between the epoxide and phosphorus oxychloride in dimethyl- or diethyl-aniline, but the product was mainly aldehyde, and the higher-boiling material contained only a little combined phosphorus or chlorine. In carbon tetrachloride solution, both phosphorus oxychloride and sulphuryl chloride gave low-boiling products—probably a mixture of chlorohydrin and chloro-trimethylpentene—which contained chlorine but no phosphorus or sulphur.

Epoxide (I) reacted with 10% aqueous sodium sulphite when heated in an autoclave to 150°. A slow reaction took place at the atmospheric b. p. Sodium 2-hydroxy-2 : 4 : 4-trimethylpentane-1-sulphonate (XIII) crystallised as a monohydrate from the aqueous layer in a yield of 55%. From the organic layer which remained, 2 : 4 : 4-trimethylpentane-1 : 2-diol (II) (10%) was isolated, together with 4 : 4-dimethylpentan-2-one and possibly some 2 : 3-epoxide (an impurity in the original epoxide).

When the hydroxy-sulphonate (XIII) was refluxed with acetic anhydride for 15 min., dehydration took place and a mixture of sodium 2 : 4 : 4-trimethylpentene-1-sulphonates was produced. The presence of the double bond was readily established by reaction with bromine. Preparation of an *S*-benzylthiuronium salt confirmed that this product was a mixture of the possible unsaturated sulphonates, but only one derivative was isolated pure.

The ease of dehydration of the hydroxy-sulphonate indicates that the hydroxy-group is attached to a tertiary carbon atom. Had addition of sodium sulphite to the epoxide taken place in the opposite direction to give sodium 1-hydroxy-2 : 4 : 4-trimethylpentane-2-sulphonate, dehydration to an unsaturated sulphonate would have been impossible.

Hydrogenation of the mixed unsaturated sulphonates readily proceeded in aqueous solution in presence of Adams's catalyst. About 80% of the theoretical amount of hydrogen was absorbed. The sodium 2 : 4 : 4-trimethylpentane-1-sulphonate (XIV) monohydrate thus obtained yielded a homogeneous *S*-benzylthiuronium salt.

The epoxide (I) was heated with an equimolecular amount of aqueous potassium cyanide in an autoclave at 140°. Part of the epoxide was still unchanged after 5 hr. The non-acidic products were complex. Two fractions were identified as the diol (II) and dihydroxy-amine (XXVI; R = H), the latter in considerable quantity. Another fraction had a nitrile-like odour; analysis showed that it was not the expected 2-hydroxy-2 : 4 : 4-trimethylpentyl cyanide (XXXVI), but a vinyl cyanide, probably (XXXVII) formed by dehydration of the initial product :

$$\text{(I)} \longrightarrow \underset{\text{(XXXVI)}}{\mathrm{CH_2Bu^t{\cdot}CMe(OH){\cdot}CH_2{\cdot}CN}} \longrightarrow \underset{\text{(XXXVII)}}{\mathrm{CH_2Bu^t{\cdot}CMe{:}CH{\cdot}CN}}$$

This inference was supported by the infra-red absorption spectrum. A fourth high-boiling fraction was not identified. Its microanalysis agreed approximately with the empirical formula $C_{16}H_{33}ON$. Examination of the infra-red spectrum did not shed any light upon its structure.

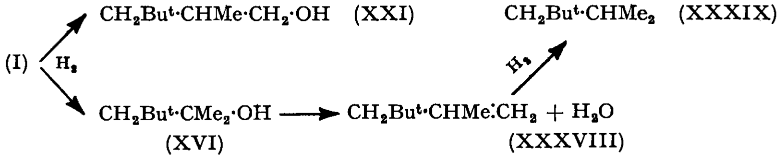
It was evident that this reaction had been unduly complicated by the high temperature and strongly alkaline conditions used. Thus, the diol formed is almost certainly due to direct hydration of the epoxide, and it is probable that the dihydroxy-amine arose from interaction of the epoxide with a limited quantity of ammonia formed by alkaline hydrolysis of some of the nitrile.

Miscellaneous Reactions.—Sodium methyl sulphide reacted exothermally with the epoxide (I) at room temperature. The expected product, 1-methylthio-2 : 4 : 4-trimethylpentan-2-ol (XV; R = Me), was obtained in moderate yield as a colourless liquid of characteristic odour. The structure was proved by hydrogenolysis of the methylthio-group with Raney nickel. The 2 : 4 : 4-trimethylpentan-2-ol (XVI) thus obtained was identified by comparison of its physical properties and spectrum with those of an authentic specimen synthesised by Ritter's method (*J. Amer. Chem. Soc.*, 1948, **70**, 4253) from 2 : 4 : 4-trimethylpent-1-ene and methyl cyanide in 92% sulphuric acid. 1-Benzylthio-2 : 4 : 4-trimethylpentan-2-ol (XV; $R = CH_2Ph$) was isolated in 75% yield from interaction of the epoxide (I) and sodium benzyl sulphide in boiling aqueous ethanol. The structure assigned to the product is based on analogy with that of the methylthio-compound.

The epoxide (I) reacted with methylmagnesium iodide to give a mixture of C_9 alcohols, containing about 50% of 3 : 5 : 5-trimethylhexan-2-ol (XX) derived from the aldehyde (XXIV), the remainder being presumably the 3-ol. The alcohol (XX) was synthesised from the aldehyde (XXIV) and methylmagnesium iodide.

Condensation of the epoxide (I) with ethyl sodioacetoacetate was achieved under rather drastic conditions (dioxan solution, 150° for 5 hr.). The product appeared to be a mixture of the expected initial product, $CH_2Bu^t{\cdot}CMe(OH){\cdot}CH_2{\cdot}CHAc{\cdot}CO_2Et$, and the lactone (XVIII). Attempted ketonic hydrolysis of this gave a product, also apparently a mixture, but which yielded a dinitrophenylhydrazone giving an analysis in agreement with that calculated for the derivative of the expected hydroxy-ketone (XIX).

The hydrogenation of the epoxide (I) was investigated briefly as a possible alternative route from the epoxide to 2 : 4 : 4-trimethylpentan-1-ol (XXI). In the liquid phase at 110—120° over Raney nickel, the products were (XXI) (50—60%), water, 2 : 4 : 4-trimethylpent-1-ene (XXXVIII), and 2 : 2 : 4-trimethylpentane (XXXIX). These results are accounted for on the assumption that the epoxide ring broke in either possible direction, and that the tertiary alcohol (XVI) so formed was dehydrated to (XXXVIII), which was then in part hydrogenated to (XXXIX) :



A somewhat similar product was obtained by vapour-phase hydrogenation over a nickel–pumice catalyst at 200°. In view of the relatively poor yields of trimethylpentanol obtained by direct hydrogenation as compared with the indirect route (see Part II, p. 2172), this method was not pursued further.

EXPERIMENTAL

Hydration of Epoxides.—Acid hydration. (i) 1 : 2-Epoxy-2 : 4 : 4-trimethylpentane (I) (320 g.) was stirred for 5 hr. with 0·1N-sulphuric acid (1 l.). After a preliminary run, the separated aqueous layer was recycled from one run to the next. The reaction was slightly exothermic, and the temperature was controlled to below 35°. The product was separated by warming the mixture to 35° to liquefy the glycol and removing the top liquid layer; this was then washed free from acid with N-sodium hydroxide, and again warmed to 30—35° to separate the phases. The resultant 2 : 4 : 4-trimethylpentane-1 : 2-diol (II) was purified from unchanged epoxide and by-products by distillation (b. p. 105—110°/10 mm.), a product, m. p. 55—57°, being obtained. The yield was about 238 g. per run; some 50 g. of unchanged epoxide, trimethylpentanal, and an intermediate fraction (unsaturated alcohol) were obtained. On a small scale it was preferable to extract the diol (II) with ether.

Table 2 shows the effect of the nature and concentration of the acid upon the yield (%) of (*a*) unchanged epoxide and aldehyde, (*b*) intermediate fraction, b. p. 50—107°/10 mm., (*c*) glycol (II), and (*d*) condensation products, b. p. 112—130°/10 mm.

TABLE 2.

Reagent	Time, hr.	(*a*)	(*b*)	(*c*)	(*d*)	Reagent	Time, hr.	(*a*)	(*b*)	(*c*)	(*d*)
N-H_2SO_4	3	6	18	40	0	0·02N-H_2SO_4......	5	26	9	43	0
0·2N-H_2SO_4	5	0	25	51	0	0·01N-H_2SO_4......	10	40	3	33	0
0·1N-H_2SO_4	5·25	4	16	71	0	0·1N-HCl	5	0	27	30	32
0·05N-H_2SO_4	5	8	12	61	0	0·01N-HNO_3 ...	5	0	6	75	0

0·1N-Sulphuric acid diluted with half its volume of ethanol gave a 75% yield of glycol after 5 hr.; addition of ethanol has no obvious advantage.

(ii) 2 : 3-Epoxy-2 : 4 : 4-trimethylpentane (XXXI) (32 g.) was shaken with 0·1N-sulphuric acid (100 ml.) at room temperature for 12 hr., by which time the organic phase was partially crystalline. After extraction and washing there were obtained 23·2 g. (64%) of 2 : 4 : 4-trimethylpentane-2 : 3-diol, b. p. 90—92°/10 mm., together with 3·5 g., b. p. 20—48°/10 mm. (? unchanged epoxide), and 4·4 g. of an intermediate fraction.

Alkaline hydration of (I). (i) The epoxide (I) (50 ml.) was refluxed for 66 hr. with N-sodium hydroxide (200 ml.), and was recovered substantially unchanged. Only a trace of glycol was formed. The epoxide distils rapidly in steam.

(ii) Epoxide (I) (64 g.) and N-sodium hydroxide (200 ml.) was heated to 200° for 2·5 hr. in a Baskerville–Lindsay autoclave with reciprocating stirrer. The organic product was separated (warming to 35° being necessary for liquefaction) and distilled without further treatment; the alkali was recycled. The combined product from three such runs gave no low-boiling material except water, 167 g. (76%) of diol (II), and 14 g. of residue (7%). A similar yield was obtained with 2N-sodium carbonate at 175° (3 hr.); 10% of epoxide was unchanged.

Alkaline hydration of some other epoxides. 2 : 3-Epoxy-2 : 4 : 4-trimethylpentane (XXXI) (64 g.) and N-sodium hydroxide (200 ml.) were heated in the same autoclave at 200° for 12 hr. The product was extracted with ether. Distillation gave 19·5 g. of 2 : 2 : 3 : 3-tetramethylbutanal, b. p. 47—50°/10 mm. (solidified), 14·3 g. of an intermediate fraction, and 9·9 g. (14%) of 2 : 3-diol, b. p. 90—94°/10 mm. Repetition with 5N-sodium hydroxide (10 hr.) gave 7·4 g. (10%) of 2 : 3-diol, together with 33·1 g. of apparently unchanged epoxide and 12·0 g. of intermediate fraction.

Styrene oxide (6 g.) was heated with N-sodium hydroxide (10 ml.) in a Carius tube to 175° for 3 hr. The product was ether-extracted, and afforded 1-phenylethane-1 : 2-diol (2·2 g.), b. p. 155—165°/12 mm., m. p. 62—64° from benzene, and much high-boiling and undistillable material.

A mixture of 1 : 2-epoxy-2-phenylpropane (55%) and, mainly, acetophenone was made by Dr. W. Webster, of this Department, by oxidisng α-methylstyrene by the method of B.P. 682,067. This fraction, b. p. 79·5—81°/10 mm. (16·5 g.), was heated with N-sodium hydroxide (70 ml.) for 4·5 hr. at 200°. Low-boiling fractions (6·3 g.), b. p. 82—114°/10 mm., were obtained from the product, followed by 2-phenylpropane-1 : 2-diol (1·7 g.), b. p. 144—150°/10 mm., m. p. 44—46° from benzene–light petroleum (Danilow and Venus-Danilowa, *Ber.*,1927, **60**, 1061, give m. p. 44°, b. p. 149—150°/11 mm.).

Miscellaneous methods. (i) Epoxide (I) (32 g.), water (100 ml.), and ethanol (20 ml.) were refluxed for 3 hr. The initial pH of the aqueous layer was 3—4. The product was extracted with ether, which gave material (9·1 g.), b. p. below 100°/10 mm. (largely 70—80°/10 mm.), and diol (II) (12·9 g., 35%).

(ii) The epoxide (I) (50 g.) was refluxed for 12 hr. with 25% acetic acid (200 ml.). A large light fraction, presumably aldehyde, was steam-distilled out; the residue gave further quantities of low-boiling material, and a liquid (16·7 g.), b. p. 112—134°/10 mm., presumably (III).

Properties and Reactions of 2 : 4 : 4-*Trimethylpentane*-1 : 2-*diol* (II) *and* -2 : 3-*diol*.—The solubility of each diol in water at 20° is 3%. Under water the 1 : 2-diol (II) melts at 36°, and two liquid phases are formed, the lower consisting of diol containing 20% of water. Above 36° the solubility decreases and later increases with temperature. The 2 : 3-diol melts under water at 43°, and the lower phase thus formed contains 10% of water. The 1 : 2-diol (II) is very soluble (>50%) in methanol and ethanol at room temperature, less so in acetone and ethyl acetate, sparingly soluble in benzene, carbon tetrachloride, toluene, ethylene dichloride, and *cyclo*hexanol, and only slightly soluble (>1%) in cold paraffin hydrocarbons, although readily soluble when hot.

The following vapour-pressure values for the 1 : 2-diol (II) were found by means of an ebulliometer :

V. p.	0·3	20	40	60	100	200	400	760 mm.
Temp. ...	20°	118·7°	134·3°	143·8°	157·1°	175·1°	196·8°	219·8° (decomp.)

The diol (II) (20 g.) was refluxed in benzene solution (150 ml.), and a drop of sulphuric acid added. Water was immediately evolved as an azeotrope and was removed in a Dean and Stark trap. The washed benzene solution then yielded quantitatively dihydro-4-methyl-4-*neo*pentyl-2-1′ : 3′ : 3′-trimethylbutyldioxole (III), b. p. 132°/10 mm., n_{D}^{20} 1·4408. Its identity with synthetic material (see below) was confirmed by infra-red spectrum. The same product resulted when the diol was distilled at 15 mm. with a trace of sulphuric acid.

The diol (II) (10 g.) was refluxed for 1 hr. with N-sulphuric acid (100 ml.). After being made alkaline, the product was isolated, and consisted of trimethylpentanal (3·5 g.), b. p. 42—54°/18 mm., n_{D}^{20} 1·4150, and the acetal (III) (4·5 g.), b. p. 130—140°/18 mm., n_{D}^{20} 1·4382.

The glycol (II) (10 g.) was refluxed for 1 hr. with 50% (by vol.) acetic acid (80 ml.) and then worked up as in the last experiment to yield low-boiling material (1·6 g.), probably aldehyde, and unchanged glycol (6·6 g.).

The diol (II) (10 g.) was shaken with concentrated hydrochloric acid at room temperature, whereupon it liquefied immediately. Next morning the product was extracted with ether, washed with aqueous sodium hydroxide, and distilled to give the cyclic acetal (III) (6·4 g.) and low-boiling material (1·4 g.).

The glycol (II) (29 g.) and trimethylpentanal (XXIV) (26 g., 1 mol.) were dissolved in benzene refluxing in a Dean and Stark apparatus. When a drop of sulphuric acid was added, an exothermic reaction ensued, and water rapidly came off as an azeotrope; 3·1 ml. were collected (calc., 3·6 ml.). When the distillate was clear, the benzene solution was washed with sodium hydroxide solution, dried, and distilled over potassium carbonate. The resultant cyclic acetal (III) (49 g., 94%) had b. p. 132°/10 mm., n_{D}^{20} 1·4409 (Found : C, 74·5; H, 13·0. Calc. for $C_{16}H_{32}O_2$: C, 75·0; H, 12·5%).

The glycol (II) (29·2 g.), *cyclo*hexanone (16·6 g.), and phosphoric acid (1 drop) were azeotropically dehydrated as above. The product (19·3 g.), *dihydro*-4-*methyl*-4-neo*pentyl*cyclo*hexane*spiro-2-*dioxole*, had b. p. 124°/10 mm., n_{D}^{20} 1·4562 (Found : C, 73·8; H, 11·5. $C_{14}H_{26}O_2$ requires C, 73·9; H, 12·0%). The diol (II) and benzaldehyde were similarly condensed to give *dihydro*-4-*methyl*-4-neo*pentyl*-2-*phenyldioxole* (XXII; R = Ph, R′ = H), b. p. 155—157°/10 mm., n_{D}^{20} 1·4961 (Found : C, 77·1; H, 9·7. $C_{15}H_{22}O_2$ requires C, 77·4; H, 9·5%).

Distillation of 2 : 4 : 4-trimethylpentane-2 : 3-diol with sulphuric acid gave two fractions, b. p. *ca.* 150° and 240—260°. Spectroscopic examination showed that the latter was an unidentified cyclic ether, and the former was a mixture of 2 : 4 : 4-trimethylpent-1-en-3-ol (~30%), 2 : 4 : 4-trimethylpentan-3-one (~20%), (?) 2 : 2 : 3 : 3-tetramethylbutanal (~30%), and unchanged diol (~5%).

The 1 : 2-diol (II) (29 g.), acetic anhydride (20 g.), and pyridine (18 g.) were warmed on the steam-bath for an hour. Working up in the normal way gave 13·5 g. of the monoacetate (XVII), b. p. 108·5—110°/10 mm., n_{D}^{20} 1·4413, spectroscopically identical with that obtained from the epoxide and acetic acid (see below). The diacetate, prepared as described by Hickinbottom (*J.*, 1948, 1333), had b. p. 120°/12 mm., n_{D}^{20} 1·4341.

Reaction with Alcohols.—Products from acid catalysis. (*a*) With ethanol. The epoxide (I) (100 g.) was slowly added to a mechanically stirred solution of sulphuric acid (1·2 g.) in ethanol (500 ml.), at such a rate that the temperature did not rise above 45°. Next morning, the catalyst was neutralised (to pH 9) with sodium hydroxide solution, and the excess of ethanol was distilled off. The residue was taken up in ether, washed with water, and submitted to fractional distillation. The fraction, b. p. 94—97°/12 mm. (34·2 g.), was identified as 2-*ethoxy*-2 : 4 : 4-*trimethylpentan*-1-*ol* (IV; R = Et), but it contained some 8% of (presumably) 2 : 4 : 4-trimethylpentanal diethyl acetal, detected by hydroxylamine titration. Much lower- and higher-boiling material were also obtained, but despite repeated attempts no pure compound was isolated therefrom. From titration results, the presence of 2-*neo*pentylprop-2-en-1-ol and the aldehyde acetal was inferred. A better product, b. p. 92—93°/10 mm., n_D^{20} 1·4403, d_4^{20} 0·8994, was obtained from a similar reaction employing 64 g. of epoxide, 250 ml. of ethanol, and 2 ml. of boron trifluoride–ethyl ether complex. This was judged to be free from acetal and from (V; R = Et) by spectroscopic examination, and gave a satisfactory analysis [Found : C, 68·6; H, 12·7; OEt, 25·6; active H (Zerewitinov), 0·59; (Smith and Bryant), 0·54. $C_{10}H_{21}O(OH)$ requires C, 69·0; H, 12·7; OEt, 25·8; active H, 0·58%]. It formed a 3 : 5-*dinitrobenzoate*, m. p. 89—90° (dinitrobenzoates were recrystallised from ethanol except where otherwise stated) (Found : C, 55·5; H, 6·54. $C_{17}H_{24}O_7N_2$ requires C, 55·4; H, 6·56%).

The effect of various catalysts may be summarised by tabulating the yield of (IV; R = Et) (Table 3).

TABLE 3.

Catalyst	Catalyst, mol.	Temp.	Yield, %	Catalyst	Catalyst, mol.	Temp.	Yield, %
H_2SO_4	0·058	20—40°	25	Zeocarb-215 ...	0·03 (equiv.)	78°	0
,, ...	0·013	,,	27	HCl	0·006	,,	0
,, ...	0·0026	,,	29	BF_3–Et_2O	0·03	20—40°	37
,, ...	0·013	−4° to −1°	13	$AlCl_3$	0·01	,,	3
H_3PO_4	0·01	78°	39	$ZnCl_2$	0·075	78°	0
p-$C_6H_4Me{\cdot}SO_3H$	0·01	,,	23				

(*b*) With methanol. Addition of epoxide (1 kg.) to methanol (4 l.) containing boron trifluoride–ether complex (32 ml.) and working up as for ethanol gave 777 g. (62%) of 2-*methoxy*-2 : 4 : 4-*trimethylpentan*-1-*ol* (IV; R = Me), b. p. 90—93·5°/12 mm., d_4^{20} 0·9129, n_D^{20} 1·4433 [Found: C, 67·1; H, 12·7; OMe, 19·3; active H (Zerewitinov), 0·70; (Smith and Bryant), 0·59. $C_9H_{19}O(OH)$ requires C, 67·5; H, 12·6; OMe, 19·4; active H, 0·63%]. Its 3 : 5-*dinitrobenzoate* had m. p. 74—75° (Found : C, 54·2; H, 6·0. $C_{16}H_{22}O_7N_2$ requires C, 54·2; H, 6·0%).

An attempt was made to distil the product directly, in the hope that the boron trifluoride would appear as a separate fraction and be recovered. Complete decomposition occurred, however. As an alternative to neutralisation with alkali, the trifluoride could be removed by refluxing the solution for ½ hr. with an excess of sodium fluoride and filtering. This method has the advantage that the recovered sodium borofluoride can be reconverted into boron trifluoride, and also that the solution is then free from inorganic material and requires no further washing.

Sulphuric acid being used as catalyst, a 47% yield of the same product was obtained. No (V; R = Me) could be detected spectroscopically in the product.

(*c*) With higher alcohols. *iso*Propanol, with sulphuric acid as catalyst, failed to give any of the desired product.

From *n*-butanol, with sulphuric acid catalyst, was obtained 2-*butoxy*-2 : 4 : 4-*trimethylpentan*-1-*ol* (IV; R = Bu^n), b. p. 114—119°/10 mm., d_4^{20} 0·8802, n_D^{20} 1·4408 (Found: C, 71·1; H, 13·0; OBu, 38·2. $C_{12}H_{26}O_2$ requires C, 71·2; H, 13·0; OBu, 36·1%) (yield 29%). The 3 : 5-*dinitrobenzoate* had m. p. 66—67° (Found : C, 57·5; H, 6·9. $C_{19}H_{28}O_7N_2$ requires C, 57·6; H, 7·1%).

(*d*) With glycols. The epoxide (128 g.) was added slowly with mechanical stirring to ethylene glycol (150 g.) containing boron trifluoride–ether complex (1·5 ml.), the temperature being controlled below 45°. Sufficient sodium hydroxide, dissolved in a little water, was added to neutralise all the catalyst, and unchanged glycol and low-boiling by-products were distilled off up to 120°/10 mm. The residue was taken up in ether, washed, and dried, and on distillation gave a main product (79·4 g., 42%), b. p. 112—116°/0·5 mm., n_D^{20} 1·4597. Analysis showed clearly that it was 2-2′-*hydroxyethoxy*-2 : 4 : 4-*trimethylpentan*-1-*ol* (IV; R = $HO{\cdot}CH_2{\cdot}CH_2$) [Found: C, 63·4; H, 11·9; active H (Zerewitinov), 0·86; (Smith and Bryant), 0·94. $C_{10}H_{20}O(OH)_2$ requires C, 63·1; H, 11·6; active H, 1·05%]. It formed a *bis*-3 : 5-*dinitrobenzoate*, m. p. 107—109° from acetone (Found: C, 49·8; H, 4·63; N, 9·75. $C_{24}H_{26}O_{13}N_4$ requires C, 49·9; H, 4·53; N, 9·7%). In another experiment, the unchanged glycol was washed out with water in order that the by-products could be examined. These proved to be similar (unsaturated alcohol, acetal) to those from reaction with ethanol.

Attempted esterification of the product with $\alpha\gamma\gamma$-trimethylvaleric acid by azeotropically removing water with toluene in presence of a little toluene-*p*-sulphonic acid as catalyst gave a mixed product of unexpectedly low b. p. Presumably fission at the C–O–C bond had occurred. The *bis-αγγ-trimethylvalerate*, b. p. 160—164°/2 μ, n_D^{20} 1·4472, was obtained in 82% yield from the glycol adduct (19·0 g.) and the acid chloride (32·5 g.) in pyridine (19·0 g.), cautiously mixed with cooling and kept overnight at room temperature (Found: equiv., 223. $C_{26}H_{50}O_5$ requires equiv., 221).

A similar reaction between the epoxide and propane-1 : 3-diol afforded 2-3′-*hydroxypropoxy*-2 : 4 : 4-*trimethylpentan*-1-*ol* (IV; R = HO·[CH$_2$]$_3$) (39%), b. p. 134°/0·5 mm., n_D^{20} 1·4623 (Found: C, 65·1; H, 11·2. $C_{11}H_{24}O_3$ requires C, 64·6; H, 11·8%). The 3 : 5-dinitrobenzoate could not be crystallised, but the *di*-p-*nitrobenzoate* recrystallised from acetone–ethanol and had m. p. 65—67° (Found: C, 59·6; H, 5·9; N, 5·82, 6·13. $C_{25}H_{30}O_9N_2$ requires C, 59·7; H, 6·1; N, 5·6%).

2-Methylpentane-2 : 4-diol gave a product in which one hydroxyl group was unreactive and presumably tertiary; it was therefore the expected 2-(3-*hydroxy*-1 : 3-*dimethylbutoxy*)-2 : 4 : 4-*trimethylpentan*-1-*ol* (IV; R = HO·CMe$_2$·CH$_2$·CHMe). The product had b. p. 113—115°/0·1 mm., n_D^{20} 1·4548 [Found: C, 68·5; H, 12·3; active H (Zerewitinov), 0·72; (Smith and Bryant), 0·415. $C_{14}H_{28}O(OH)_2$ requires C, 68·4; H, 12·3; active, H, 0·82%]. The yield was only 11%.

(*e*) With glycerol. Epoxide (128 g.) was added slowly to mechanically stirred glycerol (300 g.) and boron trifluoride–ether (2 ml.) with cooling. On addition of dilute sodium hydroxide, the mixture remained homogeneous, but triple extraction with ether removed 2-(2 : 3-dihydroxypropoxy)-2 : 4 : 4-trimethylpentan-1-ol (IV; R = OH·CH$_2$·CH(OH)·CH$_2$) (68 g., 31%), b. p. 154—158°/0·3 mm., n_D^{20} 1·4688, a very viscous liquid. This did not give good analytical figures and the dinitrobenzoate could not be obtained as a solid, but the *tri*-p-*nitrobenzoate* crystallised from acetone–ethanol and had m. p. 128—130° (Found: C, 57·6; H, 4·8; N, 6·27. $C_{32}H_{33}O_{13}N_3$ requires C, 57·6; H, 5·0; N, 6·3%).

Products from basic catalysis. (*a*) With ethanol. Preliminary experiments in which the epoxide was refluxed with ethanol containing up to 0·05N concentration of sodium ethoxide showed that no reaction took place thus.

Sodium (23 g., 1 mole) was dissolved in ethanol (500 ml.), and epoxide (128 g., 1 mole) added. No immediate reaction was apparent. After the solution had refluxed for 3 hr., most of the epoxide was found by titration to have been consumed. Most of the alcohol was evaporated off, and the residue washed with water, taken up in ether, and distilled. The main product thus obtained (118·0 g., 68%) had b. p. 79°/16 mm., d_4^{20} 0·8693, n_D^{20} 1·4277, and although it showed one hydroxyl group (Zerewitinov), it failed to react appreciably under the normal conditions of a Smith and Bryant titration, or with benzoyl chloride in diethylaniline within 1½ hr. at 60°. Its infra-red spectrum showed a tertiary hydroxyl group, and the absence of a detectable amount of (IV; R = Et). It was therefore 1-*ethoxy*-2 : 4 : 4-*trimethylpentan*-2-*ol* (V; R = Et) [Found: C, 69·1; H, 13·2; OEt, 24·0; active H (Zerewitinov), 0·57. $C_{10}H_{21}O(OH)$ requires C, 69·0; H, 12·7; OEt, 25·8; active H, 0·58%]. It gave, with some difficulty, a 3 : 5-*dinitrobenzoate*, m. p. 48—50° (Found: C, 55·5; H, 6·5. $C_{17}H_{24}O_7N_2$ requires C, 55·4; H, 6·6%), and an *acetate*, b. p. 92°/10 mm., n_D^{20} 1·4263 (Found: C, 66·8; H, 11·2. $C_{12}H_{24}O_3$ requires C, 66·6; H, 11·2%).

The same compound was obtained in 61—66% yield by substituting the equivalent amount of sodium hydroxide for sodium ethoxide, or by heating the epoxide and ethanol with sodium ethoxide (0·1 mol.) or hydroxide (0·25 mol.) to 150° for 5 hr. The last method afforded a very slow conversion at 100°.

(*b*) With other alcohols. 1-*Methoxy*-2 : 4 : 4-*trimethylpentan*-2-*ol* (V; R = Me), b. p. 65—66°/10 mm., d_4^{20} 0·8802, n_D^{20} 1·4294, was prepared in 51% yield by using sodium methoxide (1 mol.) in methanol at reflux temperature [Found: C, 67·6; H, 13·1; OMe, 19·5; active H, 0·55. $C_9H_{19}O(OH)$ requires C, 67·5; H, 12·6; OMe, 19·4; active H, 0·63%]. Its 3 : 5-*dinitrobenzoate* had m. p. 68° (Found: C, 54·2; H, 6·5. $C_{16}H_{22}O_7N_2$ requires C, 54·2; H, 6·0%). The product was spectroscopically free from (IV; R = Me).

A similar reaction with *iso*propanol gave only a 7·5% yield of the 1-iso*propoxy*-analogue (V; R = *iso*-C$_3$H$_7$); a better yield (20%) was obtained with 0·1 mol. of sodium *iso*propoxide at 150° (5·5 hr.; autoclave). The compound had b. p. 79—83°/10 mm., d_4^{20} 0·8608, n_D^{20} 1·4272 [Found: C, 70·5; H, 13·0; active H (Zerewitinov), 0·57. $C_{11}H_{23}O(OH)$ requires C, 70·2; H, 12·8; active H, 0·54%]. The dinitrobenzoate could not be satisfactorily purified.

Heating of the epoxide with *n*-butanol and sodium hydroxide (1 mol.) under reflux (3 hr.) afforded the 1-*butoxy*-compound (V; R = *n*-C$_4$H$_9$), b. p. 100—104°/10 mm., d_4^{20} 0·8668, n_D^{20}

1·4335, in 68% yield [Found: C, 71·5; H, 13·0; active H (Zerewitinov), 0·62. $C_{12}H_{25}O(OH)$ requires C, 71·2; H, 13·0; active H, 0·50%]. Slightly smaller yields were obtained on using 0·25 mol. of sodium hydroxide either under reflux or at 150° in an autoclave (3 hr.).

By heating the epoxide (64·0 g.) with dodecan-1-ol (200 g.; from fractionation of commercial lauryl alcohol) and sodium hydroxide (10·0 g.) at 175° for 2 hr. in an autoclave, a small yield of the 1-*dodecyloxy*-compound (V; R = n-$C_{12}H_{25}$), b. p. 168—180°/0·5 mm., n_D^{20} 1·4474, was obtained (Found: C, 76·6; H, 13·3. $C_{20}H_{42}O_2$ requires C, 76·4; H, 13·3%).

(*c*) With ethylene glycol. A mixture of epoxide (128 g.), ethylene glycol (150 g.), and sodium hydroxide (8 g.) was heated in a stirred autoclave at 175° for 3 hr. Water was added, and the product extracted into ether. Fractionation afforded 1-2′-*hydroxyethoxy*-2 : 4 : 4-*trimethylpentan*-2-*ol* (V; R = $OH\cdot CH_2\cdot CH_2$) (86·5 g.; 46%), b. p. 94—100°/0·3 mm., n_D^{20} 1·4541. This was not quite pure, but the structure assigned was confirmed by the detection of one reactive and one unreactive hydroxyl group [Found: C, 63·8; H, 11·0; active H (Zerewitinov), 0·95; (Smith and Bryant), 0·53. $C_{10}H_{20}O(OH)_2$ requires C, 63·1; H, 11·6; active H, 1·05%].

(*d*) With phenols. Phenol (47 g.) was dissolved in a solution of sodium hydroxide (20 g.) in ethanol (40 ml.) and water (50 ml.), epoxide (64 g.) added thereto, and the whole refluxed for 8 hr. After dilution with water the product was extracted with ether, giving 2 : 4 : 4-*trimethyl*-1-*phenoxypentan*-2-*ol* (V; R = Ph) (45 g., 40%), b. p. 148—153°/10 mm., n_D^{20} 1·4993 [Found: C, 75·6; H, 10·0; active H (Zerewitinov), 0·42. $C_{14}H_{21}O(OH)$ requires C, 75·6; H, 10·0; active H, 0·45%]. It formed a 3 : 5-*dinitrobenzoate*, m. p. 88—90° (Found: C, 60·0; H, 5·8; N, 6·82. $C_{21}H_{14}O_7N_2$ requires C, 60·5; H, 5·8; N, 6·72%). The reaction was slow, as some unchanged reagents were found on working-up.

A similar procedure with 2-naphthol gave the 1-2′-*naphthoxy*-analogue (V; R = 2-$C_{10}H_7$), b. p. 136—140°/0·003 mm. This solidified and could be recrystallised from chilled light petroleum (b. p. 40—60°) in asbestos-like needles, m. p. 46—47° (Found: C, 78·9; H, 8·5. $C_{18}H_{24}O_2$ requires C, 79·4; H, 8·9%). The reaction was exceedingly slow, only a 19% yield being obtained after 24 hr. of refluxing; reaction at 150° in an autoclave gave a very impure product.

Reactions of Ethoxytrimethylpentanols.—Both (IV) and (V; R = Et) were unchanged by 3 hours' refluxing with ethanol containing a little sulphuric acid. When (V; R = Et) was distilled over a little iodine, not much water was eliminated. The distillate, b. p. 145—148°, was mainly (87% by titration) 2 : 4 : 4-trimethylpentanal. The product from similar treatment of (IV; R = Et) was qualitatively similar.

Compound (V; R = Et) (39 g.) was shaken for 3 hr. with concentrated hydrochloric acid (100 ml.). The washed organic phase, recovered by means of ether, yielded materials (15·3 g.), b. p. 40—42°/10 mm., n_D^{20} 1·4191, and (1·8 g.), b. p. 108—114°/10 mm., and a residue (1·4 g.). The first fraction appeared by titration to consist of aldehyde (XXIV) (41%) and an ethoxytrimethylpentene (55%).

Compound (V; R = Et) (18 g.) was heated on a steam-bath with potassium permanganate (32 g.) and sodium hydroxide (40 g.) in water (500 ml.). After removal of manganese dioxide and neutral organic product, the solution was acidified and extracted with ether, which removed α-hydroxy-αγγ-trimethylvaleric acid (VI) (1·8 g.), m. p. 107—108° (undepressed by a synthetic sample, see below) [Found: C, 60·3; H, 10·1; active H (Zerewitinov), 1·22%; OEt, nil; equiv., 157. Calc. for $C_7H_{14}(OH)(CO_2H)$: C, 60·0; H, 10·1; active H, 1·26%; equiv., 160]. The same acid was obtained in similar yield by oxidation of (IV; R = Et).

4 : 4-Dimethylpentan-2-one (VII) (57 g.) in methanol (300 ml.) was added to potassium cyanide (40 g.) in water (100 ml.), and sulphuric acid (30 g.) in water (100 ml.) was added dropwise with stirring. After 2 hr. the mixture was diluted with water (2 vol.). An ethereal extract yielded much unchanged ketone, and a fraction (5 g.), b. p. 110—117°/20 mm., n_D^{20} 1·432. This was presumably the cyanohydrin. This material (2 g.) was refluxed with concentrated hydrochloric acid for 2 hr., and acidic products were isolated in ether, yielding (VI) (0·34 g.), m. p. 106° undepressed by admixture with the specimen obtained as above or from the chlorhydrin.

Reaction with Ammonia and Amines.—*With ammonia.* (*a*) The epoxide (I) (256 g., 2·0 moles) and aqueous ammonia (1·5 l.; *d* 0·88; approx. 27 moles) were heated with stirring in a steel autoclave to 190° for 5 hr. When cool, the amines were extracted twice into chloroform, and the combined extracts were washed with a small amount of water, dried (Na_2SO_4), and distilled. After the solvent, two main fractions, b. p. 85—95°/18 mm. and 170—180°/15 mm., were obtained. On occasions, a small intermediate fraction, b. p. 120—140°/14 mm., n_D^{20} 1·4535, was also obtained. By redistillation of the first main fraction, 2-*hydroxy*-2 : 4 : 4-*trimethylpentylamine* (XXV; R = H), b. p. 87—88°/14 mm., n_D^{20} 1·4580, d_{20}^{20} 0·8991, K_b 4·5 × 10^{-5}, was obtained (Found: C, 66·1; H, 13·4; N, 9·6%; equiv., 144. $C_8H_{19}ON$ requires C, 66·1; H, 13·2; N, 9·6%; equiv., 145). The *picrate* (unless stated, picrates were recrystallised from ethanol or aqueous ethanol) formed orange plates, m. p. 151—152° (Found: N, 14·8. $C_8H_{19}ON,C_6H_3O_7N_3$ requires N, 15·0%); the *hydrochloride* crystallised in plates, m. p. 183°, from ethanol–ether (Found: C, 52·8; H, 10·6; N, 7·7. $C_8H_{19}ON,HCl$ requires C, 52·9; H, 11·1; H, 7·7%). The second main fraction yielded *di-(2-hydroxy-*2 : 4 : 4-*trimethylpentyl)amine* (XXVI; R = H), b. p. 175—180°/14 mm., b. p. 130—132°/1 mm., d_{20}^{20} 0·9088, n_D^{20} 1·4619 (Found: C, 70·6; H, 13·1; N, 5·3. $C_{16}H_{35}O_2N$ requires C, 70·3; H, 12·9; N, 5·1%). The *picrate* crystallised in long prisms, m. p. 154—155° (Found: C, 52·7; H, 7·4; N, 11·2. $C_{16}H_{35}O_2N,C_6H_3O_7N_3$ requires C, 52·6; H, 7·6; N, 11·1%). The *sulphate* crystallised in prisms, m. p. 228—229°, from water containing a little ethanol (Found: N, 4·4. $2C_{16}H_{35}O_2N,H_2SO_4$ requires N, 4·3%). The *carbonate* crystallised in laths, m. p. 204°, from ethanol–ether (Found: C, 61·0; H, 11·5. $C_{16}H_{35}O_2N,H_2CO_3$ requires C, 60·9; H, 11·1%).

(*b*) The epoxide (I) (512 g., 4 moles) and aqueous ammonia (1050 ml., *d* 0·88; 20 moles) were heated with stirring in the autoclave to 158—160° for 5 hr. A maximum pressure of 31 atm. was reached. After refluxing to remove the excess of ammonia, sodium chloride (250 g.) was added, and the mixture extracted twice with toluene (500, 100 ml.). On fractionation of the combined extracts, the toluene–water azeotrope distilled out first, followed by toluene, (XXV; R = H) (313 g., 54%), and (XXVI; R = H) (166 g., 30%).

(*c*) The epoxide (I) (128 g., 1 mole) and 3·5N-ethanolic ammonia (300 ml., 1·05 moles) were heated together in an autoclave at 180° for 4 hr. The product was distilled directly. After removal of ethanol and a trace of aminotrimethylpentanol, the secondary amine was obtained in 66% yield.

The intermediate fraction mentioned above was produced occasionally from earlier batches of epoxide. It could be further purified by a second distillation, and then had b. p. 129—130°/14 mm., n_D^{20} 1·4535 (Found: C, 71·6; H, 13·4; N, 7·2; active H, 0·51. $C_{12}H_{27}ON$ requires C, 71·6; H, 13·4; N, 7·0; active H, 0·49%). A 3 : 5-*dinitrobenzoyl* derivative was prepared, which after repeated recrystallisation from aqueous ethanol and then light petroleum, had m. p. 131—132° (Found: C, 60·9; H, 7·8; N, 9·5. $C_{22}H_{35}O_6N_3$ requires C, 60·4; H, 8·0; N, 9·6%).

The effect upon the yield of mono- and di-hydroxy-amines of varying the molar proportions of epoxide to ammonia may be summarised:

Ratio NH_3 : (I)	1·15	4·25	5·0	6·75	15	67
Yield (%) of (XXV; R = H)	9	51·5	54	57	63	63
„ (XXVI; R = H)	71·5	34	30	26	9	trace

The hydroxy-amine (XXV; R = H) (20 g.) was refluxed with concentrated hydrochloric acid (100 ml.) for 2 hr. An oily layer rapidly separated. This was extracted with ether, washed, dried, and distilled, yielding 2 : 4 : 4-trimethylpentanal (XXIV), b. p. 37—40°/13 mm., n_D^{20} 1·4139 (6·9 g., 39%; 95% pure), identified as its dinitrophenylhydrazone, m. p. 143°. The acidic layer was basified with sodium hydroxide, and the oil which separated was isolated in ether. Distillation afforded an unsaturated *amine* (XXVII or XXVIII) (18%), b. p. 51—53°/13 mm., n_D^{20} 1·4488 (Found: C, 75·4; H, 13·5; N, 10·8%; equiv., 130. $C_8H_{17}N$ requires C, 75·5; H, 13·4; N, 11·0%; equiv., 127). By microhydrogenation of the amine (250 mg.) in ethanol over Adams's catalyst, hydrogen equivalent to 1·0 double bond per mole was absorbed. Picric acid was added to the filtered solution, and 2 : 4 : 4-trimethylpentylamine picrate separated, m. p. 190° after recrystallisation (cf. Part II, p. 2178).

The hydroxy-amine (XXV; R = H) (16·5 g.), sodium hydrogen carbonate (20 g.), water (200 ml.), and ether (150 ml.) were stirred and cooled in ice whilst benzoyl chloride (17 g., 20% excess) was added dropwise. A white solid began to separate, but redissolved on addition of chloroform. The solvent layer was extracted with dilute sodium hydroxide, then with sulphuric acid, and dried, and concentrated. The residue was triturated with ether and recrystallised from chloroform–light petroleum (b. p. 100—120°) to give laths (23 g., 92%) of 1-*benzamido*-2 : 4 : 4-*trimethylpentan*-2-*ol*, m. p. 103—105° (Found: C, 71·2; H, 9·4. $C_{15}H_{23}O_2N$ requires C, 72·3; H, 9·3%).

The hydroxy-amine (XXV; R = H) (22 g.) was treated with acetic anhydride (22 g.) and pyridine (20 ml.); much heat was evolved. After 1 hr., the mixture was poured into water, and the neutral product isolated in ether. Distillation gave two small fractions. The first, b. p. 70—76°/14 mm. (3 g.), n_D^{20} 1·4422, appeared to be impure 4 : 5-*dihydro*-2 : 5-*dimethyl*-5-neo*pentyloxazole* (X) (Found: C, 69·6; H, 11·1; N, 7·7%; equiv., 180. $C_{10}H_{19}ON$ requires C, 70·9; H, 11·3; N, 8·3%; equiv., 169). It gave a *picrate*, m. p. 126° (Found: C, 48·1; H, 5·5; N, 13·8. $C_{10}H_{19}ON,C_6H_3O_7N_3$ requires C, 48·2; H, 5·6; N, 14·1%). The second fraction,

b. p. 135—140°/14 mm., n_D^{20} 1·4695 (2·5 g.), was non-basic, but gave a similar analysis (Found: C, 68·8; H, 11·0; N, 7·4%).

With methylamine. A mixture of epoxide (I) (128 g., 1 mole), 33% ethanolic methylamine (70 g., 0·75 mole), and ethanol (250 ml.) was heated in the autoclave for 5 hr. at 180°. After removal of ethanol and excess of methylamine by distillation, major fractions of b. p. 79—90°/14 mm. and 160—180°/15 mm. were obtained. The former on redistillation gave 2-*hydroxy*-2 : 4 : 4 : N-*tetramethylpentylamine* (XXV; R = Me) (0·24 mole), b. p. 82°/14 mm., n_D^{20} 1·4461, K_b 8 × 10^{-4} (Found: C, 67·5; H, 13·1; N, 9·0. $C_9H_{21}ON$ requires C, 67·9; H, 13·3; N, 8·8%). The *picrate* formed yellow prisms, m. p. 129—130° (Found: N, 14·4. $C_9H_{21}ON,C_6H_3O_7N_3$ requires N, 14·4%). The second fraction slowly solidified. The waxy solid, *N*-methyldi-(2-hydroxy-2 : 4 : 4-trimethylpentyl)amine (XXVI; R = Me), could not be recrystallised. The *hydrochloride*, prepared in ether, after several recrystallisations from ethanol–ether had a somewhat indefinite m. p., 169—172° (Found: C, 63·3; H, 11·9; N, 4·1. $C_{17}H_{37}O_2N,HCl$ requires C, 63·0; H, 11·8; N, 4·3%).

An aqueous suspension of the hydrochloride was basified, and the amine extracted with ether. After being dried, the extract was concentrated, leaving the *amine* (XXVI; R = Me) as a solid, m. p. 42—43°; sublimation at 1 mm. did not raise the m. p. (Found: C, 71·0; H, 12·6; N, 5·0%; equiv., 283. $C_{17}H_{37}O_2N$ requires C, 71·0; H, 13·0; N, 4·9%; equiv., 287). The amine was very readily soluble in all organic solvents. In a similar way, the *hydrobromide*, prepared by adding concentrated hydrobromic acid to an ethanolic solution of the crude amine, and recrystallised from aqueous ethanol to m. p. 198° (Found: C, 55·7; H, 10·1; N, 4·1. $C_{17}H_{37}O_2N,HBr$ requires C, 55·4; H, 10·4; N, 3·8%), gave a regenerated amine of m. p. 66° (Found: C, 70·9; H, 12·8%; equiv., 285).

With diethylamine. Diethylamine (320 ml., 3·1 moles), ethanol (300 ml.), and epoxide (I) (256 g., 2 moles) were heated in a stainless-steel autoclave at 160° for 5 hr. with stirring. Distillation of the product afforded NN-*diethyl*-2-*hydroxy*-2 : 4 : 4-*trimethylpentylamine* (IX; R = R′ = Et), b. p. 95—96°/15 mm., 220°/756 mm., n_D^{20} 1·4401, K_b 5 × 10^{-6} [Found: C, 71·5; H, 13·6; N, 6·7; active H, 0·45%; equiv., 196. $C_{12}H_{26}N(OH)$ requires C, 71·6; H, 13·5; N, 6·9; active H, 0·50%; equiv., 201]. The *picrate* formed lemon-yellow cubes, m. p. 105° (Found: C, 50·6; H, 6·7; N, 13·2. $C_{12}H_{27}ON,C_6H_3O_7N_3$ requires C, 50·2; H, 7·0; N, 13·0%). Incomplete reaction took place in 3 hr. at 140°, some 25% of epoxide being unchanged. In the absence of ethanol, reaction only occurred to the extent of about 5%.

The amine (IX; R = R′ = Et) (150 g.) was quaternised by heating it with methyl iodide (150 g.) in methanol (500 ml.) in an autoclave at 120° for 5 hr. Evaporation left the *methiodide* (170 g., 66%), which crystallised from ethanol–ether in irregular aggregates, m. p. 147° (Found: C, 45·7; H, 8·6. $C_{13}H_{30}ONI$ requires C, 45·5; H, 8·8%). This salt was extractable into chloroform from aqueous alkaline solution. It was also prepared in poor yield by refluxing the amine with excess of dimethyl sulphate in ethanol for 5 hr., evaporating the ethanol, adding aqueous sodium hydroxide and iodide in excess, and extracting the quaternary iodide with chloroform, from which it was readily isolated.

Methyl bromide (4 g.), the amine (5 g.), and ethyl acetate (25 g.) were heated to 130° for 5 hr. in a Carius tube. The product formed two layers, the lower and more viscous of which dissolved in acetone and subsequently deposited crystals (4 g., 55%). After recrystallisation from acetone containing a little ether, the *methobromide* had m. p. 124—126° (Found: Br, 26·7. $C_{13}H_{30}ONBr$ requires Br, 27·0%). The bromide was converted into the iodide with sodium iodide in boiling acetone. The hot solution was filtered, and the corresponding quaternary iodide crystallised out on cooling. Its m. p. was 144° alone and when mixed with the pure iodide described above. The quaternary bromide was not extracted into chloroform from an alkaline aqueous solution.

With dimethylamine. Epoxide (I) (128 g., 1 mole) was heated in a 1-l. stainless-steel stirred autoclave with 33% aqueous dimethylamine (200 g., 1·5 mole) at 180° for 4 hr. The oily layer was extracted into chloroform, and the extract was dried, concentrated, and distilled, yielding 2-*hydroxy*-2 : 4 : 4 : N : N-*pentamethylpentylamine* (IX; R = R′ = Me), b. p. 77—78°/14 mm., n_D^{20} 1·4370 (76%) (Found: C, 69·8; H, 13·4; N, 7·6. $C_{10}H_{23}ON$ requires C, 69·3; H, 13·4; N, 8·1%). The *picrate* crystallised from ethanol in yellow rhombs, m. p. 128° (Found: C, 48·1; H, 6·5; N, 14·1. $C_{10}H_{23}ON,C_6H_3O_7N_3$ requires C, 47·8; H, 6·5; N, 13·9%). The *methiodide* had m. p. 129—130° after recrystallisation from ethanol–ether (Found: N, 4·0; I, 40·7. $C_{11}H_{26}ONI$ requires N, 4·4; I, 40·3%).

With aniline. Aniline (64 g., 0·69 mole), epoxide (I) (64 g., 0·5 mole), and methanol (200 ml.) were heated in a stainless-steel autoclave at 170—180° for 5 hr. The product was distilled, and after removal of methanol and excess of aniline, a fraction, b. p. 150—195°/10 mm. (mainly 185—190°) (54 g.), was obtained. Little residue remained. The high-boiling fraction largely solidified and was triturated under light petroleum (b. p. 40—60°). Recrystallisation from the same solvent afforded needles of N-2-*hydroxy*-2 : 4 : 4-*trimethylpentylaniline* (XXV; R = Ph), m. p. 68° (Found: C, 76·0; H, 10·4; N, 6·4. $C_{14}H_{23}ON$ requires C, 76·0; H, 10·5; N, 6·3%). The *picrate* crystallised from aqueous ethanol in orange plates, m. p. 134—135° (Found: C, 53·7; H, 5·8; N, 12·0. $C_{14}H_{23}ON,C_6H_3O_7N_3$ requires C, 53·3; H, 5·8; N, 12·4%).

With methylaniline. Redistilled methylaniline (17·1 g., 0·16 mole), epoxide (I) (17·1 g., 0·134 mole), and methanol (35 ml.) were heated together at 170—180° for 3·5 hr. in a stainless-steel autoclave. By distillation of the product, a main fraction, b. p. 164—166°/10 mm. (11·7 g., 38%), was obtained, which on redistillation afforded N-(2-*hydroxy*-2 : 4 : 4-*trimethylpentyl*)-N-*methylaniline* (IX; R = Ph, R′ = Me), b. p. 165—167°/10 mm., n_D^{20} 1·5282 (Found: C, 76·7; H, 10·6; N, 6·1. $C_{15}H_{25}ON$ requires C, 76·5; H, 10·7; N, 5·9%).

With morpholine. Epoxide (I) (64 g., 0·5 mole), morpholine (64 g., 0·73 mole), and methanol (250 ml.) similarly afforded 4-(2-*hydroxy*-2 : 4 : 4-*trimethylpentyl*)*morpholine*, b. p. 125—126°/12 mm., n_D^{20} 1·4633 (Found: C, 66·6; H, 11·6; N, 6·7%; equiv., 212. $C_{12}H_{25}O_2N$ requires C, 66·9; H, 11·7; N, 6·5%; equiv., 215). The *picrate* crystallised from methanol in yellow prisms, m. p. 158° (Found: C, 48·9; H, 6·4; N, 12·9. $C_{12}H_{25}O_2N,C_6H_3O_7N_3$ requires C, 48·7; H, 6·3; N, 12·6%). The *methiodide*, m. p. 108—110° (Found: C, 44·0; H, 7·6; N, 3·6. $C_{13}H_{28}O_2NI$ requires C, 43·7; H, 7·9; N, 3·9%), was recrystallised from acetone–ethyl acetate (2 : 3). The *methobromide* formed plates, m. p. 161—164° (Found: C, 50·6; H, 9·2; N, 4·3; Br, 25·7. $C_{13}H_{28}O_2NBr$ requires C, 50·3; H, 9·1; N, 4·5; Br, 25·8%), from acetone containing a little methanol.

Interaction of Ammonia with 2 : 3-*Epoxy*-2 : 4 : 4-*trimethylpentane*.—(*a*) The epoxide (XXXI) (64 g., 0·5 mole) and aqueous ammonia (500 ml.; *d* 0·88; 9·0 mole) were stirred and heated at 190° for 3 hr. in a stainless-steel autoclave. The product was extracted with ether, washed with a little water, dried, and fractionated. A main fraction of b. p. 76—81°/15 mm. (15%) (Found: equiv., 146) was obtained. Redistillation afforded a series of fractions, ranging from b. p. 73°/12 mm., n_D^{20} 1·4534, to b. p. 78°/12 mm., n_D^{20} 1·4569, which appeared to correspond to mixtures of 2-amino-2 : 4 : 4-trimethylpentan-3-ol (XXXII) and 3-amino-2 : 4 : 4-trimethylpentan-2-ol (XXXIII) (Found: C, 66·3; H, 13·1; N, 9·4. Calc. for $C_8H_{19}ON$: C, 66·1; H, 13·2; N, 9·6%). A *picrate*, prepared from a middle cut, had m. p. 188—191° after recrystallisation (Found: C, 45·0; H, 6·0; N, 14·6. $C_8H_{19}ON,C_6H_3O_7N_3$ requires C, 44·9; H, 5·9; N, 15·0%). From the lowest-boiling fractions, the same picrate was obtained, but in a less pure state and with a much lower initial m. p. The *hydrochloride*, after recrystallisation from ethanol–ether, had m. p. 222° (Found: C, 53·0; H, 10·8; N, 7·7. $C_8H_{19}ON,HCl$ requires C, 52·9; H, 11·1; N, 7·7%).

(*b*) The epoxide (XXXI) (64 g., 0·5 mole), aqueous ammonia (110 ml.; *d* 0·88; 1·8 mole), and water (150 ml.) were heated as before to 180—200° for 5 hr. The product was extracted into chloroform, washed, dried, and fractionated. After removal of a little unchanged epoxide, some ketonic material, mono-hydroxy-amines, and 2 : 4 : 4-trimethylpentane-2 : 3-diol, a main fraction, b. p. 125—128°/14 mm. (Found: equiv., 253), was obtained. Redistillation afforded (probably) 2 : 6-*di*-tert.-*butyl*-3 : 3 : 5 : 5-*tetramethylmorpholine* (XXXV), b. p. 127—129°/12 mm., n_D^{20} 1·4577 [Found: C, 75·2; H, 13·0; N, 5·8; active H, 0·34%; equiv., 253. $C_{16}H_{32}O(NH)$ requires C, 75·2; H, 13·0; N, 5·5; active H, 0·39; equiv., 255]. No hydroxyl groups were detectable by the Smith and Bryant method. The basic group was difficult to acetylate, for only 80% had reacted after 30 minutes' refluxing with acetic anhydride. The *picrate* formed bright yellow crystals, m. p. 191° (Found: C, 54·7; H, 7·5; N, 11·7. $C_{16}H_{33}ON,C_6H_3O_7N_3$ requires C, 54·5; H, 7·5; N, 11·6%).

Reaction with Acids, Salts, etc.—With acetic acid. (*a*) The epoxide (I) (30 g.) was added during 2—3 min. to glacial acetic acid (200 ml.) containing sulphuric acid (1 g.). The sulphuric acid was neutralised with an excess of powdered anhydrous sodium acetate, and after filtration, most of the acetic acid was removed under reduced pressure. The residue was partitioned between ether and water, and the alkali-washed ethereal layer distilled. Two fractions of main product were obtained: b. p. 80—110°/15 mm. (3·5 g.; n_D^{20} 1·4359) and 110—125° (mostly 113°)/15 mm. (3·4 g.; n_D^{20} 1·4395). By hydrolysis these gave equivalents of 219 and 216, respectively (calc., 188).

(*b*) Epoxide (I) (64 g.), anhydrous sodium acetate (41 g.), and acetic acid (500 ml.) were refluxed for 10 hr. The sodium acetate remained apparently unchanged. After being worked up as in (*a*), the product on distillation gave unidentified material (7·8 g.), b. p. 71—78°/10 mm.,

n_D^{20} 1·4341, and 2-*hydroxy*-2 : 4 : 4-*trimethylpentyl acetate* (12·7 g.), b. p. 107°/12 mm., n_D^{20} 1·4392 [Found : C, 63·6; H, 10·6; active H (Zerewitinov), 0·51; (Smith and Bryant), 0·30%; equiv., 192. $C_{10}H_{19}O_2(OH)$ requires C, 63·8; H, 10·7; active H, 0·54%; equiv., 188]. The infra-red spectrum proved it to be identical with the synthetic glycol monoacetate (XVII), and showed a non-primary hydroxyl group.

(*c*) The epoxide (I) (64 g.) was added slowly to acetic acid (250 ml.) containing boron trifluoride–ether complex (2 ml.); the reaction was exothermic. After removal of most of the acetic acid under reduced pressure, the residue was washed with sodium hydroxide solution and extracted with ether. The main product (34·1 g.; b. p. 35—44°/10 mm.) was largely aldehyde (XXIV); only 4·9 g. of a fraction, b. p. 103—110°/10 mm., were obtained.

With acetyl chloride. Epoxide (I) (64 g.) was added slowly to boiling acetyl chloride (40 g.) and carbon tetrachloride (250 ml.), and the mixture distilled. The product was complex and no pure compound was isolated. From analytical data, the presence of the following was inferred : unchanged acetyl chloride (12·4 g.), together with solvent in fractions of b. p. <100°/760 mm.; chlorotrimethylpentene, b. p. <131°/760 mm.; trimethylpentenyl acetate, b. p. 34—82°/12 mm.; trimethylchloropentyl acetate, b. p. 82—105°/12 mm.

With hydrogen chloride. Epoxide (I) (32 g., 0·25 mole) was added to 3·5N-ethereal hydrogen chloride (80 ml., 0·275 mole) at 0°, and after an exothermic reaction had taken place the mixture was left at 0° for 2 hr. The excess of hydrogen chloride was removed by ice-cold water, and the ether layer was dried ($MgSO_4$ and MgO) and distilled. The fraction, b. p. 65—75°/14 mm. (10·2 g., 25%), was redistilled, giving 1-*chloro*-2 : 4 : 4-*trimethylpentan*-2-*ol* (XII), b. p. 70—71°/13 mm., n_D^{20} 1·4519 [Found : C, 58·5; H, 10·7; Cl, 22·8; active H, 0·56. $C_8H_{16}Cl(OH)$ requires C, 58·3; H, 10·4; Cl, 21·5; active H, 0·61%]. In addition, a large fraction, b. p. 148—152°/760 mm., was obtained, which contained trimethylpentanal (*ca.* 60%), identified as its dinitrophenylhydrazone, together with a chlorine-containing compound, the halogen of which was stable to cold aqueous alkali.

Titration of the chlorohydrin (XII) in ethanol with aqueous sodium hydroxide to phenolphthalein resulted in slow absorption of alkali equivalent to the whole of the chlorine present.

The chlorohydrin (XII) (10 g.), potassium acetate (8 g.), and methanol (20 ml.) were heated in a Carius tube at 140° for 16 hr. The product was concentrated and poured into water, and the oily layer isolated in ether. Distillation gave 2 : 4 : 4-trimethylpentane-1 : 2-diol (II) (2·7 g.), b. p. 100—107°/13 mm., m. p. 60° undepressed by authentic material.

The chlorohydrin (XII) (3·5 g.), diethylamine (6 ml.), and methanol (5 ml.) were heated in a Carius tube at 160° for 3 hr. The contents of the tube were diluted with ether, and diethylamine hydrochloride, m. p. 222°, was filtered off. The filtrate was concentrated, and the basic portion isolated in ether. From this, *NN*-diethyl-2-hydroxy-2 : 4 : 4-trimethylpentylamine (IX; R = R′ = Et) (1·4 g.), b. p. 90—95°/13 mm., n_D^{20} 1·4409, was obtained. Its identity with the material obtained as above was confirmed by preparation of the picrate, m. p. and mixed m. p. 104°.

The chlorohydrin (XII) (8 g.) and 9N-methanolic ammonia (45 g.) were heated in a Carius tube at 140° for 19 hr. The product was concentrated, the residue dissolved in chloroform, and the solution washed with dilute sodium hydroxide and finally distilled. 2-Hydroxy-2 : 4 : 4-trimethylpentylamine (XXV; R = H) (3 g., 43%), b. p. 83—87°/14 mm., n_D^{20} 1·4598, was obtained therefrom, and was identified as the hydrochloride, m. p. and mixed m. p. 183° (cf. above).

The chlorohydrin (XII) (10 g.) was distilled from anhydrous oxalic acid (10 g.). Some water first distilled, followed by an oil, which was taken up in ether, washed, dried, and fractionated giving a *trimethylchloropentene*, b. p. 151—152°, n_D^{20} 1·4438—1·4445 (Found : C, 65·2; H, 10·8; Cl, 23·7; active H, nil. $C_8H_{15}Cl$ requires C, 65·5; H, 10·3; Cl, 24·2%) (chlorodi*ïso*butylene has b. p. 53—54°/20 mm., n_D^{20} 1·4473; Umnowa, *loc. cit.*).

The chlorohydrin (XII) (5 g.), potassium permanganate (5 g.), sodium hydroxide (3 g.), and water (100 ml.) were heated on a steam-bath with occasional shaking for 4—5 hr. Manganese dioxide and a small oily layer were removed, and the aqueous solution was acidified and extracted with ether, giving α-hydroxy-αγγ-trimethylvaleric acid (VI), m. p. 107° not depressed by the material obtained as above.

With sodium sulphite. Epoxide (I) (64 g., 0·5 mole), sodium sulphite heptahydrate (126 g., 0·5 mole), and water (500 ml.) were stirred in a stainless-steel autoclave at 140—150° for 6 hr. An oily layer was separated from the product with ether, and the aqueous solution soon deposited a white crystalline solid. This was filtered off and washed with ice-cold water and then ethanol; further crops were obtained on concentration of the mother-liquor, giving a total of 74·5 g. (55%). After recrystallisation from 95% ethanol, sodium 2-hydroxy-2 : 4 : 4-trimethylpentane-1-sulphonate (XIII) formed colourless lustrous plates of the *monohydrate*, m. p. 202° [Found: C, 38·6; H, 7·6; S, 12·7; ash, 28·6; loss in vacuum at 100°, 7·3. $C_8H_{17}O_4SNa,H_2O$ requires C, 38·4; H, 7·7; S, 12·8; ash (Na_2SO_4), 28·4; H_2O, 7·2%]. The S-*benzylthiuronium salt* crystallised from aqueous ethanol in laths, m. p. 135° (Found: C, 51·1; H, 7·3. $C_8H_{10}N_2S,C_8H_{18}O_4S$ requires C, 51·1; H, 7·5%). Distillation of the oily product afforded mainly 4 : 4-dimethylpentan-2-one, b. p. 115—125°/760 mm. (identified as dinitrophenylhydrazone), and the diol (II), m. p. 60—62°.

The hydroxy-sulphonate (XIII) (25 g.) and acetic anhydride (75 ml.) were refluxed gently for 15 min., water was added, and the bulk of the acetic acid removed by steam-distillation. A solid crystallised on cooling, which was recrystallised from 90% ethanol giving an unsaturated *sulphonate monohydrate* as plates, m. p. 216° (decomp.) (Found: C, 41·8; H, 7·5; S, 13·3. $C_8H_{15}O_3SNa,H_2O$ requires C, 41·4; H, 7·4; S, 13·8%). The S-*benzylthiuronium salt*, m. p. 153—157°, was prepared in aqueous solution. On repeated recrystallisation from ethanol the least soluble fraction formed needles, m. p. 180—181° (Found: C, 53·9; H, 7·4. $C_8H_{10}N_2S,C_8H_{16}O_3S$ requires C, 53·6; H, 7·3%). No pure component could be isolated from the mother-liquors.

An aqueous solution of the unsaturated sulphonate (6 g.) was hydrogenated over Adams's catalyst. Hydrogen equivalent to 0·8 double bond per mole was absorbed. The filtered solution was evaporated to dryness and the residual solid (5 g.) triturated with ethanol and recrystallised from 90% ethanol; *sodium* 2 : 4 : 4-*trimethylpentane*-1-*sulphonate* (XIV) *monohydrate* formed plates of indefinite m. p. (Found: C, 40·6; H, 8·1. $C_8H_{17}O_3SNa,H_2O$ requires C, 41·0; H, 8·2%). The S-*benzylthiuronium salt* crystallised from aqueous ethanol in long blunt-ended needles, m. p. 151° (Found: C, 53·4; H, 7·9; N, 7·6. $C_8H_{10}N_2S,C_8H_{18}O_3S$ requires C, 53·3; H, 7·8; N, 7·8%).

With potassium cyanide. Epoxide (I) (128 g., 1 mole), 96% potassium cyanide (68 g., 1 mole), potassium hydroxide (2 or 3 pellets), and water (400 ml.) were heated in an autoclave at 130—140° for 5 hr. The product had a strong ammoniacal odour. The oily layer was isolated in ether and fractionated. 4 : 4-Dimethylpentan-2-one and unchanged epoxide (25% of the charge) came over first, followed by fractions (i) b. p. 85—110°/14 mm., (ii) 110—125°/14 mm., (iii) 125—140°/14 mm., and (iv) 150—170°/14 mm. Fraction (ii) was mainly the 1 : 2-diol (II) (4%), m. p. 60°. Fraction (iv) was identified as the dihydroxy-amine (XXVI; R = H) (20%), by preparation of the sulphate, m. p. 222°, and picrate, m. p. 149°, neither depressed by authentic samples. Fraction (i) was redistilled, and gave a main product, b. p. 85—86°/12 mm., n_D^{20} 1·4528, which appeared to be substantially 2 : 4 : 4-*trimethylpent*-1-*enyl cyanide* (XXXVII) (9%) (Found: C, 78·8; H, 11·6; N, 10·2. $C_9H_{15}N$ requires C, 78·8; H, 11·0; N, 10·2%). The infra-red absorption spectrum had bands at 819 and 835 cm.$^{-1}$, characteristic of trisubstituted ethylenes, thus confirming the vinyl cyanide structure. Fraction (iii) was redistilled and gave a fraction, b. p. 125—132°/14 mm. (14%), n_D^{20} 1·4525—1·4529, of a basic substance [Found: C, 74·3; H, 13·0; active H, 0·47%; equiv., 251. $C_{16}H_{32}ON(H)$ requires C, 75·2; H, 13·0; active H, 0·3%; equiv., 255].

Miscellaneous Reactions.—With sodium alkyl or aralkyl sulphides. (*a*) Methanethiol (from 55·5 g. = 0·40 mole of methylthiuronium sulphate; cf. *Org. Synth.*, Coll. Vol. II, p. 345) was passed into ethanol (150 ml.) containing sodium ethoxide (from sodium, 8 g., 0·34 mole). The epoxide (I) (50 g., 0·39 mole) was then added slowly; an exothermic reaction took place, the temperature rising to 40°. The mixture was finally warmed to 70°, and next morning was diluted with water. The oily product was isolated in ether, well washed, dried, and distilled. The fraction of b. p. 90—98°/14 mm. (23·6 g., 38% on sodium used) was redistilled, giving 2 : 4 : 4-*trimethyl*-1-*methylthiopentan*-2-*ol* (XV; R = Me), b. p. 96—98°/14 mm., n_D^{20} 1·4749 [Found: C, 62·0; H, 11·6; S, 17·5; active H, 0·6. $C_9H_{19}S(OH)$ requires C, 61·3; H, 11·5; S, 18·2; active H, 0·57%].

A mixture of this product (7 g.), Raney nickel (100 g.), and ethanol (50 ml.) was refluxed for 5 hr. The filtrate and ethanol washings from the nickel were distilled, first removing ethanol and then the whole of the remaining liquid product, and leaving a whitish inorganic residue. The product was taken up in ether, traces of ethanol were washed out with water, and when dried it was redistilled. A main fraction, n_D^{20} 1·4238, was collected at 143—145° (Found: C, 73·3; H, 14·0. Calc. for $C_8H_{18}O$: C, 73·8; H, 13·9%). This was shown to contain at least 90% of 2 : 4 : 4-trimethylpentan-2-ol (XVI), by comparison of its infra-red absorption spectrum with that of an authentic sample, b. p. 145—146°, n_D^{20} 1·4281, prepared by Ritter's method (*loc. cit.*) (Found: C, 73·5; H, 14·0%).

(*b*) Toluene-ω-thiol (12·4 g., 0·1 mole), sodium hydroxide (6 g., 0·15 mole), water (10 ml.), ethanol, and (I) (14·0 g., 0·109 mole) were refluxed for 2·5 hr. The oil which separated on pouring of the product into water was taken up in ether, washed with dilute sodium hydroxide, then water, dried, and distilled. The fraction, b. p. 175—185°/14 mm. (19·0 g., 75%), was redistilled, giving 1-*benzylthio*-2 : 4 : 4-*trimethylpentan*-2-*ol* (XV; R = CH_2Ph), b. p. 104—105°/0·1 mm., n_D^{20} 1·5290 (Found: C, 71·5; H, 9·5. $C_{15}H_{24}OS$ requires C, 71·4; H, 9·5%).

With methylmagnesium iodide. The epoxide (I) (64 g., 0·5 mole) reacted gently with methylmagnesium iodide (0·5 mole) in ether. After hydrolysis with 2N-hydrochloric acid, the product on distillation gave a badly coloured main fraction (22·5 g., 31%), b. p. 73—76°/15 mm., and a large resinous residue. Redistillation of the main fraction gave fractions, still badly coloured: (i) b. p. 71·5—72°/14 mm. (7·2 g.), n_D^{20} 1·4382, (ii) 72—73·5°/14 mm. (7·6 g.), n_D^{20} 1·4390, (iii) 73·5—77°/14 mm. (6·0 g.), n_D^{20} 1·4420. Comparison of the infra-red spectra of fractions (i) and (iii) with that of synthetic 3 : 5 : 5-trimethylhexan-2-ol (XX) (see below) indicated that each contained approximately 50% of this alcohol, and that the other component of the mixture gave a strong hydroxyl band and an ethyl band. This second component is therefore probably 3 : 5 : 5-trimethylhexan-3-ol. Fraction (ii) gave a 3 : 5-dinitrobenzoate, m. p. 39—40° not raised by further recrystallisation.

2 : 4 : 4-Trimethylpentanal (XXIV) and methylmagnesium iodide (0·5 mole of each) were allowed to react in ether, affording after the usual procedure 3 : 5 : 5-trimethylhexan-2-ol (XX) as a pale yellow liquid, b. p. 75—80°/18 mm., n_D^{20} 1·4325 (71%), giving a 3 : 5-*dinitrobenzoate*, m. p. 61° (Found: C, 56·9; H, 6·5. $C_{16}H_{22}O_6N_2$ requires C, 56·8; H, 6·6%).

With ethyl acetoacetate. Sodium (11·5 g., 0·5 mole) was "powdered" under toluene and transferred to dry dioxan. Ethyl acetoacetate (65 g., 0·5 mole) was added slowly, dissolution of the sodium being finally hastened by warming. This solution together with epoxide (I) (64 g., 0·5 mole) was heated in an autoclave for 5 hr. at 150°. Water was added to the product followed by dilute sulphuric acid until acid, and the oily product was extracted with ether, washed, dried, and fractionated. A main fraction, b. p. 104—115°/0·7 mm. (21·1 g.), n_D^{20} 1·4614, was collected, together with low- and high-boiling by-products. From its analysis this product was a mixture, but it readily gave a pale yellow 2 : 4-*dinitrophenylhydrazone*, m. p. 114—115°, from aqueous ethanol and then methanol, of composition approximately that of the derivative of (XVIII) (Found: C, 55·6; H, 5·7; N, 13·4. $C_{20}H_{30}O_7N_4$ requires C, 55·2; H, 6·2; N, 14·3%).

The product (10 g.) was hydrolysed by boiling it with potassium hydroxide (4 g.) in water (100 ml.) and ethanol (50 ml.) for 4 hr. The organic layer was worked up to yield a fraction, b. p. 105—115°/12 mm. (mostly 112°/12 mm.; 2·7 g.), n_D^{20} 1·4430. This gave an equivalent weight by hydroxylamine titration of 238 [calc. for hydroxy-ketone (XIX), 188], so the product was probably a mixture. It did, however, give a yellow 2 : 4-*dinitrophenylhydrazone*, m. p. 81—82° (from ethanol), which gave analyses in approximate agreement with the derivative of 2-methyl-4-oxo-2-*neo*pentylpentan-1-ol (XIX) (Found: C, 55·5; H, 6·9; N, 15·4. $C_{17}H_{26}O_5N_4$ requires C, 56·1; H, 7·2; N, 15·4%).

Hydrogenation. (*a*) The epoxide (I) (256 g.; b. p. 138—142°) was hydrogenated in an autoclave, Raney nickel (in the minimum quantity of ethanol) being used as catalyst. The hydrogen pressure was raised initially to 100 atm. Absorption started when the temperature reached 100°, with slight evolution of heat, and was complete in 2—3 hr. at 110—120°. The decrease in pressure corresponded to an absorption of 110% of the theoretical amount of hydrogen. The catalyst was found to be coagulated with separated water. The product was fractionated, and 2 : 4 : 4-trimethylpentan-1-ol (XXI) (128 g., 50%), b. p. 73—77°/16 mm., was obtained. The lower-boiling material consisted of water, 2 : 4 : 4-trimethyl-pentane and -pent-1-ene (identified by infra-red examination), and a little unchanged epoxide.

(*b*) 291 g. of epoxide were similarly hydrogenated, but with addition of 50 ml. of dioxan and 2 drops of 40% sodium hydroxide solution. The reaction was finished in 4 hr. at 110—120°. The product was similar in composition to that obtained in (*a*), but the yield of trimethylpentanol was 60%.

(*c*) Hydrogenation of epoxide (I) in the vapour phase over 5% nickel–pumice at 200° yielded trimethylpentanol, some unchanged epoxide, water, and hydrocarbon (trimethylpentene containing a little trimethylpentane). The yield of trimethylpentanol was 40—50%.

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