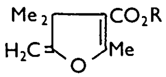
896. *The Reaction between 3-Chloro-3-methylbutyne and Methyl Sodioacetoacetate.*

By L. Crombie and K. Mackenzie.

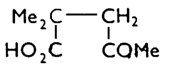
3-Chloro-3-methylbutyne and methyl sodioacetoacetate react according to the scheme on p. 4422. According to the conditions, various of six products are obtained, none of them containing a terminal acetylenic group. α-Reaction of the halide, followed by ring-closure, gives a 4 : 5-dihydro-5-methylene-3-furoic ester (I) (a novel type), and thence by action of acid other dihydrofuran derivatives (XXI, B and C). γ-Reaction, followed by deacetylation, leads to the methyl hexadienoate (XXIV), or if followed by Michael addition of more acetoacetate and cyclisation leads to the *cyclo*hexene derivative (XXVIII), which in light gives a dimer (a di*cyclo*hexano*cyclo*butane). Structures of these products are established and some analogous reactions briefly studied.

According to the literature,[1] 3-chloropropyne yields the expected ethyl α-propynylacetoacetate when treated with ethyl sodioacetoacetate. We have found that if 3-chloro-3-methylbutyne is used in a similar reaction the distilled products give no colour with ferric chloride and show no terminal acetylenic absorption in the infrared spectrum. The nature of the products depends on the reaction conditions. When the halide (1·0 mol.) is treated with methanolic methyl sodioacetoacetate (1·1 mol.) for seven days at 20°, two products A and D are obtained. The same reaction under reflux conditions (20 hr.) gives product D, and a mixture of two compounds A and F which are separable by controlled hydrolysis but not by distillation. If, after reaction at the boiling point, much of the methanol is removed and the residue is poured into water and just acidified before completion of the working up, a fourth compound C intrudes and can be isolated by distillation. Varying the proportion of halide to sodioacetoacetate in the reflux reaction from 1 : 1·1 to 2 : 1 yields a new substance B, as well as D. All the products mentioned are liquid except D, and this, when exposed to light, forms another substance E. Apart from these substances, the low-boiling solvolysis and elimination products, 3-methoxy-3-methylbutyne and 2-methylbut-1-en-3-yne, could be formed but they are not considered further. These observations define the problem. In the sequel, first the constitutions of the six substances A—F are decided, and then the reaction is considered as a whole.

Substance A, $C_{10}H_{14}O_3$.—This is methyl 4 : 5-dihydro-2 : 4 : 4-trimethyl-5-methylene-3-furoate (I; R = Me), the first representative of the dihydromethylenefurans. The ester was slowly hydrolysed in a basic medium (sterically hindered and α-unsaturated methoxycarbonyl) to the crystalline acid (I; R = H) which re-formed the original ester when treated with diazomethane. On ozonolysis the ester yielded formaldehyde and, from the hydrolysed non-volatile fraction, dimethylmalonic acid. The acid (I; R = H) gave acetic acid and 2 : 2-dimethyl-4-oxopentanoic (mesitonic) acid (II) under similar degradative conditions: the enol-lactone (III) is the precursor of (II). These



(I)



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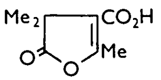
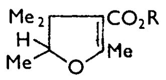
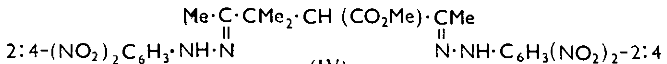


(III)



(V)



$$\underset{2{:}4\text{-}(NO_2)_2C_6H_3\cdot NH\cdot N}{\overset{}{Me\cdot \underset{\|}{C}}}\cdot CMe_2\cdot CH(CO_2Me)\cdot \underset{N\cdot NH\cdot C_6H_3(NO_2)_2\text{-}2{:}4}{\underset{\|}{C}Me}$$

(IV)

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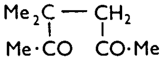
[1] Colonge and Gelin, *Compt. rend.*, 1953, **236**, 2074; **237**, 71, 393; *Bull. Soc. chim. France*, 1954, 208, 797; Gaudemar, *Ann. Chim.* (*France*), 1956, **1**, 161.

facts, taken with spectroscopic evidence and the formation of the bis-2 : 4-dinitrophenylhydrazone (IV) derived from a saturated diketone [max. 360 mμ (ε 43,500)] containing an ester function (1742 s cm.$^{-1}$), clearly demonstrate the structure (I; R = Me) for substance A.

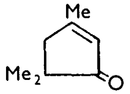
In the ultraviolet spectrum the ester (I; R = Me) had a maximum at 266 mμ (ε 14,300) which was not shifted by alkali, whilst in the infrared range there were bands at 1695 s (α-unsaturated ester; frequency lower than usual), 1656 m and 889 m ($H_2C{:}C\cdot O-$) and 1637 m cm.$^{-1}$ (conjugated $C{:}C\cdot CO-$). On hydrogenation over palladium one mol. of hydrogen was slowly absorbed and the product [ultraviolet max. 256 mμ (ε 10,100)] contained only two of the four infrared bands mentioned, those due to the vinyl group having disappeared. This ester (V; R = Me) could be hydrolysed to the same crystalline acid (V; R = H) as was obtained when the unsaturated acid (I; R = H) was similarly hydrogenated.

Further evidence for the correctness of structure (I) came from acidic hydrolysis of the acid (I; R = H). This gave 3 : 3-dimethylhexane-2 : 5-dione (VI) which was converted into 2 : 2-dimethylsuccinic acid by the haloform reaction and cyclised to a mixture of the trimethyl*cyclo*pentenones (VII) and (VIII) [2] in the presence of base. The *cyclo*pentenone mixture had the expected spectroscopic properties, formed a red α-unsaturated 2 : 4-dinitrophenylhydrazone, and on oxidation yielded mesitonic acid which must come from the isomer (VII).

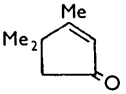


$$\begin{array}{cc} Me_2C & \!\!-\!\!-\; CH_2 \\ | & | \\ Me\cdot CO & CO\cdot Me \end{array}$$

(VI)

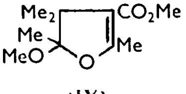


(VII)

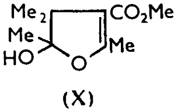


(VIII)

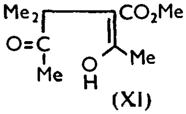
Substances B, $C_{11}H_{18}O_4$, *and C,* $C_{10}H_{16}O_4$.—The empirical formulæ for B and C differ from that of the ester (I; R = Me) by the elements of methanol and water respectively, and their kinship to this structure is seen from the fact that all three substances give the same bis-2 : 4-dinitrophenylhydrazone (IV) in acid solution. From this, and the ultraviolet [max. 250 mμ (ε 10,900); insignificantly affected by alkali] and infrared [1695 s (α-unsaturated ester) and 1639 s (conjugated $C{:}C\cdot O-$), no vinylic ether absorption near 1656 cm.$^{-1}$] spectra, substance B must be methyl 4 : 5-dihydro-5-methoxy-2 : 4 : 4 : 5-tetramethyl-3-furoate (IX). In confirmation it can be prepared in excellent yield from the vinyl ether (I; R = Me) by treating the latter at 20° with methanol containing a drop of sulphuric acid. Structure (X) might therefore be expected for substance C and two further chemical facts are in agreement: first, the "glycosidic" hydroxyl group is methylated by acidic methanol to give substance B (IX), and secondly, the substance C is easily prepared by shaking the vinyl ether (I; R = Me) with dilute aqueous acid at room temperature.



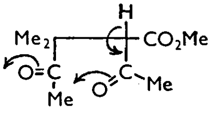
(IX)



(X)



(XI)



(XII)

The spectral results for substance C are, however, not fully consistent with formula (X). In the ultraviolet region (ethanol) there is a maximum in the expected position (252 mμ) but the molecular extinction coefficient is only 2200 (in alkaline solution this band slowly declines in intensity and a new one arises at 280 mμ). Similarly, a liquid-film infrared spectrum shows the expected hydroxylic band at 3440 cm.$^{-1}$ (broad) but the carbonyl

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[2] Sargent, *J. Org. Chem.*, 1942, **7**, 154; Wallach, *Annalen*, 1915, **408**, 202; 1924, **437**, 190.

double-bond region is complex with bands at 1743 s (α-saturated $\mathrm{CO_2Me}$), 1724 shoulder (saturated $\mathrm{C{:}O}$), 1710 s (α-unsaturated $\mathrm{CO_2Me}$) and 1634 m cm.$^{-1}$ (conjugated $\mathrm{C{:}C{\cdot}O^{-}}$). These conflicting data are reconciled if it is accepted that compound (X) is but one component of a tautomeric mixture. Two other species (XI) and (XII) must be taken into account. Compound (XII) is certainly present, but the extent to which (XI) participates in the equilibrium is less certain. The substance C gives no colour with alcoholic ferric chloride even when kept with the reagent for a week. It is true that compound (XI) is a *trans*-enol and that such substances do not give an immediate ferric chloride colour, but often colour gradually develops because of stereomutation to the iron salt of the *cis*-enol which forms a coloured stable chelate.*[3] This suggests that the concentration of form (XI) may be small and that the main equilibrium is between (X) and (XII), the proton on $\mathrm{C_{(3)}}$ ionising and returning to the oxygen at $\mathrm{C_{(5)}}$ as shown. As such it is a linked triad and ring-chain tautomeric system, pentad overall. If we discount formula (XI), infrared analysis using the $\mathrm{{\cdot}C{=}C{\cdot}}$ stretching vibration for (X) (1633 cm.$^{-1}$ in chloroform) shows that substance C in approx. 0·7% solution in chloroform contains 19·7—22·3% of (X) depending on whether compound (V) or (IX) is used as the intensity standard. Similarly, analysis by ultraviolet methods gives a content of 21·0—19·5% in chloroform (*c* ∼0·04%) and 21·6—20·1% in ethanol depending on whether (V) or (IX) is the standard.

Nuclear magnetic resonance data (see Table) are also only reasonably interpreted by considering material C to be a tautomeric mixture. No evidence in favour of the species (XI) was obtained however, inasmuch as no band due to a bonded enolic proton could be detected in the 700—1000 toluene unit region (methyl acetoacetate and ethyl α-methylacetoacetate have bands at 797 and 765 respectively): the lower limit of detection was 1%. The band for methyl protons in the environment $\mathrm{HO{\cdot}C(C}\mathit{H}_3\mathrm{){\cdot}O}$ in structure (X) lies on the side of that due to the $\mathrm{{\cdot}C(C}\mathit{H}_3\mathrm{)_2}$ band in the tautomeric mixture C. Estimation of relative areas gives a rough figure of 21% for the concentration of compound (X) in the neat liquid. Rough estimates for (X) based on the band areas of peaks assigned to $\mathrm{{\cdot}O{\cdot}C(C}\mathit{H}_3\mathrm{){=}C{\cdot}}$ and $\mathrm{C}\mathit{H}_3\mathrm{{\cdot}CO{\cdot}}$ give 25% and 33% when the *gem*-dimethyl standard is used.

Nuclear magnetic resonance: chemical shifts.

(I)	$\mathrm{>C(C}\mathit{H}_3\mathrm{)_2}$ 1215; $\mathrm{{\cdot}CO_2C}\mathit{H}_3$ 1125; $\mathrm{{\cdot}O{\cdot}C(C}\mathit{H}_3\mathrm{){:}C}$ 1181; $\mathit{H}_2\mathrm{C{:}}$ 1096 (a pair of doublets).
(V)	$\mathrm{>C(C}\mathit{H}_3\mathrm{)_2}$ 1217 (doublet 7 c.p.s.); $\mathrm{CO_2C}\mathit{H}_3$ 1121; $\mathrm{O{\cdot}C(C}\mathit{H}_3\mathrm{){:}C}$ 1181; $\mathrm{C}\mathit{H}_3\mathrm{{\cdot}CH{\cdot}O}$ 1216 (doublet 6 c.p.s.); $\mathrm{CH_3{\cdot}C}\mathit{H}\mathrm{{\cdot}O}$ 1097 (quartet 6 c.p.s.).
(IX)	$\mathrm{>C(C}\mathit{H}_3\mathrm{)_2}$ 1218 (doublet 4 c.p.s.); $\mathrm{CO_2C}\mathit{H}_3$ 1118; $\mathrm{O{\cdot}C(C}\mathit{H}_3\mathrm{){:}C}$ (side-band) 1180; $\mathrm{C}\mathit{H}_3\mathrm{{\cdot}C(O{\cdot}){\cdot}OCH_3}$ 1209; $\mathrm{CH_3{\cdot}C(O{\cdot}){\cdot}OC}\mathit{H}_3$ 1134.
(X) $\rightleftharpoons$ (XII)	$\mathrm{>C(C}\mathit{H}_3\mathrm{)_2}$ 1218 (doublet 5 c.p.s.); $\mathrm{CO_2C}\mathit{H}_3$ 1118; $\mathrm{O{\cdot}C(C}\mathit{H}_3\mathrm{){:}C}$ and $\mathrm{C}\mathit{H}_3\mathrm{{\cdot}CO}$ 1183; $\mathrm{C}\mathit{H}_3\mathrm{{\cdot}C(O{\cdot}){\cdot}OH}$ 1209 (infl.).
$\mathrm{Me{\cdot}CO{\cdot}CH_2{\cdot}CO_2Me} \rightleftharpoons$ $\mathrm{Me{\cdot}C(OH){:}CH{\cdot}CO_2Me}$	$\mathrm{{:}C(CH_3){\cdot}O}\mathit{H}$ 797; $\mathrm{C}\mathit{H}_3\mathrm{{\cdot}CO}$ 1185; $\mathrm{CO_2C}\mathit{H}_3$ 1127; $\mathrm{CO{\cdot}C}\mathit{H}_2\mathrm{{\cdot}CO_2CH_3}$ 1132.
$\mathrm{Me{\cdot}CO{\cdot}CHMe{\cdot}CO_2Et} \rightleftharpoons$ $\mathrm{Me{\cdot}C(OH){:}CMe{\cdot}CO_2Et}$	$\mathrm{{:}C(CH_3){\cdot}O}\mathit{H}$ 765; $\mathrm{C}\mathit{H}_3\mathrm{{\cdot}CO}$ 1185; $\mathrm{CO_2{\cdot}C}\mathit{H}_2\mathrm{{\cdot}CH_3}$ 1106 (quartet); $\mathrm{CO_2{\cdot}CH_2{\cdot}C}\mathit{H}_3$ 1223 (triplet); $\mathrm{CO{\cdot}C}\mathit{H}\mathrm{(CH_3){\cdot}CO_2Et}$ 1129 (quartet); $\mathrm{C}\mathit{H}_3\mathrm{{\cdot}CH(CO{\cdot}CH_3){\cdot}CO_2Et}$ 1223 (doublet).
$\mathrm{Me{\cdot}CO{\cdot}Et}$	$\mathrm{C}\mathit{H}_3\mathrm{{\cdot}CO}$ 1195; $\mathrm{CH_3{\cdot}C}\mathit{H}_2$ 1187 (doublet; partially resolved); $\mathrm{C}\mathit{H}_3\mathrm{{\cdot}CH_2}$ 1241 (triplet).
$\mathrm{Me{\cdot}CO{\cdot}CMe_2{\cdot}CH_2{\cdot}CO{\cdot}Me}$...	$\mathrm{C}\mathit{H}_3\mathrm{{\cdot}CO}$ 1187; $\mathrm{Me{\cdot}CO{\cdot}C(C}\mathit{H}_3\mathrm{)_2}$ 1224; $\mathrm{Me{\cdot}CO{\cdot}C}\mathit{H}_2$ 1155.

* Measured on pure liquids relative to water at 21° and expressed in toluene units (aromatic hydrogen 1000 units by definition).

During these determinations, some chemical shifts for the dihydromethylenefuran (I), its dihydro-derivative (V), and the methoxy-compound (IX) were measured and agree with the proposed structures (Table above). Two points relating to splitting are relevant. First, in compounds (V) and (IX), and in mixture C, the *gem*-dimethyl bands are

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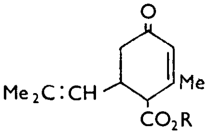
* This is so for 3-*iso*propylacetylacetone (14% enol) but α-*iso*propylacetoacetic ester (1% enol) gives no colour even on storage.

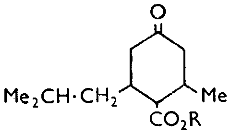
[3] Henecka, (*a*) "Chemie der Beta-dicarbonyl Verbindungen," Springer-Verlag, Berlin, 1950, p. 122; (*b*) *Chem. Ber.*, 1948, **81**, 189.

split through chemical shift as each methyl lies in a different environment. In (I) the environments are identical and the *gem*-dimethyl band is single. Secondly, the $H_2C=$ band is split as a pair of doublets in (I) because the environments of the two protons, this time within the plane of the ring, are not identical.

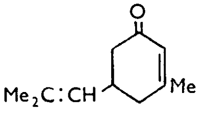
Substance D, $C_{13}H_{18}O_3$.—This substance proved to be methyl 6-*iso*but-1′-enyl-2-methyl-4-oxo*cyclo*hex-2-enecarboxylate (XIII; R = Me). It had an ultraviolet maximum at 232 mμ (ε 13,000) and infrared bands at 1733 s (ester), 1661 s (α-unsaturated ketone), 1623 m (conjugated ·C:C·) and 851 m cm.$^{-1}$ (RR′C:CH). The α-unsaturated keto-function was further demonstrated by spectroscopic data for the semicarbazone and the red 2 : 4-dinitrophenylhydrazone. Ozonolysis gave an excellent yield of acetone. Though the substance gave no colour with ferric chloride, it was hydrolysed, under carefully defined basic conditions, to the crystalline acid (XIII; R = H) which re-formed the original ester (XIII; R = Me) when treated with diazomethane but was decarboxylated at its melting point. On the other hand, the saturated compound (XIV; R = Me), formed by hydrogenating the ester (XIII; R = Me) over palladium in ethyl acetate, gave on hydrolysis an acid (XIV; R = H) which was not decarboxylated when heated above the melting point. These facts establish the vinylogous β-keto-ester group as in formula (XIII).



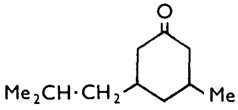
(XIII)



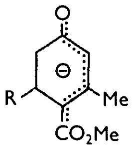
(XIV)



(XV)



(XVI)



(XVII)

If basic hydrolysis of the ester (XIII; R = Me) was prolonged, decarboxylation ensued to give the ketone (XV) having an ultraviolet maximum at 230 mμ (ε 13,000) and infrared bands at 1672 s (α-unsaturated ketone) and 1631 m (conjugated ·C:C·); the 2 : 4-dinitrophenylhydrazone had the expected light-absorption. The same ketone, contaminated with an α-saturated isomer (ketone band 1718 cm.$^{-1}$) was obtained after the thermal decarboxylation mentioned above and indicates the operation of the well-known cyclic transition-state mechanism which results in a $\beta\gamma$-shift. By hydrogenating the ketone (XV), the saturated ketone (XVI) was prepared; its 2 : 4-dinitrophenylhydrazone proved to be the same as a synthetic specimen prepared from the hydrogenation product of authentic 5-*iso*butyl-3-methyl*cyclo*hexenone. This establishes the relationship of the *iso*butenyl, methyl, and oxo-groups in the compound (XIII) and completes the proof of structure. The open methylene position alpha to the keto-group is also demonstrated by the formation of a dibenzylidene derivative by the dimer E (below).

Another observation supporting structure (XIII) is the shift of maximal absorption in ~0·01N-alkali to 394 mμ (ε 9000): methyl 2-methyl-4-oxo*cyclo*hex-2-enecarboxylate (Hagemann's ester) shows a parallel shift from 232 mμ (ε 11,800) to 390 mμ (ε 9500). Presumably this is due to formation of the ambidentate ion (XVII; R = Me_2C:CH· or H). It is well known in this context that the anion of Hagemann's ester is alkylated in the 3-position.[4]

Substance E, $C_{26}H_{36}O_6$.—The *cyclo*hexenone (XIII; R = Me) forms large diamond-shaped crystals which when kept in light become opaque through formation of a dimer.

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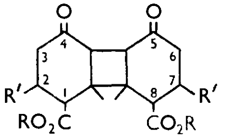
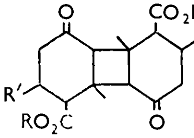
[4] Edgar, Harper, and Kazi, *J.*, 1957, 1083.

The latter is readily isolated since it is sparingly soluble in methanol. This dimerisation is more conveniently carried out ($>$80% yield) by exposing finely ground material to light from an ultraviolet lamp. Work on this photodimer is not yet complete and it is not directly involved in the reaction to be discussed below. Nevertheless its di*cyclo*hexano*cyclo*butane structure is certain and this supports the structure for compound (XII) since other 3-methyl*cyclo*hex-2-enones are known to dimerise in ultraviolet light (though in solution in methanol–water).[5] Apart from stereochemical features, the outstanding point to be decided is whether it has a parallel (XVIII) or antiparallel (XIX) structure: this must be governed by the crystal lattice of compound (XIII). Subsequent discussion will be in terms of structure (XIX) but without prejudice to the alternative.

The ebullioscopic molecular weight agreed exactly with the dimer structure (XIX; $R = Me$, $R' = CH{:}CMe_2$) and there was no high-intensity ultraviolet absorption. The yellow-orange bis-2 : 4-dinitrophenylhydrazone showed that the keto-function was unconjugated in the usual sense [max. 368 mμ (ε 47,500)]. In the infrared spectrum there were bands at 1739 s (saturated ester), 1695 s (saturated keto alpha to *cyclo*butane) and 850 m cm.$^{-1}$ ($Me_2C{:}CH\cdot$), and the two reactive methylenic positions were demonstrated by formation of a dibenzylidene derivative. On hydrogenation a tetrahydro-derivative (XIX; $R = Me$, $R' = Me_2CH\cdot CH_2$) was formed, whilst ozonolysis of the dimer gave



(XVIII)



(XIX)

$>$1 mol. of acetone and the diacid diester (XIX; $R = Me$, $R' = CO_2H$). The resistance of the parent dimer to hydrolysis corroborates the hindered position of the ester function. Thus, of the functional groupings in (XIII), only the α-double bond has disappeared, and this without formation of a new double bond between two molecules of monomer. Only the di*cyclo*hexano*cyclo*butane system is therefore acceptable.

Substance F, $C_8H_{12}O_2$.—Though efficiently fractionated, this substance could not be adequately separated from the dihydromethylenefuran (I). Since the latter is hydrolysed slowly, the mixture was stirred with 5% aqueous sodium hydroxide and the acid derived from compound F was isolated almost quantitatively. It was re-esterified with diazomethane to give pure compound F. Infrared analysis showed that the mixture used contained 25·4% of compound F and 74·6% of compound (I), and a synthetic mixture of these proportions exactly simulated the infrared curve of the original. Chemical analysis, performed by adding methanol to component (I) under acid conditions and then estimating the content of compound F in the mixture by hydrogenation, showed 26·3% of compound F.

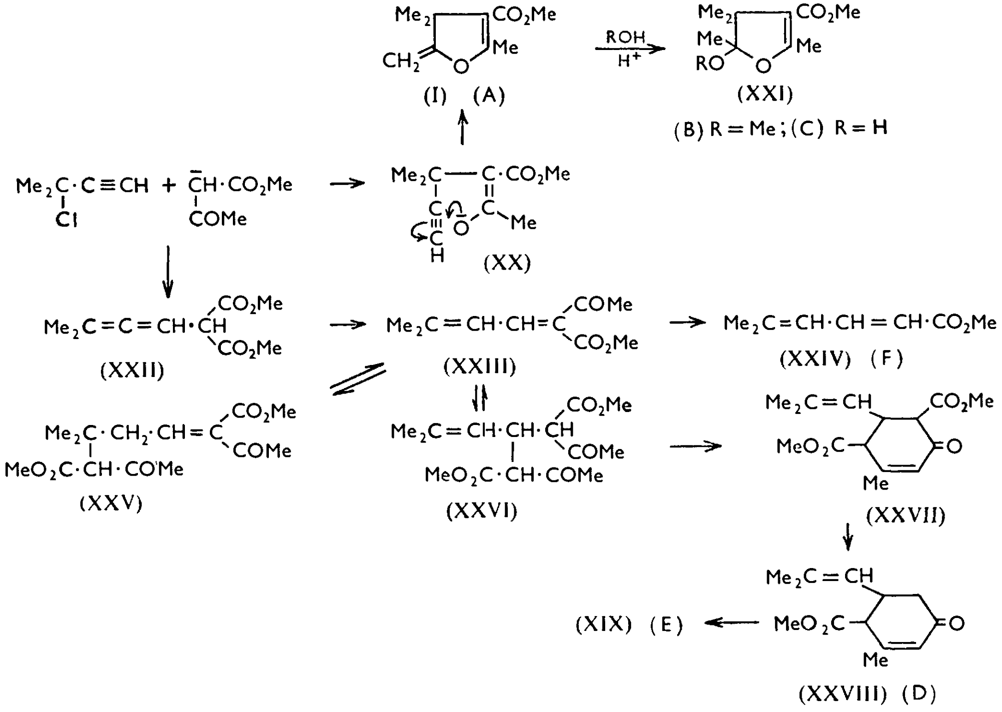
Compound F was shown to be methyl 5-methylhexa-2 : 4-dienoate as follows. The crystalline acid, m. p. 113°, had a maximum at 272 mμ (ε 24,000) and formed a crystalline *p*-bromophenacyl ester. There were infrared bands at 1681 s (α-unsaturated CO_2H), 1626 s and 1600 s (conjugated diene), and 995 m cm.$^{-1}$ (conjugated *trans*-$CH{:}CH\cdot$). On hydrogenation two mols. of hydrogen were absorbed and the product, 5-methylhexanoic acid, was identified by comparing its *p*-bromophenacyl ester with an authentic specimen. As the only literature reference [6] to 5-methylsorbic acid gave m. p. 105°, the identification was made rigorous by preparing the acid in another way, by a Reformatski reaction between 3-methylcrotonaldehyde and ethyl bromoacetate, and comparing the *p*-bromophenacyl esters of the two specimens.

We are now in a position to consider the main reaction.

The Reaction between 3-*Chloro*-3-*methylbutyne and Methyl Sodioacetoacetate.*—The

[5] Triebs, *Ber.*, 1930, **63**, 2738; *J. prakt. Chem.*, 1933, **138**, 299.
[6] Reid and Sause, *J.*, 1954, 516.

products A—F are accommodated by the annexed scheme involving net α- and γ-attack on the acetylenic halide.* At this stage no examination of the detail of the phase which initiates the reaction has been made, but a parallel with corresponding reactions of allylic halides is obvious. In view of the nucleophilic character of the reagent, the fairly low ionising power of the solvent ($Y = -1{\cdot}09$),[9] and the fact that the S_N1 solvolysis of 3-chloro-3-methylbutyne in 80% ethanol is very much slower than the S_N2 hydrolysis,[10] the reaction will be considered, for the present, as an S_N2 and S_N2' replacement. The considerable S_N2' element in the reaction is then ascribed to steric screening of $C_{(3)}$ by the *gem*-dimethyl grouping and the unhindered character of $C_{(1)}$. It is to be noted, however, that formation of a 3-methylbutynyl enol ether of acetoacetic ester by *O*-alkylation, followed by a cyclic rearrangement, could also provide an explanation for the γ-attack.



Direct α-attack must lead initially to methyl 2-(1 : 1-dimethylpropynyl)acetoacetate, the enolate (XX) of which cyclises as shown to yield compound A. If the reaction is conducted with halide in considerable excess the pH change in the solution, when all the base has been consumed, enables addition of methanol to the dihydromethylenefuran to proceed and compound B is formed. This was confirmed by refluxing together methanol, 3-chloro-3-methylbutyne, and the dihydromethylenefuran (I), which gave an excellent

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* In this connexion Zakharova reports [7] that 3-chloro-3-methylbutyne, when treated with silver acetate in glacial acetic acid, gives 1-acetoxy-3-methylbuta-1 : 2-diene and 1 : 2-diacetoxy-3-methylbut-2-ene as well as 3-acetoxy-3-methylbutyne. Pudovic [8] also reports γ-attack by triethyl phosphite on this halide.

[7] Zakharova, *Zhur. obshchei Khim.*, 1945, **15**, 425; 1947, **17**, 686, 1277; 1949, **19**, 1297; *J. Gen. Chem.* (*U.S.S.R.*), 1949, **19**, 75; Zakharova and Dobromyslova, *ibid.*, 1950, **20**, 2099; Zakharova and Sapozhnikova, *ibid.*, 1952, **22**, 1843.

[8] Pudovic, *ibid.*, 1950, **20**, 97; 1951, **21**, 1593.

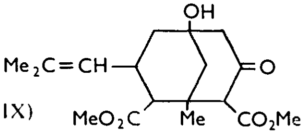
[9] Eliel in Newman's " Steric Effects in Organic Chemistry," Wiley, New York, 1956, p. 69.

[10] Burawoy and Spinner, *J.*, 1954, 3752; Hennion and Maloney, *J. Amer. Chem. Soc.*, 1951, **73**, 4735; Hennion and Nelson, *ibid.*, 1957, **79**, 2142.

yield of compound B. The origin of small amounts of compound C if aqueous suspensions of the precursor A are acidified during the working up is obvious.

The γ-attack must involve the initial formation of an allenic acetoacetate (XXII) which would be expected to rearrange prototropically [11] in a fast reaction to give the diene (XXIII). Depending on the conditions, the latter can be deacylated to yield the diene ester F, or undergo a Michael reaction with more acetoacetate.* Michael addition, which has long been recognised as reversible, could occur 1 : 2 or 3 : 4 (or 1 : 4 if prototropic equilibrium is not established). Since irreversible cyclisation of the product from the 1 : 2 mode of addition occurs readily in basic media, only this is of significance here. The product (XXVII) undergoes hydrolysis and decarboxylation in the presence of base (the preparation of Hagemann's ester is a well-known analogy) to yield the crystalline *cyclo*hexenone D.

In the reaction at reflux temperature between 3-chloro-3-methylbutyne (1·0 mol.) and methyl sodioacetoacetate (1·1 mol.), the isolated yield of diene ester F was 9·5% and of the *cyclo*hexenone D, 3%. At 20°, however, the deacylation is less able to compete with formation of compound D, and the yield of this rises to 8%, whilst the hexadienoate F is not found. Similarly, and in agreement with the proposed scheme, the use of two mol. of acetoacetate to one of halide causes the yield of compound D to rise to 9% and the diene F could not be detected: the yield of methylenefuran A was 72%. Although accumulation of compound D at the expense of F, since both are derived from the common intermediate (XXIII), seems logical, it is to be noted that, particularly when excess of acetoacetic ester is employed, the disappearance of the diene ester F may also be associated with its involvement in a Michael addition. The reaction is too complex for more than a qualitative assessment of the importance of competing reaction paths since the crystalline *cyclo*hexenone is always isolated from high-boiling fractions containing uncrystallisable yellow viscous oils which are very difficult to purify. Some show hydroxylic infrared absorption and give colours with ferric chloride. According to circumstances, dehydroacetic acid, Michael addition products, and other substances might be present but we know little of the amounts involved. In particular we have searched for the product of a Rabe reaction [13] from compound D, the bicyclic ketone (XXIX), but it has not been found.



(XXIX)

$Me_2C{=}C{=}CHCl$

(XXX)

Two other points in connexion with the part of the reaction involving γ-attack have received some attention. First, there is the possibility that part of the 3-chloro-3-methylbutyne isomerises to 1-chloro-3-methylbuta-1 : 2-diene [14] (XXX) before reaction and that this then undergoes a normal displacement reaction. In experiments at 20° this can be ruled out, for it was found that the chloroallene and methyl sodioacetoacetate in methanol underwent no appreciable reaction in seven days and only unchanged reagents could be isolated. Under reflux conditions (16 hr.) about 5% of an impure product containing the dihydromethylenefuran A and the diene F in the ratio 2·2 : 1 was isolated. One possible explanation is that the allenic halide (XXX) is undergoing slow reaction by an S_N2' and an S_N2 path.

* Michael addition to 6-methylhepta-3 : 5-dien-2-one is not a suitable alternative as the product of 1 : 2-addition would be expected, from analogies,[12] to give methyl 6-*iso*but-1′-enyl-4-methyl-2-oxo*cyclo*hex-3-enecarboxylate.

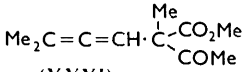
[11] Jones, Witham, and Whiting, *J.*, 1954, 3201.

[12] See ref. 3(*a*), p. 263.

[13] Rabe and Appuhn, *Ber.*, 1943, **76**, 982, who refer to the earlier work.

[14] Hennion, Sheehan, and Maloney, *J. Amer. Chem. Soc.*, 1950, **72**, 3542.

Secondly, if methyl sodio-α-methylacetoacetate is used in the reaction with 3-chloro-3-methylbutyne it might be possible to isolate the allene (XXXI) which could not undergo the usual prototropic rearrangement. Under reflux conditions (20 hr.) a mixture of esters, showing no appreciable infrared allenic absorption, was isolated. After hydrolysis, the two acids expected from α- and γ-attack were isolated crystalline. The first (XXXII; R = H) had infrared bands at 3236 s, 2112 mw ($\cdot C{\equiv}CH$), and 1724 s (saturated CO_2H) and absorbed two mol. of hydrogen on catalytic hydrogenation: its precursor methyl α-(1 : 1-dimethylpropynyl)-α-methylacetoacetate, cannot cyclise to a dihydromethylenefuran as no enolic hydrogen is available. The other (XXXIII; R = H) was identified



$Me_2C{=}C{=}CH\cdot C(Me)(CO_2Me)(COMe)$

(XXXI)

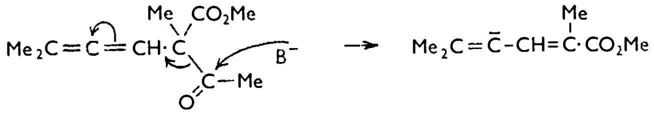
$HC{\equiv}C\cdot CMe_2\cdot CHMe\cdot CO_2R$

(XXXII)

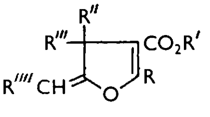
$Me_2C{=}CH\cdot CH{=}CMe\cdot CO_2R$

(XXXIII)

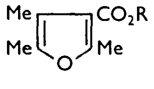
by spectroscopic data and direct comparison with authentic 2 : 5-dimethylhexa-2 : 4-dienoic acid.[15] In attempts to trap the allene (XXXI) the reflux period was reduced to 30 min. and finally the reaction was carried out at 20° for 90 min. In both cases ultraviolet data indicated that appreciable amounts of the diene (XXXIII; R = Me) had been formed but infrared analysis showed that only very small quantities of allene were present: in some experiments it was not detectable. The allene must be removed by a fast reaction which does not involve the prototropic shift available for the methyl acetoacetate case. The simplest explanation seems to be a rapid deacylation-isomerisation mechanism:



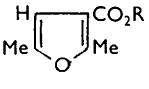
Comment on the scope of the reaction between substituted α-acetylenic halides and β-keto-esters as a method for making dihydromethylenefurans can only be made in a most superficial manner but may provide indications for further work. By varying the structure of the reactants, the alkyl groups R, R′, R″ and R‴ in (XXXIV) can be varied, but a case in which R⁗ is other than H has not been tested. If R‴ is H (*e.g.*, employing 3-chlorobutyne in the reaction), the product from a reaction under reflux conditions contains both dihydromethylenefuran and furan ester (XXXV; R = Et), as demonstrated by ozonolysis and spectroscopic study of the fractions. On hydrolysis, only the crystalline furoic acid (XXXV; R = H), formed by prototropic rearrangement and identical with authentic 2 : 4 : 5-trimethyl-3-furoic acid,[16] was obtained. In the case of 3-chloropropyne (R‴ = R″ = H), the product is complex and, even though refluxing is prolonged, successive fractions from the distillation contain much terminally acetylenic material. Spectroscopic results and ozonolysis show that both the dihydromethylenefuran and



(XXXIV)



(XXXV)



(XXXVI)

furoic ester (XXXVI; R = Et) are present and hydrolysis gave the furoic acid (XXXVI; R = H), identical with authentic material.[17] Base-catalysed cyclisation in this case seems to be much less favoured than when R″ = R‴ = Me. Colonge and Gelin [1] have

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[15] Crombie, Harper, and Sleep, *J.*, 1957, 2743.

[16] Reichstein, Zschokke, and Syz, *Helv. Chim. Acta*, 1932, **15**, 1112.

[17] Dann, Distler, and Merkel, *Chem. Ber.*, 1952, **85**, 457.

observed that ethyl α-propargylacetoacetate gives 2 : 5-dimethyl-3-furoic acid if refluxed for 4 hours with 50% sodium hydroxide solution and suggest a preliminary acetylene–allene rearrangement. The above results indicate that this postulate is unnecessary and that internal addition involves the terminal acetylenic linkage: prototropic rearrangement then follows.

EXPERIMENTAL

The ultraviolet absorptions (Mrs. A. I. Boston) were determined for solutions in pure ethanol (unless another solvent is indicated) using either a Spectracord recording instrument or a Unicam S.P. 500 manual instrument. Infrared measurements (Mr. R. L. Erskine) were made with a Grubb-Parsons double-beam instrument; unless stated otherwise, liquid samples were examined as pure films, and solid samples as paraffin mulls. Nuclear magnetic resonance data were obtained with a Varian (40 mc) instrument.

Reaction between Methyl Sodioacetoacetate and 3-*Chloro*-3-*methylbutyne at* 20°.—The chloro-compound was prepared by a known method [14] and purified by fractionation through a column packed with glass helices (b. p. 75°, n_D^{21} 1·4180): all samples were examined spectroscopically to ascertain freedom from allenic and other impurities. 3-Chloro-3-methylbutyne (46·1 g., 0·45 mol.) was added dropwise to methyl sodioacetoacetate (at 20°) prepared from sodium (11·5 g.), methyl acetoacetate (58 g., 0·5 mol.), and dry methanol (250 ml.). The mixture was set aside: sodium chloride began to be deposited after 12 hr. After 7 days the mixture was filtered and the filtrate evaporated. The pale yellow liquid, after being held *in vacuo*, showed no acetylenic absorption in the infrared region: it was poured into water and extracted with ether. The ethereal layer was dried (Na_2SO_4), evaporated, and distilled to give a fraction b. p. 85—108°/20 mm. (42·8 g.). This was contaminated with a little methyl acetoacetate but on redistillation *methyl* 4 : 5-*dihydro*-2 : 4 : 4-*trimethyl*-5-*methylene*-3-*furoate* (I) was obtained pure, b. p. 98°/20 mm., $n_D^{21·5}$ 1·4803—1·4810, giving no ferric chloride reaction (Found: C, 66·05; H, 7·95. $C_{10}H_{14}O_3$ requires C, 65·9; H, 7·75%). In ~0·01N-ethanolic alkali, the absorption max. remained at 266 mμ (ε after 0, 4, and 24 hr.; 16,400, 16,300, and 12,200).

Continuing the main distillation at 0·1 mm. gave, after rejection of a small intermediate cut, a fraction of b. p. 120—145° (15·5 g.) which solidified with evolution of heat. When stirred with a little cold methanol and filtered, the solid gave *methyl* 6-iso*but*-1′-*enyl*-2-*methyl*-4-*oxo*cyclo*hex*-2-*enecarboxylate* (XIII) (8 g.): crystallisation from methanol gave large colourless diamond-shaped crystals, m. p. 73° [Found: C, 70·3; H, 8·2%; *M* (Rast), 222·4. $C_{13}H_{18}O_3$ requires C, 70·25; H, 8·15%; *M*, 222·3].

Reaction between Methyl Sodioacetoacetate and 3-*Chloro*-3-*methylbutyne in Refluxing Methanol.*—3-Chloro-3-methylbutyne (238 g., 2·32 moles) was added dropwise to a stirred and refluxing solution of methyl sodioacetoacetate prepared from sodium (58·7 g., 2·55 g.-atoms), methyl acetoacetate (296 g., 2·55 moles), and dry methanol (1·2 l.). Heating and stirring were continued (20 hr.). After filtration, most of the methanol was removed by distillation and the product was poured into water, neutralised, and extracted with ether. After drying and evaporation, the extract was distilled through a 2 ft. 6 in. Stedman gauze-packed column with a variable take-off head. Twenty-one fractions of approximately equal size were taken with the b. p. approximately constant (90°/~10 mm., pressure controlled by an electrically operated manostat), except for the first fraction (b. p. 84—88°/11 mm., n_D^{20} 1·4898). The contents of tubes 2 and 3 had n_D^{20} 1·4926 and n_D^{20} 1·4931: the refractive index then fell steadily (tube 5, n_D^{20} 1·4924; tube 9, n_D^{20} 1·4919; tube 17, n_D^{20} 1·4884; tube 21, n_D^{20} 1·4819) (Found, for fraction 5: C, 66·1; H, 8·15. Found, for fraction 17: C, 66·5; H, 8·2. Calc. for $C_8H_{12}O_2$: C, 68·55; H, 8·65. Calc. for $C_{10}H_{14}O_3$: C, 65·9; H, 7·75%). Infrared spectra of the contents of tubes 1, 5, 17, and 21 showed that the products were mixtures of methyl 5-methylsorbate and methyl 4 : 5-dihydro-2 : 4 : 4-trimethyl-5-methylene-3-furoate, the concentration of the former decreasing in the later fractions. Fractions 1—21 were united (mixture M, 120 g.), n_D^{21} 1·4896. The ultraviolet max. was at 270 mμ ($E^{1\%}_{1\,\mathrm{cm.}}$ 900). The composition of this mixture was estimated by an infrared method using intensity measurements (CS_2) for bands at 877 cm.$^{-1}$ (methyl 5-methylsorbate) and 889 cm.$^{-1}$ (furan ester). It contained 25·4% of the sorbate and 74·6% of the furan: a synthetic mixture of this composition, n_D^{21} 1·4899, gave an infrared spectrum (liquid film) identical with that of the united fractions 1—21 (M).

The composition was also estimated by adding the mixture (0·51 g.) to methanol (10 ml.) containing a drop of sulphuric acid and after 4 hr. neutralising it with methanolic potassium hydroxide and hydrogenating the resultant mixture of methyl sorbate and the methoxy-compound (IX) over 5% palladium–barium sulphate. The uptake was 46 ml. of hydrogen (20°/760 mm.) corresponding to 26·3% of diene-ester.

Distillation was continued: fractions 22, 23, and 24 had respectively n_D^{20} 1·4786 (5·9 g.), n_D^{20} 1·4654 (4·8 g.), and n_D^{20} 1·4866 (2·0 g.). The next group of fractions (25—30) had b. p. 148°/15 mm., n_D^{20} 1·4866—1·5042 (29·3 g.), and partially crystallised. Finally, with the distillation temperature unsteady, a yellow oil (11·5 g.) (which did not crystallise, even when seeded) was obtained. The contents of tubes 24—29 were triturated with methanol at 0° and methyl 6-*iso*but-1′-enyl-2-methyl-4-oxo*cyclo*hex-2-enecarboxylate (15·1 g., 3%) was isolated by filtration. A black carbonaceous residue remained in the distillation flask.

Isolation of 5-Methylsorbic Acid from the Mixture M.—The mixture M (see above, 9·1 g.) was stirred at 20° with sodium hydroxide (2·3 g.) in water (46 ml.) for 20 hr. Unhydrolysed ester was extracted with ether and isolated (6·5 g., 71·5%) by evaporation. On distillation, methyl 4 : 5-dihydro-2 : 4 : 4-trimethyl-5-methylene-3-furoate (5·7 g., 63% : purity checked by infrared spectrum), b. p. 93—95°/22 mm., n_D^{22} 1·4819, was obtained (Found: C, 66·05; H, 7·95%).

The aqueous-alkaline solution was acidified (no effervescence) and extracted with ether. The ethereal extracts were themselves extracted with sodium hydroxide solution and evaporation of the ethereal layer showed that no ketone was present. The alkaline solution was acidified and extracted with ether to give crude 5-methylsorbic acid (2·0 g., 24·5%). A portion of the crude acid (0·25 g.) was esterified with diazomethane and distilled (n_D^{23} 1·5113): examination of its infrared spectrum showed it to be virtually pure methyl 5-methylsorbate (below). The remainder of the crude acid (1·75 g.) was crystallised twice from aqueous ethanol, to give pure *5-methylsorbic acid* (1·4 g., 20%), plates, m. p. 113° (Found: C, 66·8, 66·45; H, 8·3, 8·0. $C_7H_{10}O_2$ requires C, 66·7; H, 8·0%). The acid sublimed in needles at 0·2 mm. Its p-*bromophenacyl ester*, m. p. 121°, crystallised from aqueous ethanol (Found: C, 55·7; H, 4·7. $C_{15}H_{15}O_3Br$ requires C, 55·7; H, 4·9%).

5-Methylsorbic acid absorbed 2 mol. of hydrogen over 5% palladium–barium sulphate in ethyl acetate, and the p-*bromophenacyl ester* of the liquid product, 5-methylhexanoic acid, had m. p. 77°, undepressed by a specimen prepared from authentic acid (m. p. 76°) (Found: C, 55·2; H, 6·0. $C_{15}H_{19}O_3Br$ requires C, 55·0; H, 5·8%). The p-*phenylphenacyl* ester of the hydrogenation product had m. p. 78° (Found: C, 77·5; H, 7·8. $C_{21}H_{24}O_3$ requires C, 77·75; H, 7·5%). It depressed the m. p. of the *p*-phenylphenacyl ester (m. p. 74—75°) of 4 : 4-dimethylpentanoic acid to 58—63°.

Pure 5-methylsorbic acid gave, on treatment with diazomethane, the *methyl ester*, b. p. 92°/20 mm., n_D^{23} 1·5139 (Found: C, 68·1; H, 8·75. $C_8H_{12}O_2$ requires C, 68·5; H, 8·6%), $\lambda_{max.}$ 272 mμ (ε 27,000), $\nu_{max.}$ 1709 (α-unsaturated CO_2Me) and 1634 and 1609 cm.$^{-1}$ (conjugated diene).

In an identical hydrolysis of mixture M, in which stirring was continued for only 5½ hr., 7·2 g. (79%) of unhydrolysed ester were obtained. On distillation, this gave methyl 4 : 5-dihydro-2 : 4 : 4-trimethyl-5-methylene-3-furoate (6·7 g., 73·5%), b. p. 95—97°/23 mm., n_D^{24} 1·4825. From the alkaline solution 5-methylsorbic acid (1·8 g., 22%) was obtained, having m. p. 112° after crystallisation (1·3 g., 16%). The dihydrofuroate (6·2 g.) when boiled for 90 min. with potassium hydroxide (2·5 g.) in methanol (30 ml.) gave unchanged ester (2 g.) and the corresponding acid (3 g.), m. p. 124° after crystallisation.

Treatment of Mixture M with Methyl Sodioacetoacetate.—Mixture M (9·1 g.) was heated under reflux for 16 hr. with methyl sodioacetoacetate [from sodium (1·3 g.), methyl acetoacetate (5·8 g.), and dry methanol (50 ml.)]. The product was poured into water and separated into acidic (0·91 g.) and neutral material. The latter, on distillation, gave a product (7·2 g.) of b. p. 94—100°/22 mm., n_D^{28} 1·4840 (ferric chloride test negative). The residue from this distillation (approx. 100 mg.) gave no methyl 6-*iso*but-1′-enyl-2-methyl-4-oxo*cyclo*hex-2-enecarboxylate even after prolonged cooling and seeding.

Reaction between Methyl Sodioacetoacetate (2 *Mol.*) *and* 3-*Chloro*-3-*methylbutyne* (1 *Mol.*) *in Refluxing Methanol.*—3-Chloro-3-methylbut-1-yne (38·5 g., 0·375 mole) was added dropwise to a stirred and refluxing solution of methyl sodioacetoacetate [made from sodium (17·2 g., 0·75 g.-atom), methyl acetoacetate (87 g., 0·75 mole), and dry methanol (250 ml.)], and the mixture was stirred on a steam-bath for 22 hr. Most of the methanol was removed by distillation and the residue was poured into water (300 ml.), just acidified with mineral acid, and extracted with ether. The ethereal extracts were dried, evaporated, and fractionally distilled, thirteen fractions being collected and examined spectroscopically (ultraviolet and infrared).

After elimination of a small fore-run, methyl 4 : 5-dihydro-2 : 4 : 4-trimethyl-5-methylene-3-furoate (49·2 g., 71%) was isolated; it had b. p. 92—101°/~15 mm., n_{D}^{20} 1·4810—1·4820. The infrared spectrum showed none of the characteristic bands of methyl 5-methylsorbate. The next fractions, b. p. 96—108°/~0·5 mm., n_{D}^{20} 1·4724—1·4776 (7·5 g.), showed hydroxylic infrared absorption and scrutiny indicated that methyl 4 : 5-dihydro-5-hydroxy-2 : 4 : 4 : 5-tetramethyl-3-furoate was present in the mixture (see below). Following these, material of b. p. 108—118°/~0·5 mm. was isolated (17·7 g.): this partly crystallised and from it pure methyl 6-*iso*but-1′-enyl-2-methyl-4-oxo*cyclo*hex-2-enecarboxylate (7·6 g., 9·1%) was obtained. The uncrystallisable viscous residue gave a purple-red ferric reaction. Finally, two fractions boiling erratically near 122°/~0·5 mm., n_{D}^{20} 1·5147, $\lambda_{\max}$ 228 mμ (ε 8200) (1·0 g.), and n_{D}^{20} 1·5238, $\lambda_{\max}$ 225 mμ (ε 7750) (0·7 g.), were isolated. Both showed hydroxylic infrared absorption and gave purple-red ferric colours. When united and refractionated, a little more of the crystalline *cyclo*hexenone was isolated, but no other component could be obtained pure.

In a second experiment the results were similar, though the dihydrofuroate contained small quantities of methyl 5-methylsorbate.

Reaction between Methyl Sodioacetoacetate (1 *Mol.*) *and* 3-*Chloro*-3-*methylbutyne* (2 *Mol.*) *in Refluxing Methanol.*—3-Chloro-3-methylbut-1-yne (51·5 g., 0·5 mole) was added dropwise to a stirred, refluxing solution of methyl sodioacetoacetate [from sodium (5·75 g., 0·25 g.-atom), methyl acetoacetate (29 g., 0·25 mole), and methanol (250 ml.)], and the mixture was stirred on a steam-bath for 20 hr. Most of the methanol was distilled off, and water (300 ml.) was added. The organic layer was isolated with ether and distilled. After elimination of material of b. p. 52—88°/12 mm. (1·18 g.), n_{D}^{20} 1·4314, the following fractions were taken: (i) b. p. 88—106°/12 mm. (1·00 g.), n_{D}^{20} 1·4612; (ii) b. p. 106—110°/12 mm. (1·74 g.), n_{D}^{20} 1·4672, $\lambda_{\max}$ 250 mμ (ε 8000); (iii) b. p. 66—86°/0·2 mm. (2·60 g.), n_{D}^{20} 1·4668, $\lambda_{\max}$ 250 mμ (ε 7500); (iv) b. p. 86—104°/0·2 mm (2·53 g.), n_{D}^{20} 1·4906, $\lambda_{\max}$ 233 mμ (ε 7000). Infrared spectra, run on all fractions, showed that (ii) was almost pure methyl 4 : 5-dihydro-5-methoxy-2 : 4 : 4 : 5-tetramethyl-3-furoate (see below), and that (i) and (iii) contained material of slightly lower purity. From fraction (iv), methyl 6-*iso*but-1′-enyl-2-methyl-4-oxo*cyclo*hex-2-enecarboxylate (m. p. and mixed m. p. 72°) separated during some days.

Methyl 4 : 5-dihydro-2 : 4 : 4-trimethyl-5-methylene-3-furoate (1 g.), 3-chloro-3-methylbutyne (1 g.), and dry methanol (25 ml.) were heated under reflux for 4 hr. The methanol and excess of chloro-compound were removed by evaporation and the residue distilled to give pure methyl 4 : 5-dihydro-5-methoxy-2 : 4 : 4 : 5-tetramethyl-3-furoate (infrared spectrum) in almost quantitative yield.

Methyl 4 : 5-*Dihydro*-2 : 4 : 4-*trimethyl*-5-*methylene*-3-*furoate* (I).—Under the usual acidic conditions, the dihydromethylenefuran formed a yellow-orange *bis*-2 : 4-*dinitrophenylhydrazone*, m. p. 232° (decomp.) (from methyl cellosolve) (Found: C, 47·5; H, 4·55; N, 20·2. $C_{22}H_{24}O_{10}N_8$ requires C, 47·15; H, 4·35; N, 20·0%), $\lambda_{\max}$ 360 mμ (ε 43,500) (in chloroform).

Ozonolysis of Methyl 4 : 5-*Dihydro*-2 : 4 : 4-*trimethyl*-5-*methylene*-3-*furoate.*—The ester (1·82 g.) in glacial acetic acid (50 ml.) was treated at 10° with 4—5% ozonised oxygen, the product added to zinc dust (3 g.) and water (50 ml.), and the mixture steam-distilled. The distillate (250 ml.) was neutralised, and dimedone (3 g.) in 50% aqueous ethanol (100 ml.) added: the mixture was set aside (18 hr.). The crystalline product which separated (950 mg., 35%) had m. p. 190°, undepressed by the dimedone derivative of formaldehyde.

In another experiment the ozonolysis was carried out at 0° in carbon tetrachloride solution, and the ozonide decomposed by water. The organic layer was separated, washed, dried, and evaporated to give an oil which reacted vigorously with warm 10% alcoholic potassium hydroxide (15 ml.) and was then heated under reflux for 1 hr. The product was evaporated, diluted with a little water, and acidified. An acid was precipitated which, crystallised from benzene, had m. p. 186—188° (vigorous effervescence) undepressed on admixture with dimethylmalonic acid.

4 : 5-*Dihydro*-2 : 4 : 4-*trimethyl*-5-*methylene*-3-*furoic Acid.*—The corresponding methyl ester (19·6 g.) was heated under reflux with 10% alcoholic potassium hydroxide (50 ml.) for 6 hr. Most of the ethanol was distilled off and water (100 ml.) was added. A little unhydrolysed material was removed with ether, and the purple aqueous solution was warmed to expel dissolved solvent, cooled to 0°, and just acidified (the purple colour disappeared sharply near

neutrality point). The precipitated 4 : 5-*dihydro*-2 : 4 : 4-*trimethyl*-5-*methylene*-3-*furoic acid*, m. p. 122°, was filtered off and recrystallised from light petroleum (b. p. 60—80°), then having m. p. 124—125° (10 g.) (Found: C, 64·6; H, 7·4%; equiv., 168. $C_9H_{12}O_3$ requires C, 64·3; H, 7·2%; equiv., 168), $\lambda_{max.}$ 263 mμ (ε 12,000), $\nu_{max.}$ (mull) 1691 m, 1675 s (bonded and α-unsaturated CO_2H), 1649 s and 892 m ($CH_2{:}C{<}$), and 1620 s cm.$^{-1}$ (conjugated C=C). The acid was reconverted by diazomethane into the methyl ester, b. p. 92°/20 mm., $n_D^{19\cdot5}$ 1·4830, whose infrared spectrum was identical with that of the ester mentioned earlier.

Oxidation of 4 : 5-*Dihydro*-2 : 4 : 4-*trimethyl*-5-*methylene*-3-*furoic Acid with Permanganate.*—The acid (10 g.) was added to water (100 ml.) and neutralised with potassium hydroxide. Potassium permanganate (20 g.) was added with vigorous stirring, at <35°. The mixture was stirred for 18 hr., then filtered, and the manganese dioxide was washed. The filtrate and washings were concentrated to 100 ml., acidified (much carbon dioxide evolved), and continuously extracted with ether. Cautious evaporation of the ether left an oil which was distilled at 40° *in vacuo*, the volatile product being collected in a cold trap. This formed a *p*-bromophenacyl ester, m. p. 84°, undepressed when admixed with authentic *p*-bromophenacyl acetate.

The white solid remaining from the distillate crystallised from light petroleum, then having m. p. 78—79° [Found: C, 58·2, 58·5; H, 8·7, 8·5; O (direct), 32·9%; equiv., 142. Calc. for $C_7H_{12}O_4$: C, 58·3; H, 8·4; O, 33·3%; equiv., 144·2], $\nu_{max.}$ (mull) 1703 and 1689 cm.$^{-1}$ (just resolved: saturated $C{:}O$ and CO_2H). There was no high-intensity absorption in the ultraviolet spectrum. The 2 : 4-*dinitrophenylhydrazone* crystallised from ethanol in yellow-orange needles, m. p. 212° after softening (Found: C, 48·05; H, 5·2; N, 16·7. $C_{13}H_{16}O_6N_4$ requires C, 48·15; H, 5·0; N, 17·3%). The semicarbazone had m. p. 190° if heated slowly and 198° on more rapid heating (all m. p.s with effervescence but without darkening). The instantaneous m. p. was 218° (Kofler hot-bar), the melting-front gradually receding. Despite the dependence of m. p. on the conditions for its determination there was a clear depression on admixture with the semicarbazone of 3 : 3-dimethyl-4-oxopentanoic acid [18] (m. p. 198° on rapid heating: instantaneous m. p. 208—210°) but none with the semicarbazone of 2 : 2-dimethyl-4-oxopentanoic acid.[19] The identity and non-identity were confirmed by comparison of infrared spectra.

3 : 3-*Dimethylhexane*-2 : 5-*dione.*—4 : 5-Dihydro-2 : 4 : 4-trimethyl-5-methylene-3-furoic acid (9 g.) was heated to 90° for 15 min. with 2N-sulphuric acid (30 ml.). Carbon dioxide was evolved, the suspended acid disappeared, and a liquid layer was formed. After saturation with salt, the solution was extracted with ether, and the extracts were washed with brine dried, and evaporated. Distillation gave 3 : 3-*dimethylhexane*-2 : 5-*dione* (3 g.), b. p. 77—78°/10 mm., n_D^{20} 1·4380 (Found: C, 67·6; H, 10·2. $C_8H_{14}O_2$ requires C, 67·55; H, 9·9%), $\nu_{max.}$ 1715 cm.$^{-1}$ (strong; saturated ketone). The *disemicarbazone* had m. p. 205—206° (decomp.) (from aqueous ethanol) (Found: C, 47·6; H, 8·1; N, 32·4. $C_{10}H_{20}O_2N_6$ requires C, 46·9; H, 7·8; N, 32·8%). The orange-yellow *bis*-2 : 4-*dinitrophenylhydrazone* crystallised from methyl cellosolve in needles, m. p. 217—218° (Found: C, 47·95; H, 4·65; N, 21 8. $C_{20}H_{22}O_8N_8$ requires C, 47·95; H, 4·4; N, 22·1%).

Patrick reports b. p. 93°/20 mm., n_D^{25} 1·4363, for 3 : 3-dimethylhexane-2 : 5-dione but made no derivatives.[20]

Oxidation of 3 : 3-*Dimethylhexane*-2 : 5-*dione with Hypochlorite.*—The diketone gave a strong iodoform reaction. It (2 g.) was added to excess of sodium hypochlorite (10—14% w/v) during 1 hr. and stirred for a further 2 hr. Sodium hydrogen sulphite was added to remove the hypochlorite, and the acidified solution was boiled to expel sulphur dioxide. The solution was then thoroughly extracted with ether, and the extracts were evaporated to a brown oil (500 mg.) from which crystals separated. The latter, recrystallised from concentrated hydrochloric acid, had m. p. 141·5—142° alone or mixed with 1 : 1-dimethylsuccinic acid (m. p. 142·5—143·5°) prepared from ethyl 2-cyano-3-methylbut-2-enoate and potassium cyanide.

Base-catalysed Cyclisation of 3 : 3-*Dimethylhexane*-2 : 5-*dione.*—The dione (9 g.) was heated in 2% aqueous sodium hydroxide under reflux for 20 min., the opalescent pink solution becoming clear. The solution was saturated with salt and extracted thoroughly with ether. Drying, evaporation, and distillation at 12 mm. gave a fraction (6·3 g.), b. p. 74—76°, n_D^{20} 1·4666—1·4688,

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[18] Baumgarten and Gleason, *J. Org. Chem.*, 1951, **16**, 1658.

[19] Lapworth, *J.*, 1904, 1214.

[20] Patrick, *J. Org. Chem.*, 1952, **17**, 1269.

containing 3 : 4 : 4- and 3 : 5 : 5-trimethyl*cyclo*pent-2-enone[2] (Found: C, 77·4; H, 9·6. Calc. for $C_8H_{12}O$: C, 77·35; H, 9·75%), $\lambda_{max.}$ 226 mμ (ε 11,400), $\nu_{max.}$ 1710 s (unsaturated 5-ring ketone) and 1634 m cm.$^{-1}$ (conjugated •C=C•). The product gave a 2 : 4-dinitrophenylhydrazone, m. p. 163° undepressed by that formed in the baryta-hydrolysis experiment reported below (Found: C, 55·7; H, 5·7%). The semicarbazone had m. p. 171—173° (decomp.) (Found: C, 59·1; H, 8·3. $C_9H_{15}ON_3$ requires C, 59·6; H, 8·3%).

The *cyclo*pentenone product (2 g.) was stirred with water (50 ml.), and potassium permanganate (8 g.) added during 2 hr., at <35°. Stirring was continued for 18 hr. and the manganese dioxide filtered off and washed. The filtrate and washings were concentrated to 35 ml. and a portion (15 ml.) was acidified (carbon dioxide evolved). The solution was neutralised and semicarbazide hydrochloride (300 mg.) and sodium acetate (500 mg.) were added. After 18 hr. crystals (100 mg.) were filtered off and recrystallised from water; they had m. p. 183·5°, raised by further crystallisation to 187—188° (slow heating). The semicarbazone, which melted with decarboxylation, depressed the m. p. of the semicarbazone of 3 : 3-dimethyl-4-oxopentanoic acid but not that of the semicarbazone of 2 : 2-dimethyl-4-oxopentanoic acid. Identity was confirmed by infrared spectra.

Baryta-hydrolysis of an Ethyl Ester Similar to M.—The ethyl ester (47 g.) obtained in an experiment similar to that described for mixture M was stirred under reflux with barium hydroxide octahydrate (60 g.) in water (1 l.) for 72 hr. After cooling and acidification (not excess), the mixture was extracted with ether, and the extracts were dried, evaporated, and distilled at 10 mm. to give a product (14 g.), b. p. 80—94°, n_D^{20} 1·4574—1·4535. Two redistillations (10 mm.) gave the following materials: (i) b. p. 72—74°, n_D^{20} 1·4602—1·4592 (4·5 g.), $\lambda_{max.}$ 226 mμ (ε 11,500); (ii) b. p. 74—75°, n_D^{20} 1·4572 (2·0 g.); (iii) b. p. 75—76°, n_D^{20} 1·4562 (2·0 g.). Fraction (i) gave an orange 2 : 4-dinitrophenylhydrazone, m. p. 163° (from ethanol) (Found: C, 54·7; H, 5·2. Calc. for $C_{14}H_{16}O_4N_4$: C, 55·25; H, 5·3%), $\lambda_{max.}$ 381 mμ (ε 25,800).

The residue in the flask after the original distillation solidified, and on crystallisation gave 5-methylsorbic acid, m. p. and mixed m. p. 112° (*p*-bromophenacyl ester, m. p. and mixed m. p. 121°).

4 : 5-Dihydro-2 : 4 : 4 : 5-tetramethyl-3-furoic Acid.—4 : 5-Dihydro-2 : 4 : 4-trimethyl-5-methylene-3-furoic acid (0·324 g.) was hydrogenated in ethanol over 5% palladium–barium sulphate (1·1 mol. of hydrogen absorbed). The *product*, crystallised from light petroleum (b. p. 60—80°), had m. p. 95·5—96°, undepressed by the specimen below (Found: C, 63·5; H, 8·5%; equiv., 167. $C_9H_{14}O_3$ requires C, 63 5; H, 8·3%; equiv., 170), $\lambda_{max.}$ 254 mμ (ε 11,200).

Ethyl 4 : 5-dihydro-2 : 4 : 4-trimethyl-5-methylene-3-furoate was similarly hydrogenated [1·02 mol. of hydrogen absorbed: uptake slow (48 hr.)]; the product, b. p. 86°/10 mm., n_D^{20} 1·4680, had $\lambda_{max.}$ 256 mμ (ε 10,150 in ethanol) which was not altered after 24 hr. in approx. 0·01N-ethanolic alkali. In chloroform the max. was at 257 mμ (ε 10,050). There were two strong infrared bands, at 1694 and 1630 cm.$^{-1}$. On hydrolysis with 10% alcoholic potassium hydroxide (15 hr. under reflux) the above acid (m. p. and mixed m. p. 95·5—96°) was obtained.

Methyl 4 : 5-Dihydro-5-methoxy-2 : 4 : 4 : 5-tetramethyl-3-furoate (IX).—Methyl 4 : 5-dihydro-2 : 4 : 4-trimethyl-5-methylene-3-furoate (3 g.) was added to dry methanol (20 ml.) containing concentrated sulphuric acid (5 drops). The mixture became warm and was set aside for 18 hr. Alcoholic potassium hydroxide was added to neutrality. The mixture was filtered and evaporated. The residue was extracted with ether, washed, dried, evaporated, and distilled to give *methyl 4 : 5-dihydro-5-methoxy-2 : 4 : 4 : 5-tetramethyl-3-furoate* (2 g.), b. p. 104—106°/10 mm., n_D^{20} 1·4683—1·4688 (Found: C, 61·6; H, 8·45. $C_{11}H_{18}O_4$ requires C, 61·7; H, 8·4%), $\lambda_{max.}$ 250 mμ (ε 10,900 in ethanol), 251 mμ (ε 10,800 in chloroform). In alcoholic N/100-potassium hydroxide the max. was at 250 mμ (ε 9400) soon after dissolution and at 253 mμ (ε 7400) after 4 and 24 hr. There were infrared bands at 1736 w, 1695 s (α-unsaturated ester) and 1639 s cm.$^{-1}$ (conjugated •C=C•). The origin of the weak band at 1736 cm.$^{-1}$ is uncertain: it is not removed by treatment with potassium borohydride. The methoxy-compound formed the bis-2 : 4-dinitrophenylhydrazone, m. p. 232° (decomp.), mentioned above (mixed m. p. and infrared comparison).

Methyl 4 : 5-Dihydro-5-hydroxy-2 : 4 : 4 : 5-tetramethyl-3-furoate (tautomeric mixture X $\rightleftharpoons$ XII).—(a) *From condensations between 3-chloro-3-methylbutyne and methyl sodioacetoacetate worked up under slightly acid conditions.* The fractions lying between those containing the dihydromethylenefuran with methyl 5-methylsorbate and the crystalline *cyclo*hexenone

(b. p. in one case 65—97°/0·02 mm.) were repeatedly distilled, the composition being followed by the hydroxylic infrared absorption. The *dihydrohydroxyfuran* had b. p. 71°/0·1 mm., n_{16}^{D} 1·4561, and gave no colour with ferric chloride even after 7 days in the reagent (Found: C, 60·5; H, 8·35. $C_{10}H_{16}O_4$ requires C, 60·0; H, 8·05%). It was not hydrogenated in ethyl acetate over 25% palladium–carbon, 10% palladium–barium sulphate, or Adams platinum catalyst. In the presence of the last catalyst, with glacial acetic acid as solvent, 2·02 mol. of hydrogen were absorbed. The dihydrohydroxyfuran had $\lambda_{max.}$ 250 mμ shifted to 278 mμ in approx. 0·01N-ethanolic alkali. Its infrared spectrum was identical with that of the specimen below. Under the usual conditions, a yellow-orange bis-2 : 4-dinitrophenylhydrazone was formed, having m. p. 235° (decomp.) (bath), 248° (decomp.) (Kofler hot-bar), after crystallisation from methyl cellosolve, washing with methanol, and drying at 100°/0·02 mm. (Found: C, 47·45; H, 4·55; N, 20·15), $\lambda_{max.}$ (in chloroform) 360 mμ (ε 43,500), $\nu_{max.}$ 1742 cm.$^{-1}$ ($\cdot CO_2Me$). The derivative was identical (mixed m. p. and infrared trace) with the bis-2 : 4-dinitrophenylhydrazone from methyl 4 : 5-dihydro-2 : 4 : 4-trimethyl-5-methylene-3-furoate and from methyl 4 : 5-dihydro-5-methoxy-2 : 4 : 4 : 5-tetramethyl-3-furoate.

(b) *From methyl* 4 : 5-*dihydro*-2 : 4 : 4-*trimethyl*-5-*methylene*-3-*furoate*. This substance (3 g.) was shaken at 20° with 5% aqueous sulphuric acid (25 ml.) for 3 hr. The product was extracted with ether, and the extract was dried (Na_2SO_4), evaporated, and distilled, to give the hydroxy-compound (2·64 g.), b. p. 72—73°/0·07 mm., n_D^{19} 1·4550 (Found: C, 60·45; H, 8·1%), $\lambda_{max.}$ 252 mμ (ε 2200 in ethanol); in 0·01N-ethanolic alkali a double max. developed at 252 and 280 mμ and the former gradually subsided leaving, after 4 hr., the max. at 280 mμ (ε 2200). The spectrum shows other interesting variations with time which are being examined.

The hydroxy-compound (300 mg.), methanol (5 ml.), and 1 small drop of sulphuric acid were set aside for 2 days at 20°, then poured into water. The product was isolated with ether; its infrared spectrum was identical with that of the methoxy-compound (IX).

4-*Ethyl*-4 : 5-*dihydro*-2 : 4-*dimethyl*-5-*methylene*-3-*furoic* *Acid*.—3-Chloro-3-methylpentyne (40 g.; b. p. 105°, n_D^{20} 1·4330) was added to a refluxing solution of ethyl sodioacetoacetate (10% excess) from sodium (8·4 g.), ethyl acetoacetate (48 g.), and methanol (170 ml.), and the mixture was heated and stirred for 15 hr. The product was worked up in the usual way and gave an *ester*, b. p. 95—96°/10 mm., n_D^{20} 1·4823 (27·5 g., 41%) (Found: C, 67·3; H, 8·1. $C_{11}H_{16}O_3$ requires C, 67·3; H, 8·2%), $\lambda_{max.}$ 267 mμ (ε 12,000). From the analytical data it appears to be methyl 4-ethyl-4 : 5-dihydro-2 : 4-dimethyl-5-methylene-3-furoate containing little, if any, material arising from γ-attack. The ester (1·97 g.), when ozonised in glacial acetic acid (50 ml.) as described above, gave formaldehyde dimedone derivative (1·4 g., 56%), m. p. and mixed m. p. 190°. The ester (19·6 g.) was heated under reflux for 6 hr. with 10% alcoholic potassium hydroxide (60 ml.). Working up as previously described gave 4-*ethyl*-4 : 5-*dihydro*-2 : 4-*dimethyl*-5-*methylene*-3-*furoic acid* (15 g., 83%), m. p. 107—108° [from light petroleum (b. p. 40—60°)] (Found: C, 65·9; H, 7·6. $C_{10}H_{14}O_3$ requires C, 65·9; H, 7·75%), $\lambda_{max.}$ 265 mμ (ε 11,500). There were infrared bands at 1698 m, 1669 s (bonded α-unsaturated CO_2H), 1647 s and 900 m ($CH_2{=}C{<}$), and 1621 s cm.$^{-1}$ (conjugated $\cdot C{=}C\cdot$). When warmed with 2N-sulphuric acid (20 ml.) for 20 min., the acid (2·2 g.) gave, after extraction and working up, 3-*ethyl*-3-*methylhexane*-2 : 5-*dione* (1·2 g., 80%), b. p. 102°/10 mm., n_D^{20} 1·4433 (Found: C, 68·75; H, 10·5. $C_9H_{16}O_2$ requires C, 69·2; H, 10·3%).

Reaction between Ethyl Sodioacetoacetate and 3-*Chlorobutyne*.—3-Chlorobutyne (21·6 g., 0·24 mole) was heated under reflux for 30 hr. with ethyl sodioacetoacetate prepared from sodium (6·2 g., 0·27 g.-atom), ethyl acetoacetate (35·1 g., 0·27 mole), and dry ethanol (110 ml.). Much of the ethanol was distilled off, and the residue was poured into water and worked up in the usual way. Distillation gave a fore-run (0·9 g.), b. p. 90°/15 mm., n_D^{20} 1·4559, giving a faint ferric chloride reaction. Fractions (showing no ferric reaction) were then taken as follows: (*a*) b. p. 100—104°/15 mm., n_D^{20} 1·4772 (3·8 g.), $\lambda_{max.}$ 264 mμ ($E_{1\,cm.}^{1\%}$ 535); (*b*) b. p. 104—106°/15 mm., n_D^{20} 1·4753 (3·3 g.), $\lambda_{max.}$ 264 mμ ($E_{1\,cm.}^{1\%}$ 390); (*c*) b. p. 106—107°/15 mm., n_D^{20} 1·4712 (1·4 g.), $\lambda_{max.}$ 254 mμ ($E_{1\,cm.}^{1\%}$ 230); (*d*) b. p. 64°/0·25 mm., n_D^{20} 1·4708 (1·0 g.), $\lambda_{max.}$ 258 mμ ($E_{1\,cm.}^{1\%}$ 200); (*e*) b. p. 64—70°/0·25 mm., n_D^{20} 1·4696 (0·6 g.), $\lambda_{max.}$ 258 mμ ($E_{1\,cm.}^{1\%}$ 182); (*f*) b. p. 70—80°/0·25 mm., n_D^{20} 1·4718 (0·4 g.), $\lambda_{max.}$ 256 mμ ($E_{1\,cm.}^{1\%}$ 210). Finally material of b. p. 90—112°/0·25 mm., n_D^{20} 1·4826—1·4906 (0·55 g.), giving a ferric reaction, was isolated. The infrared spectrum of (*a*) showed it to be mainly the dihydromethylenefuran ester [bands at 1701 s (α-unsaturated ester), 1653 s (conjugated $C{=}C{-}O$), and 899 m cm.$^{-1}$ ($CH_2{:}C$)]. There was only a small band at 1587 cm.$^{-1}$ indicative of ethyl 2 : 4 : 5-trimethyl-3-furoate. The intensity of the last band increased in the higher fractions whilst the band at 899 cm.$^{-1}$ disappeared. Fractions (*c*)—(*f*) were nearly pure furoic ester. The terminal acetylenic vibration was negligible in (*a*)—(*f*).

In a similar experiment, with methanol as solvent and a reflux period of 15 hr., methyl ester, b. p. 94—100°/12 mm., n_D^{20} 1·4790—1·4773 (76%), was isolated. A redistilled sample had b. p. 96—98°/12 mm., n_D^{20} 1·4792 (Found: C, 64·4; H, 6·9. Calc. for $C_9H_{12}O_3$: C, 64·3; H, 7·2%). On ozonolysis the formaldehyde dimedone derivative (26%; m. p. and mixed m. p. 190°) was obtained. The ester (16·8 g.) was heated under reflux for 2 hr. with 10% alcoholic potassium hydroxide (60 ml.). Most of the solvent was distilled off, the residue was diluted with water, and a little unchanged ester removed with ether. The aqueous solution was warmed to expel dissolved ether, cooled to 0°, and acidified. An oil separated and rapidly solidified, to give crude 2 : 4 : 5-trimethyl-3-furoic acid (14 g.). Crystallised from 40% aqueous acetic acid (400 ml.; charcoal) it gave pure acid (10 g.), m. p. 132—133°, undepressed by an authentic specimen kindly supplied by Professor Reichstein.[16] There were infrared bands at 1667 (broad), s (conjugated CO_2H), 1629 s, and 1576 s (furan). The ultraviolet max. was at 258 mμ (ε 3700).

The acid (1·54 g.), with diazomethane in ether, gave the methyl ester (1·3 g.), b. p. 104°/10 mm. The ethyl ester, prepared by esterification with diazoethane, had infrared bands at 1709 s (conjugated ester), 1642 w, 1585 s (furan band), and no absorption near 899 cm.$^{-1}$; the infrared spectrum closely simulated that of fractions (*c*)—(*f*) but was very different from that of (*a*); the ultraviolet max. was at 259 mμ (ε 3300).

Reaction between Methyl Sodioacetoacetate and 3-Chloropropyne.—The usual reaction was carried out, with 3-chloropropyne (37 g.) and methyl sodioacetoacetate [from sodium (12·6 g.), ethyl acetoacetate (71·5 g.), and dry methanol (250 ml.)]. After being stirred at 20° for 7 hr. the mixture was heated under reflux for 15 hr. and worked up and distilled in the usual way. The product was difficult to separate and only a central cut, b. p. 92—95°/10 mm., n_D^{20} 1·4878—1·4882 (6 g.), was examined. It had an ultraviolet max. at 260 mμ (ε 3230). On ozonolysis it yielded formaldehyde dimedone derivative (13%; m. p. and mixed m. p. 190°). The ester (2 g.) was hydrolysed by refluxing it for 2 hr. with potassium hydroxide (0·82 g.) in water (2 ml.) and ethanol (8 ml.); the acid (approx. 1 g.), isolated in the usual way, had m. p. 136—137° [from light petroleum (b. p. 60—80°)] and did not depress the m. p. of authentic 2 : 5-dimethyl-3-furoic acid.[17] The acid showed a strong broad band at 1678 (conjugated CO_2H) and bands at 1637 m, 1615 w, and 1582 s cm.$^{-1}$ (furan). The ethyl ester, prepared by diazoethane, had bands at 1709 s (furan CO_2Me), 1623 w, and 1592 s cm.$^{-1}$ (furan).

In a second experiment involving a reflux period of 30 hr., with ethanol as solvent, the product was isolated and distilled through a helix-packed column. All the fractions were impure and contained terminal-acetylenic bands. After elimination of a ketonic fraction (strong infrared band at 1736 cm.$^{-1}$), material of b. p. 84°/9 mm., but with a large refractive index spread (n_D^{20} 1·4684—1·4808), was isolated. Bands at 1695 s (α-unsaturated CO_2Me) 1647 s (conjugated ·C=C·), and 913 m [$CH_2{:}C(\cdot O-)$] cm.$^{-1}$ suggest that dihydromethylenefuran is probably present in the impure earlier cuts. In the later fractions the characteristic furan band at 1592 cm.$^{-1}$ appears clearly.

*Methyl 6-*iso*But-1′-enyl-2-methyl-4-oxo*cyclo*hex-2-enecarboxylate* (XIII; R = Me).—The substance separated from methanol in large, well-formed, lozenge-shaped crystals, m. p. 73°, giving no colour with ferric chloride [Found: C, 70·55, 70·1, 70·6, 70·3; H, 8·35, 8·5, 8·2, 8·1%; *M* (Rast), 222. $C_{13}H_{18}O_3$ requires C, 70·25; H, 8·15%; *M*, 222], $\lambda_{max.}$ 232 mμ (ε 13,000); in approx. 0·01N-ethanolic sodium hydroxide a new maximum appeared at 394 mμ (ε 9000, slowly declining). There were infrared bands at 1733 s (ester), 1661 s (α-unsaturated ketone), 1623 m (conjugated ·C=C·), and 851 m cm.$^{-1}$ ($Me_2C{:}CH$). On microhydrogenation (platinum in acetic acid), 3·1 mols. of hydrogen were absorbed. Methyl 2-methyl-4-oxo*cyclo*hex-2-enecarboxylate had $\lambda_{max.}$ 232 mμ (ε 11,800), shifted to 390 mμ (ε 9500) in ~0·01N-ethanolic alkali (ε declines gradually); there were infrared bands at 1728 s (ester), 1672 s (α-unsaturated ketone) and 1631 m cm.$^{-1}$ (conjugated ·C=C·).

Methyl 6-*iso*but-1′-enyl-2-methyl-4-oxo*cyclo*hex-2-enecarboxylate formed a red 2 : 4-*dinitrophenylhydrazone*, m. p. 165—166° (Found: C, 56·8; H, 5·5; N, 13·6. $C_{19}H_{22}O_6N_4$ requires C, 56·7; H, 5·5; N, 13·9%), $\lambda_{max.}$ (in chloroform) was at 385 mμ (ε 30,000). The *semicarbazone* had m. p. 186° (decomp.), $\lambda_{max.}$ 268 mμ (ε 21,000) (Found: C, 60·1; H, 7·5; N, 15·7. $C_{14}H_{21}O_3N_3$ requires C, 60·2; H, 7·6; N, 15·0%).

6-iso*But-1′-enyl-2-methyl-4-oxo*cyclo*hex-2-enecarboxylic Acid* (XIII; R = H).—Methyl 6-*iso*but-1′-enyl-2-methyl-4-oxo*cyclo*hex-2-enecarboxylate (2 g.) was heated under reflux with 2N-sodium hydroxide (25 ml.). The substance melted and a clear solution was obtained after 5 min.: slight cloudiness then developed and the solution was cooled rapidly to 20° and extracted with ether. This extract contained 5-*iso*but-1′-enyl-3-methyl*cyclo*hex-2-enone (110 mg.), $\nu_{max.}$ 1669 and 1629 cm.$^{-1}$ (Found: C, 80·6; H, 9·8%), $\lambda_{max.}$ 232 mμ (ε 13,200). The aqueous solution was just acidified at 20° and extracted with ether. Drying and evaporation at low temperature gave a pale brown gum (1·84 g.) which, after trituration with benzene–light petroleum (b. p. 60—80°), crystallised, giving the crude acid (1·4 g.), m. p. 97—102°. After recrystallisation from the same solvent, and then twice from a small volume of benzene, the *acid* had m. p. 109—110° (with effervescence) (Found: C, 68·95; H, 7·8%; equiv., 202. $C_{12}H_{16}O_3$ requires C, 69·2; H, 7·75%; equiv., 208), $\lambda_{max.}$ 232 mμ (ε 12,000), $\nu_{max.}$ 1730 s and 1626 s cm.$^{-1}$. The first $\nu_{max.}$ is assigned to the carboxyl group; the latter is unusually low for an α-unsaturated keto-grouping and it must overlie the ⁚C=C· str. frequency.

When esterified with diazomethane in ether, the acid gave the starting ester, m. p. and mixed m. p. 73—74° (infrared comparison).

5-iso*But-1′-enyl-3-methyl*cyclo*hex-2-enone* (XV).—The ester (XIII; R = Me) (2 g.) was heated under reflux for 1 hr. with 2N-sodium hydroxide (25 ml.), then extracted with ether, and the extract was dried, evaporated, and distilled to give 5-iso*but-1′-enyl-3-methyl*cyclo*hex-2-enone* (1·12 g.), b. p. 81—82°/0·6 mm., $n_D^{21\cdot5}$ 1·5033 (Found: C, 80·5; H, 10·0. $C_{11}H_{16}O$ requires C, 80·45; H, 9·85%), $\lambda_{max.}$ 230 mμ (ε 13,100), $\nu_{max.}$ (liquid film) 1672 s (α-unsaturated ketone) and 1631 m cm.$^{-1}$ (α-double bond). On its microhydrogenation in acetic acid over a platinum catalyst 2·8 mols. of hydrogen were absorbed. The 2 : 4-*dinitrophenylhydrazone* crystallised from ethanol in red, flat needles with a golden sheen, m. p. 120° after softening (melt clear 122°) (Found: C, 59·5; H, 5·7; N, 16·0. $C_{17}H_{20}O_4N_4$ requires C, 59·3; H, 5·85; N, 16·25%), $\lambda_{max.}$ (in chloroform) 387 mμ (ε 30,200).

The ketone was also made by keeping 6-*iso*but-1′-enyl-3-methyl-4-oxo*cyclo*hex-2-enecarboxylic acid (500 mg.) above its m. p. until effervescence ceased, and then distilling the residue. The specimen (350 mg.) had b. p. 78°/0·1 mm., n_D^{19} 1·5002—1·5029 (Found: C, 80·65; H, 9·75%), $\lambda_{max.}$ 232 mμ (ε 11,000). Besides the infrared bands at 1671 and 1633 cm.$^{-1}$ there was one at 1718 cm.$^{-1}$ (saturated C⁚O): except for the latter, the spectrum closely resembled that of the ketone made under basic conditions.

3-Methyl*cyclo*hex-2-enone has $\lambda_{max.}$ 232 mμ (ε 13,500), unaffected by dilute alkali, and $\nu_{max.}$ 1677 s and 1626 m cm.$^{-1}$.

3-iso*Butyl-5-methyl*cyclo*hexanone* (XVI).—5-*iso*But-1′-enyl-3-methyl*cyclo*hex-2-enone (0·89 g.) was hydrogenated in ethyl acetate solution over palladium–carbon (absorption 263 ml. at 23°/765 mm.; 2 mol. = 261 ml.). Removal of the catalyst, evaporation, and distillation gave 3-iso*butyl-5-methyl*cyclo*hexanone* (780 mg.), b. p. 65°/0·1 mm., n_D^{17} 1·4513 (Found: C, 78·85; H, 12·2. $C_{11}H_{20}O$ requires C, 78·5; H, 12·0%). The ketone had no high-intensity ultra-violet absorption. On microhydrogenation in acetic acid with Adams platinum catalyst a further 0·95 mol. of hydrogen was absorbed. The 2 : 4-*dinitrophenylhydrazone* crystallised in yellow-orange needles (from ethanol), m. p. 141° (Found: C, 58·6; H, 6·95; N, 16·15. $C_{17}H_{24}O_4N_4$ requires C, 58·6; H, 6·95; N, 16·1%).

An independent specimen was made as follows.[21] *iso*Valeraldehyde (8·6 g.), ethyl aceto-acetate (26 g.), and piperidine (1 g.) were mixed with water-cooling, and the product was heated at 100° for 2 hr. Sodium sulphate (anhydrous) was added to bind the water and the crude diethyl 2-*iso*butyl-4-methyl-6-oxo*cyclo*hex-4-ene-1 : 3-dicarboxylate was poured into a solution from sodium (2·3 g.) in ethanol (100 ml.). After 2 hours' refluxing most of the ethanol was distilled off and the residue was treated with water (50 ml.) and acetic acid (8 ml.) and extracted with ether. The extract was dried and evaporated (28 g.). A portion (18 g.) was distilled to give *ethyl* 6-iso*butyl-2-methyl-4-oxo*cyclo*hex-2-enecarboxylate* (6·7 g.), boiling mainly at 104°/0·05 mm., n_D^{24} 1·4773 (Found: C, 70·5; H, 9·4. $C_{14}H_{22}O_3$ requires C, 70·55; H, 9·3%), λ_{max} 232 mμ (ε 11,000) $\nu_{max.}$ 1730 s (ester), 1674 s (α-unsaturated ketone) and 1636 m cm.$^{-1}$ (conjugated ·C=C·). As the substance (in ethanol) gives a dirty-purple ferric reaction it probably contains some 2-oxo*cyclo*hex-3-enecarboxylate as contaminant. The other portion of diester (10 g.) was heated under reflux with water (60 ml.), sulphuric acid (7 ml.), and acetic acid (50 ml.) for 7 hr.

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[21] Cf. Knoevenagel, *Annalen*, 1895, **288**, 321.

The solution was made alkaline and worked up by ether-extraction in the usual way. Distillation gave 5-*iso*butyl-3-methyl*cyclo*hex-2-enone (2·3 g.), b. p. 70—73°/0·35 mm., n_D^{17} 1·4818, $\lambda_{max.}$ 232 mμ (ε 12,000), $\nu_{max.}$ 1669 s (α-unsaturated ketone), and 1631 m cm.$^{-1}$ (conjugated •C=C•). The 2 : 4-*dinitrophenylhydrazone* formed orange-red needles, m. p. 106—107°, from ethanol (Found: C, 58·5; H, 6·4. $C_{17}H_{22}O_4N_4$ requires C, 58·95; H, 6·4%). When hydrogenated over palladium–carbon in ethyl acetate the *cyclo*hexenone (870 mg.) absorbed exactly one mol. of hydrogen. After working up and distillation (a Silicone antifoam agent was needed), 3-*iso*butyl-5-methyl*cyclo*hexanone (680 mg.), b. p. 50°/0·15 mm., n_D^{21} 1·4500, was obtained. Infrared examination showed that the product was less pure than the sample obtained by degradation, so it was purified as the 2 : 4-dinitrophenylhydrazone, which, after crystallisation from ethanol, had m. p. 142° (Found: C, 58·95; H, 7·05; N, 16·15%) and was identical (mixed m. p. and infrared spectra) with that of the degradation product described above.

Methyl 2-iso*Butyl*-6-*methyl*-4-*oxo*cyclo*hexanecarboxylate* (XIV; R = Me).—Methyl 6-*iso*but-1′-enyl-2-methyl-4-oxo*cyclo*hex-2-enecarboxylate (1·8 g.) was hydrogenated in ethyl acetate over palladium–carbon. Approx. 2 mol. of hydrogen were absorbed. After filtration, evaporation, and crystallisation from methanol, the cyclo*hexanone* (1·37 g.), m. p. 95—99° was obtained. On recrystallisation it formed thick blunt needles, m. p. 98—99·5° (Found: C, 69·1; H, 9·8. $C_{13}H_{22}O_3$ requires C, 69·0; H, 9·8%), $\nu_{max.}$ (mull) 1720 s (saturated ester) and 1710 s (saturated ketone) cm.$^{-1}$ (no strong band near 850 cm.$^{-1}$). The 2 : 4-*dinitrophenylhydrazone* crystallised from methanol in orange-yellow plates, m. p. 137° (Found: C, 56·35; H, 6·65. $C_{19}H_{26}O_6N_4$ requires C, 56·15; H, 6·45%), $\lambda_{max.}$ (in chloroform) 364 mμ (ε 25,200).

2-iso*Butyl*-6-*methyl*-4-*oxo*cyclo*hexanecarboxylic Acid* (XIV; R = H).—The foregoing ester (540 mg.) was heated under reflux (60 min.) with 2N-sodium hydroxide (10 ml.): the substance needed to be melted down from the condenser from time to time. Extraction with ether gave no neutral ketone. On acidification and extraction with ether, the aqueous phase gave the *acid* which, after crystallisation from benzene–light petroleum (b. p. 60—80°), had m. p. 140—141° without decarboxylation (m. p. after re-solidification 140—141°) (Found: C, 67·4, 67·95; H, 9·65, 9·65. $C_{12}H_{20}O_3$ requires C, 67·9; H, 9·5%). There was no high-intensity, ultraviolet light absorption. There was one rather broad, unresolved band at 1704 cm.$^{-1}$ (acid and ketone groups).

Ozonolysis of Methyl 6-iso*But*-1′-*enyl*-2-*methyl*-4-*oxo*cyclo*hex*-2-*enecarboxylate*.—The ester (300 mg.) was ozonised (2½ hr.) in " AnalaR " glacial acetic acid (8 ml.), then added to water (50 ml.) containing zinc dust (2 g.) and steam-distilled into 2 : 4-dinitrophenylhydrazine reagent. The derivative of the steam-volatile product was purified by chromatography from benzene on neutral alumina. It (300 mg.) had m. p. 127° undepressed by admixture with acetone 2 : 4-dinitrophenylhydrazone, m. p. 127°.

The Photodimer (XVIII or XIX; R = Me, R′ = $CMe_2{:}CH$).—Crystals of methyl 6-*iso*but-1′-enyl-2-methyl-4-oxo*cyclo*hex-2-enecarboxylate which had been kept in daylight were dissolved in a little methanol, and the white powder which remained was crystallised from a large volume of methanol, to give *dimethyl* 2 : 7(or 2 : 6)-*di*iso*but*-1′-*enyl*-8a : 8b(or 4*b* : 8*b*)-*dimethyl*-4 : 5(or 4 : 8)-*dioxodi*cyclo*hexano*cyclo*butane*-1 : 8(or 1 : 5)-*dicarboxylate*, needles, m. p. 248° [instantaneous m. p. (Kofler bar) 250°] [Found: C, 70·2; H, 8·4; O (direct), 22·1%; *M* (ebullioscopic), 444·5. $C_{26}H_{36}O_6$ requires C, 70·25; H, 8·15; O, 21·6%; *M*, 444·6].

The dimer was more conveniently prepared as follows. Ground crystals of the monomeric ester (3 g.) on a 3½″ Petri dish were exposed for 4 days to the light from a Hanovia ultraviolet lamp. The substance was crushed and turned over at intervals and crumbled to an extremely white powder. On crystallisation from methanol the photodimer (2·20 g.) was isolated. Evaporation of the mother-liquors and re-irradiation of the ground product gave a further quantity (0·25 g.; total yield 82%). The dimer is sparingly soluble in ether and formaldehyde methyl acetal, but soluble in chloroform and can be crystallised from benzene or methanol–chloroform. It formed a *bis*-2 : 4-*dinitrophenylhydrazone* which crystallised from a large volume of tetrahydrofuran or methyl cellosolve in yellow needles, m. p. 281° (decomp.; placed in the bath at 260°; darkened before melting). With fast heating, m. p. 287° (decomp.) was recorded. The substance was dried at 100°/0·05 mm. for 2 hr. (Found: C, 56·55; H, 5·8; N, 13·2. $C_{38}H_{44}O_{12}N_8$ requires C, 56·7; H, 5·5; N, 13·9%).

The dimer (500 mg.) was dissolved in boiling methanol (150 ml.), and potassium hydroxide (3 g.) in ethanol (25 ml.) added. After 3·5 hours' heating under reflux most of the methanol was evaporated, water was added, and a product (490 mg.), m. p. 239—248°, isolated with chloroform. Two crystallisations raised the m. p. to 248—249° (undepressed by the starting material).

The dimer (300 mg.) was refluxed with potassium hydroxide (1 g.) in methanol (25 ml.), and benzaldehyde (1 g.) was added. Refluxing was continued for 1 hr., water added, and the *dibenzylidene derivative* filtered off and twice crystallised from methanol–chloroform; it had m. p. 210—213° [Found: C, 77·75; H, 7·45; O (direct), 15·35%; *M* (ebullioscopic), 631·1. $C_{40}H_{44}O_6$ requires C, 77·4; H, 7·15; O, 15·45%; *M*, 620·8], $\lambda_{max.}$ 295 mμ (ε 22,200), $\nu_{max.}$ 1739 s (saturated CO_2Me), 1684 s (α-unsaturated ketone), 1610 ms (conjugated ·C=C·), 1594 mi, 1575 mw, 1486 m, 735 ms, 700 s, and 691 ms (various Ph vibrations), and 840 m cm.$^{-1}$ ($Me_2C{=}CH$).

Hydrogenation of the Photodimer.—The dimer (800 mg.) was hydrogenated in ethyl acetate (40 ml.) at 25% palladium–carbon. Kieselguhr was added and the mixture was filtered and concentrated to give the *di*iso*butyl dimer*, needles, m. p. 210° (Found: C, 69·7; H, 9·1. $(C_{13}H_{20}O_3)_2$ requires C, 69·6; H, 9·0%). In a second experiment an uptake of 2·02 mol. of hydrogen was measured and the product (75%) had m. p. 212°. There were infrared bands at 1733 s (saturated ester) and 1691 s cm.$^{-1}$ (CO α to *cyclo*butane). The band at 850 cm.$^{-1}$ had disappeared.

Ozonolysis of the Photodimer.—The dimer (500 mg.) almost all dissolved when ozonised in " AnalaR " glacial acetic acid for 90 min. The product was diluted with water and distilled into 2 : 4-dinitrophenylhydrazine reagent. After two recrystallisations the 2 : 4-dinitrophenylhydrazone [330 mg. crude; 310 mg. crystallised (equiv. to 1·2 mol. of acetone)] formed needles, m. p. 128° undepressed by authentic acetone 2 : 4-dinitrophenylhydrazone. As the sample from the ozonolysis route was slightly more orange than the authentic specimen, identity was confirmed by infrared methods.

The residue from the distillation was concentrated and set aside at 0°; this gave powdery crystals (100 mg.) of the *dimethoxycarbonyldimethyldioxo*cyclo*hexano*cyclo*butanedicarboxylic acid* (XVIII or XIX; R = Me, R′ = CO_2H), m. p. 309° (with effervescence and darkening) which crystallised from a large volume of ethanol–water as plates or needles (Found: C, 56·15, 56·65; H, 6·05, 6·1. $C_{20}H_{24}O_{10}$ requires C, 56·6; H, 5·7%), $\nu_{max.}$ 1723 s (bonded saturated ester), 1698 s (CO α to *cyclo*butane), and 1677 s cm.$^{-1}$ (bonded CO_2H).

Reaction Between Methyl Sodio-α-methylacetoacetate and 3-*Chloro*-3-*methylbutyne.*—The chloro-compound (34·5 g.) was added to refluxing methyl sodio-α-methylacetoacetate [from sodium (7·7 g.) and methyl α-methylacetoacetate (39 g.)] in dry methanol (150 ml.). A sample (25 ml.) was withdrawn after 30 min. and on working up and distillation gave a product having strong absorption at 274 mμ ($E^{1\%}_{1\,cm.}$ of successive fractions 810, 530, and 450). Weak allenic absorption (1950 cm.$^{-1}$) was detected in the spectrum of the middle fraction. A second sample (25 ml.), withdrawn after 2½ hr., showed similar slight allenic absorption. After boiling for 20 hr. the main material was worked up and distilled, having b. p. mainly 100—117°/21 mm., n_D^{20} 1·4768 rising to n_D^{20} 1·4860 and then falling to n_D^{20} 1·4673 (15·3 g.). The ultraviolet max. was at 274 mμ ($E^{1\%}_{1\,cm.}$ 440, equiv. to 28% of methyl 2 : 5-dimethylsorbate).

The crude ester (14·2 g.) was heated under reflux with 15% alcoholic potassium hydroxide (60 ml.) for 18 hr. and the product was then separated into neutral (1·2 g.) and acidic (9·0 g.) material. The former contained α-saturated ketonic material having a terminal acetylenic band [$\nu_{max.}$ 3242, 2112 (·C≡CH) and 1701 cm.$^{-1}$ (·C=O); 2 : 4-dinitrophenylhydrazone, m. p. 128°, $\lambda_{max.}$ 363 mμ ($E^{1\%}_{1\,cm.}$ 810)], which was not further examined. Part of the acidic product (1·0 g.) was reconverted into the methyl ester, b. p. 69—98°/20 mm., n_D^{21} 1·4810, $\lambda_{max.}$ 274 mμ ($E^{1\%}_{1\,cm.}$ 918, equiv. to 59% of methyl 2 : 5-dimethylsorbate). Crystallisation of the rest of the acidic product from light petroleum (b. p. 40—60°) gave pure 2 : 5-dimethylsorbic acid (2·85 g.), m. p. 136—137° (Found: C, 68·35; H, 8·8. Calc. for $C_8H_{12}O_2$: C, 68·5; H, 8·6%). The ultraviolet max. was at 274 mμ (ε 25,000) and the infrared spectrum was identical with that of the specimen, m. p. 137°, described by Crombie, Harper, and Sleep.[15] Its *methyl ester*, prepared by diazomethane, had n_D^{21} 1·5167 (Found: C, 70·05; H, 9·35. $C_9H_{14}O_2$ requires C, 70·1; H, 9·15%), $\lambda_{max.}$ 274 mμ (ε 24,100), $\nu_{max.}$ 1706 s (conjugated ester) and 1637 s and 1605 m cm.$^{-1}$ (conjugated diene).

The liquid residues from the crystallisation were distilled at 0·1 mm. The distillate (2 g.) solidified and when crystallisation was continued from light petroleum (b. p. 40—60°) gave 2 : 3 : 3-*trimethylpent*-4-*ynoic acid*, m. p. 81°, as needles (Found: C, 68·6; H, 8·85. $C_8H_{12}O_2$ requires C, 68·5; H, 8·6%). On microhydrogenation 1·98 mols. of hydrogen were absorbed. The methyl ester, n_D^{21} 1·4330, had bands at 3247 and 2119 (·C≡CH) and 1733 cm.$^{-1}$ (α-saturated ester).

A similar reaction was carried out at 20° for 90 min. The undistilled product had $\lambda_{\max.}$ 275 mμ ($E^{1\%}_{1\,\text{cm.}}$ 36) but negligible infrared absorption in the allenic region.

Reaction between Methyl Sodioacetoacetate (1·0 *Mol.*) *and* 1-*Chloro*-3-*methylbuta*-1 : 2-*diene* (0·9 *Mol.*).—The chloro-compound was prepared according to the directions of Hennion *et al.*[14] and purified by fractionation through an 18″ vacuum-jacketed column packed with helices. It had b. p. 59°/15 mm., n_D^{22} 1·4751, and showed an intense allene band at 1972 cm.$^{-1}$: it was free from acetylenic absorption.

(1) *At the b. p.* 1-Chloro-3-methylbuta-1 : 2-diene (9·2 g.) was added dropwise to a refluxing solution of methyl sodioacetoacetate [from methyl acetoacetate (11·6 g.), sodium (2·3 g.), and dry methanol (50 ml.)], and refluxing was continued for 5 hr. The mixture was set aside for 48 hr., then refluxed for a further 11 hr. Most of the methanol was removed by distillation and the residue was poured into water. Isolation of the product in the usual way gave, after evaporation and rejection of a small fore-run giving a ferric chloride reaction, material of b. p. 94°/24 mm., n_D^{19} 1·4795—1·4961 (0·82 g.). This gave no ferric chloride colour, and infrared examination showed it to be a mixture containing mainly methyl 4 : 5-dihydro-2 : 4 : 4-trimethyl-5-methylene-3-furoate and methyl 5-methylsorbate in the ratio 2·2 : 1. Continuation of the distillation gave material, b. p. 73°/0·4 mm., n_D^{19} 1·5103—1·5179 (0·3 g.), giving no ferric chloride colour. No methyl *iso*but-2′-enyl-2-methyl-4-oxo*cyclo*hex-2-enecarboxylate could be isolated from this or the distillation residue.

(2) *At* 20°. The same process was carried out at 20° for 7 days. On working up, only methyl acetoacetate and 1-chloro-3-methylbuta-1 : 2-diene, identified by their infrared spectra, were isolated.

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