703. *The Condensation of Aliphatic Diketones with Hex-*1*-yne.*

By J. Cymerman and (Miss) P. Rowe-Smith.

Condensations have been effected between hexynylmagnesium bromide and diacetyl, acetonylacetone, and *cyclo*hexane-1 : 4-dione, giving the expected diacetylenic glycols (I), (II), and (III) in excellent yields. Their structures have been proved by complete hydrogenation to the saturated glycols (IV), (V), and (VI), of which (IV) and (V) have also been prepared by independent syntheses.

Although there exists an abundant literature dealing with the condensation of acetylene with both saturated and unsaturated carbonyl compounds (cf. Johnson, "The Chemistry of the Acetylenic Compounds," London, 1946), no such condensations with dicarbonyl compounds have been reported. Dane (*Annalen*, 1938, **536**, 195) reports failure to obtain the required diacetylenic glycol from ethynylmagnesium bromide and *cyclo*pentane-1 : 2-dione. Similarly, there exist very few reports of the reaction of substituted acetylenes with dicarbonyl compounds. Wilson and Hyslop (*J.*, 1923, 2612; 1924, 1556) obtained the diacetylenic glycols from phenylacetylenylmagnesium bromide and diacetyl or acetonylacetone, but report failure to condense this Grignard reagent with acetylacetone, benzil, or dibenzoylethylene, and octadec-1-ynylmagnesium bromide was condensed with the long-chain diketone, dodecane-3 : 18-dione, by Meyer (*Helv. Chim. Acta*, 1937, **20**, 1179) to give the expected diacetylenic diol.

While our work was in progress, Milas, Brown, and Phillips (*J. Amer. Chem. Soc.*, 1948, **70**, 2862) described the condensation of acetylene with diacetyl and acetonylacetone to give the expected diacetylenic glycols. Work on the preparation of such glycols is proceeding in our laboratories and the results will be published in due course. Meanwhile the condensation of the substituted acetylene, hex-1-yne, with three simple aliphatic diketones has been studied.

When hexynylmagnesium bromide (3 moles; Cymerman, Heilbron, and Jones, *J.*, 1944, 146) reacted with diacetyl (1 mole) in boiling ether, the expected 7 : 8-*dimethyltetradeca*-5 : 9-*diyne*-7 : 8-*diol* (I) was obtained in 96% yield. The product contained 2 active hydrogen atoms (Zerewitinoff), and absorbed 4 moles of hydrogen on quantitative hydrogenation. It showed no appreciable light absorption in the ultra-violet region. Evidence for the αβ-glycol structure was supplied by reaction with lead tetra-acetate (Criegee, *Annalen*, 1930, **481**, 275; *Ber.*, 1931, **64**, 260) which afforded the known oct-3-yn-2-one (VII). Apparently the only reported use of lead tetra-acetate for fission of an acetylenic 1 : 2-glycol is due to Ruzicka, Plattner, and Widmer (*Helv. Chim. Acta*, 1942, **25**, 1086) who obtained the acid (VIII) by fission of the diol (IX).

(I.) $CH_3\cdot[CH_2]_3\cdot C\vdots C\cdot CMe(OH)\cdot CMe(OH)\cdot C\vdots C\cdot[CH_2]_3\cdot CH_3$ $CH_3\cdot[CH_2]_3\cdot C\vdots C\cdot CO\cdot CH_3$ (VII.)

(IX.) $CH_3\cdot C\vdots C\cdot[CH_2]_7\cdot CH(OH)\cdot CH(OH)\cdot[CH_2]_7\cdot C\vdots C\cdot CH_3$ $CH_3\cdot C\vdots C\cdot[CH_2]_7\cdot CO_2H$ (VIII.)

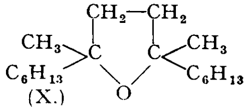
Hydrogenation of the glycol (I) afforded 7 : 8-*dimethyltetradecane*-7 : 8-*diol* (IV) which was also synthesised from methyl hexyl ketone by an adaptation of the method of Adams and Adams (*Org. Synth.*, Coll. Vol. I, p. 459). This material, a viscous oil, could not be induced to crystallise, probably owing to its existence in *meso*- and racemic modifications.

Condensation of hexynylmagnesium bromide with acetonylacetone gave an 80% yield of 7 : 10-*dimethylhexadeca*-5 : 11-*diyne*-7 : 10-*diol* (II) which closely resembled (I) in behaviour. Complete hydrogenation of (II) gave 7 : 10-*dimethylhexadecane*-7 : 10-*diol* (V), solidifying on storage to crystals (m. p. 32°) which must be a stereochemically pure form of the compound.

$CH_3\cdot[CH_2]_3\cdot C\vdots C\cdot CMe(OH)\cdot(CH_2)_2\cdot CMe(OH)\cdot C\vdots C\cdot[CH_2]_3\cdot CH_3$ (II.)

$CH_3\cdot[CH_2]_5\cdot CMe(OH)\cdot CMe(OH)\cdot[CH_2]_5\cdot CH_3$ (IV.)

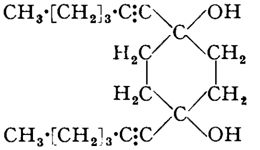
$CH_3\cdot[CH_2]_5\cdot CMe(OH)\cdot[CH_2]_2\cdot CMe(OH)\cdot[CH_2]_5\cdot CH_3$ (V.)

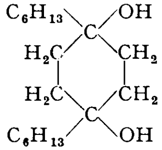

(X.)

This was also synthesised in quantitative yield by the action of hexylmagnesium bromide on acetonylacetone.

The preparation of substituted tetrahydrofurans from αδ-glycols is well known, and dehydration of the glycol (V) by means of potassium hydrogen sulphate afforded 2 : 5-*dimethyl*-2 : 5-*di*-n-*hexyltetrahydrofuran* (X), which was also obtained as a by-product in the distillation of (V) obtained by hydrogenation of (II).

The interesting cyclic diketone, *cyclo*hexane-1 : 4-dione, was condensed with hexynylmagnesium bromide to give a quantitative yield of the crystalline 1 : 4-*dihex*-1′-*ynyl*cyclo*hexane*-1 : 4-*diol* (III). Purification afforded evidence of two stereoisomeric forms, only one of which (m. p. 88—89°) could be isolated pure, the other (m. p. 73—75°) being readily converted into the stable higher-melting form during repeated recrystallisation. Hydrogenation of the glycol (m. p. 88—89°) yielded 1 : 4-*di*-n-*hexyl*cyclo*hexane*-1 : 4-*diol* (VI) as a pure stereomer, m. p. 98—99°, in excellent yield. Attempted synthesis of (VI) from *n*-hexylmagnesium bromide and *cyclo*hexane-1 : 4-dione gave only an uncrystallisable oil; this behaviour is not surprising since the compound must exist as a mixture of racemic and *meso*-forms.

(III.)



(VI.)

EXPERIMENTAL.

7 : 8-*Dimethyltetradeca*-5 : 9-*diyne*-7 : 8-*diol* (I).—A solution of hex-1-yne (29·5 g.) in ether (150 c.c.) was added to an ethereal solution of ethylmagnesium bromide (from 7·2 g. of magnesium), and the mixture refluxed for 3 hours. A solution of diacetyl (8·6 g.) in ether (100 c.c.) was dropped into the cooled reaction mixture in a nitrogen atmosphere, after which the whole was refluxed with stirring for 4 hours and then set aside overnight. The complex was decomposed by the addition of ammonium chloride solution (ice), the aqueous layer acidified to Congo-red with dilute sulphuric acid (10%), and the product isolated in the usual manner by extraction with ether. Distillation of the washed and dried ethereal extracts afforded 7 : 8-*dimethyltetradeca*-5 : 9-*diyne*-7 : 8-*diol* (24·3 g., 96%) as a colourless pleasant-smelling oil, b. p. 94—95°/0·01 mm., 113°/0·08 mm., n_{D}^{23} 1·4746 (Found : C, 77·1 ; H, 10·55. $C_{16}H_{26}O_2$ requires C, 76·8 ; H, 10·5%). Active hydrogen (Zerewitinoff) : the glycol (97·1 mg.) evolved 18·9 c.c. of methane at 24°/757 mm., equivalent to 2·0 active hydrogen atoms per mol. It showed no light absorption of appreciable intensity in the ultra-violet region (2150—3500 A.).

Quantitative hydrogenation. A solution of the glycol (247 mg.) in methyl acetate (25 c.c.), shaken with platinic oxide (25 mg.) and hydrogen until absorption ceased, absorbed 98 c.c. of hydrogen at 28°/755 mm., equivalent to 4·0 double bonds per mol.

Oct-3-*yn*-2-*one*.—A solution of the above glycol (2 g.) in dry benzene (50 c.c.) was treated with glacial acetic acid (5 drops) and lead tetra-acetate (5·5 g.). The mixture was set aside for 48 hours at room temperature, and unused lead tetra-acetate then decomposed by addition of water. Precipitated lead peroxide was filtered off and the filtrate extracted with ether. Removal of solvent from the washed and dried extracts left a residue of oct-3-yn-2-one (0·4 g., 20%) as a colourless liquid, b. p. 100—102°/35 mm., n_{D}^{22} 1·4465 (Kroeger and Nieuwland, *J. Amer. Chem. Soc.*, 1936, **58**, 1861, give b. p. 76—77·5°/15 mm., n_{D}^{25} 1·4446). The 2 : 4-dinitrophenylhydrazone had m. p. 87—88°, undepressed on admixture with an authentic specimen (Bowden, Heilbron, Jones, and Weedon, *J.*, 1946, 43 ; m. p. 87—88°).

7 : 8-*Dimethyltetradecane*-7 : 8-*diol*.—(*a*) A solution of 7 : 8-dimethyldeca-5 : 9-diyne-7 : 8-diol (2·5 g.) in methyl acetate (100 c.c.) was shaken with platinic oxide (100 mg.) and hydrogen until absorption ceased. The catalyst was filtered off and the solvent removed, leaving a residue of 7 : 8-*dimethyltetradecane*-7 : 8-*diol* (2·25 g., 90%) as a colourless viscous oil, b. p. 114°/0·02 mm., n_{D}^{25} 1·4560 (Found : C, 74·0; H, 13·6. $C_{16}H_{34}O_2$ requires C, 74·3; H, 13·25%). Active hydrogen (Zerewitinoff) : the diol (56·6 mg.) evolved 11·0 c.c. of methane at 29°/758 mm., equivalent to 2·0 active hydrogen atoms per mol.

(*b*) A solution of mercuric chloride (4·5 g.) in dry ether was added gradually to magnesium (4 g.)

covered with a solution of methyl hexyl ketone (15 g.) in dry benzene (40 c.c.), and the mixture refluxed for 6 hours with frequent shaking. The reaction mixture was set aside overnight and filtered from magnesium, the solid being returned to a flask and refluxed for 10 minutes with benzene–ether (25 c.c.; 1 : 1) which was then filtered. The combined filtrates were dried and the solvent removed, leaving a residue of 7 : 8-dimethyltetradecane-7 : 8-diol (10 g., 66%) as a colourless viscous liquid, b. p. 112°/0·02 mm., 116°/0·05 mm., n_D^{25} 1·4556. Attempted distillation at 2 mm. resulted in extensive dehydration. Active hydrogen (Zerewitinoff) : the diol (61·0 mg.) evolved 11·8 c.c. of methane at 27°/760 mm. (2·0 active hydrogen atoms per mol.).

7 : 10-*Dimethylhexadeca*-5 : 11-*diyne*-7 : 10-*diol* (II).—Condensation of hexynylmagnesium bromide, from hex-1-yne (24·5 g.) and magnesium (7·2 g.), with acetonylacetone (11·4 g.) in ether (400 c.c.) by the method described above afforded 7 : 10-*dimethylhexadeca*-5 : 11-*diyne*-7 : 10-*diol* (22·2 g., 80%) as a colourless viscous liquid, b. p. 131—132°/0·01 mm., n_D^{21} 1·4800 (Found : C, 78·3; H, 10·9. $C_{18}H_{30}O_2$ requires C, 77·75; H, 10·85%). Active hydrogen (Zerewitinoff) : the diol (95·5 mg.) evolved 16·7 c.c. of methane at 20·5°/752 mm. (2·0 active hydrogen atoms per mol.). It showed no light absorption of appreciable intensity in the ultra-violet. Quantitative hydrogenation : a solution of the glycol (279 mg.) in methyl acetate (25 c.c.), shaken with platinic oxide (25 mg.) and hydrogen until absorption ceased, absorbed 94 c.c. of hydrogen at 22°/758 mm. (3·9 double bonds per mol.).

7 : 10-*Dimethylhexadecane*-7 : 10-*diol*.—(*a*) A solution of 7 : 10-dimethylhexadeca-5 : 11-diyne-7 : 10-diol (3·2 g.) in methyl acetate (120 c.c.) was shaken with platinic oxide (25 mg.) and hydrogen until absorption ceased. Removal of the catalyst by filtration and distillation of the residue afforded 2 fractions : (i) 2 : 5-dimethyl-2 : 5-di-*n*-hexyltetrahydrofuran (0·4 g., 13%), b. p. 88°/0·006 mm., n_D^{25} 1·4550, as a pale yellow mobile liquid (see below), and (ii) 7 : 10-*dimethylhexadecane*-7 : 10-*diol* (1·6 g., 50%) as a colourless very viscous oil, b. p. 120°/0·006 mm., n_D^{25} 1·4600, which on storage solidified to give white needles, m. p. 30—32° (Found : C, 75·45; H, 13·8. $C_{18}H_{38}O_2$ requires C, 75·45; H, 13·4%). Active hydrogen (Zerewitinoff) : the diol (42·8 mg.) evolved 7·7 c.c. of methane at 23°/764 mm., equivalent to 2·1 active hydrogen atoms per mol.

(*b*) A solution of *n*-hexylmagnesium bromide, from *n*-hexyl bromide (8 g.) and magnesium (1·15 g.) in ether (50 c.c.), was cooled to 0° (ice) and treated with a solution of acetonylacetone (2·28 g.) in ether (50 c.c.). The mixture was refluxed for 10 hours and set aside overnight. Isolation of the product as described above afforded 7 : 10-*dimethylhexadecane*-7 : 10-*diol* (5·7 g., 99%) as a colourless very viscous oil, b. p. 131—133°/0·02 mm., n_D^{23} 1·4606, which on storage solidified to white needles, m. p. 30—31°, undepressed on admixture with the specimen obtained above.

2 : 5-*Dimethyl*-2 : 5-*di*-n-*hexyltetrahydrofuran*.—A mixture of 7 : 10-dimethylhexadecane-7 : 10-diol (0·68 g.) and freshly powdered potassium hydrogen sulphate (1 g.) in a small Claisen flask was maintained at 180—190° (bath temperature) for 1·5 hours under a vacuum of 20 mm. Distillation of the product, using an oil pump, afforded 2 : 5-*dimethyl*-2 : 5-*di*-n-*hexyltetrahydrofuran* (0·4 g., 66%) as a pale yellowish mobile liquid possessing a pleasant odour, b. p. 128°/0·3 mm., n_D^{25} 1·4551 (Found : C, 80·55; H, 13·8. $C_{18}H_{36}O$ requires C, 80·55; H, 13·5%). The compound showed no active hydrogen by the Zerewitinoff method.

1 : 4-*Dihex*-1′-*ynyl*cyclo*hexane*-1 : 4-*diol* (III).—Condensation of hexynylmagnesium bromide, from hex-1-yne (24·5 g.) and magnesium (7·2 g.) in ether (250 c.c.), with *cyclo*hexane-1 : 4-dione (10·2 g., purified by sublimation at 80—90°/0·02 mm.) in dry ether–benzene (150 c.c.; 1 : 1) was effected by the method described above. Addition of dry benzene (100 c.c.) was necessary to dissolve the white magnesium complex formed. Isolation of the product in the usual manner gave a white solid (24·5 g.), m. p. 67—71°, which on crystallisation from light petroleum (b. p. 60—80°) afforded white needles (18·5 g., 74%) of 1 : 4-*dihex*-1′-*ynyl*cyclo*hexane*-1 : 4-*diol*, m. p. 88—89° (Found : C, 78·25; H, 9·95. $C_{18}H_{28}O_2$ requires C, 78·2; H, 10·2%). Active hydrogen (Zerewitinoff) : the diol (97·7 mg.) evolved 16·5 c.c. of methane at 22°/758 mm. (1·95 active hydrogen atoms per mol.). It showed no light absorption of appreciable intensity in the ultra-violet region.

1 : 4-*Di*-n-*hexyl*cyclo*hexane*-1 : 4-*diol*.—A solution of 1 : 4-dihex-1′-ynyl*cyclo*hexane-1 : 4-diol (0·24 g.) in methyl acetate (25 c.c.), shaken with hydrogen in the presence of platinic oxide (25 mg.) until absorption ceased, absorbed 88 c.c. of hydrogen at 27°/750 mm., equivalent to 4·0 double bonds per mol. The catalyst was filtered off and removal of solvent left a residue of 1 : 4-*di*-n-*hexyl*cyclo*hexane*-1 : 4-*diol* (0·22 g., 88%), crystallising from light petroleum (b. p. 60—80°) in white plates, m. p. 98—99° (Found : C, 75·55; H, 12·9. $C_{18}H_{36}O_2$ requires C, 76·0; H, 12·75%). Active hydrogen (Zerewitinoff) : the diol (25·4 mg.) evolved 4·3 c.c. of methane at 23·5°/767 mm. (2·0 active hydrogen atoms per mol.).

The authors thank Miss J. Fildes, B.Sc., and Drs. Weiler and Strauss for microanalyses, and are indebted to the Commonwealth Research Fund for financial support.

ORGANIC CHEMISTRY DEPARTMENT,
THE UNIVERSITY OF SYDNEY, N.S.W., AUSTRALIA.

[*Received, September* 12*th*, 1949.]