Tetrahedron Vol. 38, No. 7, pp. 1003 to 1007, 1982
Printed in Great Britain.

0040-4020/82/071003-05$03.00/0
Pergamon Press Ltd.

HETEROLYTIC CLEAVAGE OF HOMOALLYLIC ALCOHOLS—I

FRAGMENTATION OF 6-HYDROXYCAMPHENE DERIVATIVES[a,b]

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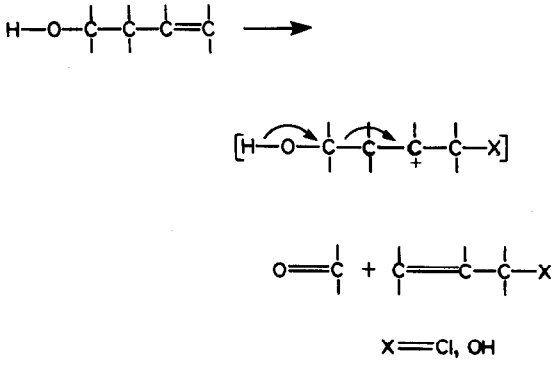
(*Received in U.K.* 2 *September* 1981)

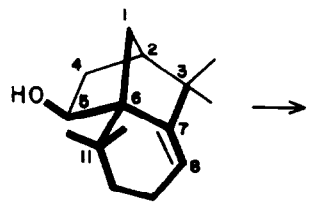
Abstract—Heterolytic fragmentation of homoallylic alcohols incorporated in a bicyclo[2,2,1]heptane system with electrophilic reagents or that of the corresponding epoxides with acids, is described. A short route, *via* this fragmentation, to synthon **25**, potentially useful in the syntheses of *cis*-jasamone and prostanoids, is reported.

Heterolytic fragmentations of Y–C–C–C–X, where X and Y are nucleofuge and electrofuge respectively, to –C=C– and Y^+=C moieties have been extensively studied[1] and frequently made use of in organic synthesis.[2] We wish to report a related yet novel cleavage of homoallylic alcohols incorporated in a bicyclo[2,2,1]heptane system under conditions of electrophilic additions or acid-catalysed ring-opening of the corresponding epoxides. In generalised terms, this fragmentation can be depicted as follows:



The reaction differs from Grob fragmentations[1] in producing allylic halides or alcohols, instead of olefins and, in appropriate cases, this can be of distinct value for synthetic operations.[3]

The cleavage was first observed while studying the reactions of an isolongifolene derivative **1**[4] which on treatment with 1 molar equivalent of chlorine (5% soln in CCl_4) at 0° in presence of excess Li_2CO_3, yielded the allylic chloride **2** (IR: CHO 2720, 1730 cm^{-1}. PMR: CHCl, br sig, 4.56 ppm, W_H = 7 Hz; CHO, t, 9.78 ppm, J = 1.5 Hz), in almost quantitative yield. The compound was found to be labile and its properties could only be studied in CCl_4 soln, as attempts at its purification through distillation or chromatography led to decomposition. The stereochemistry of the C–Cl bond in **2** follows from the known propensity for *endo* attack (with reference to norbornyl part) in isolongifolene derivatives.[5] The configuration of the OH group was found to be inconsequential since the other epimer of **1** (5 - *endo* - hydroxyisolongifolene) fragmented with equal ease to give the same product **2**.



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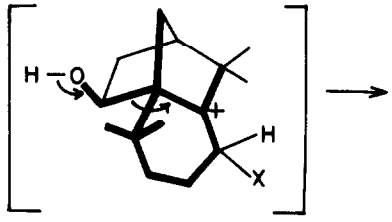

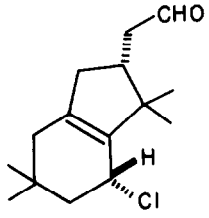

2

[a]MRC communication No. 28.
[b]Preliminary communication: *Tetrahedron Letters* 201 (1977).
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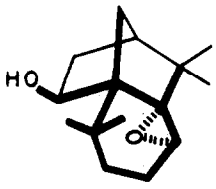

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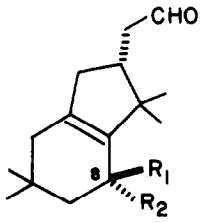
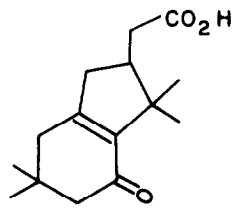


4: $R_1 = H$, $R_2 = OH$

5: $R_1 = OH$, $R_2 = H$



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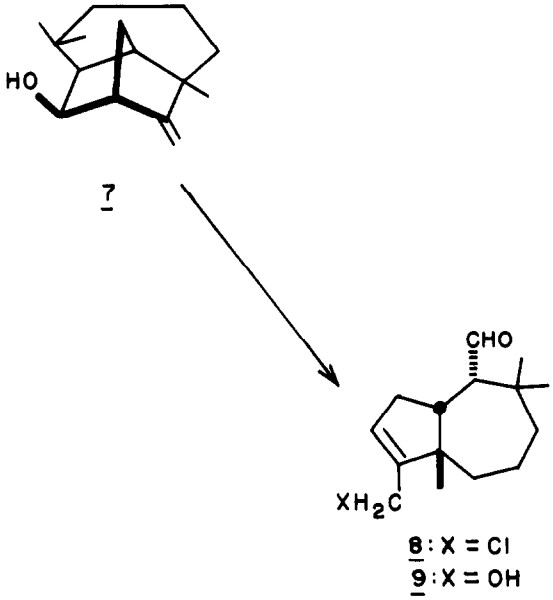
In an obvious extention of the above, epoxide **3** on exposure to 0.35% $HClO_4$ in 90% aqueous dioxane (10°, 15 min) furnished, in almost quantitative yield, a mixture of epimeric alcohols **4** (PMR: C$\underline{H}$OH, br sig, 4.21 ppm, $W_H = 9$ Hz; C$\underline{H}$O, t, 9.83 ppm, J = 1.5 Hz) and **5** (PMR: C$\underline{H}$OH, br sig, 4.04 ppm, $W_H = 8$ Hz; C$\underline{H}$O, t, 9.76 ppm, J = 1.5 Hz) in which **4** predominated. The formation of both isomers, rather than only **4**, is ascribed to acid-catalysed epimerisation (to some extent) at C-8 under the reaction conditions. The same epimeric mixture but in which now **5** predominates, is obtained by solvolysis (aq. dioxane, Li CO_3) of the chloroaldehyde **2**. The epimeric mixture of alcohols from both the reactions, on Jones' oxidation,[6] furnished the same keto acid **6** (λ_{max}^{EtOH} 250.5 nm, 15150). These transformations also serve to further support the structures of the fragmentation products **2** and **4**/**5**.

Another homoallylic alcohol **7**[7] (m.p. 171.5–172.5°) on exposure to Cl_2 yielded (~90%) the expected chloroaldehyde **8** (IR: CHO 2705, 1705 cm^{-1}. PMR: C$\underline{H}_2$Cl, brs, 4.01 ppm; C–C$\underline{H}$, brs, 5.72 ppm, $W_H = 9$ Hz; C$\underline{H}$O, d, 9.80 ppm, J = 4 Hz) while the derived epoxide on acid cleavage furnished (~95%) the anticipated hydroxyaldehyde **9** (PMR: C$\underline{H}_2$OH, brs, 4.14 ppm; C=C$\underline{H}$, bs, 5.50 ppm, $W_H = 7$ Hz; C$\underline{H}$O, d, 9.91 ppm, J = 4 Hz).



7

8: X = Cl

9: X = OH

In both of the systems studied above, the moiety undergoing fragmentation forms a part of a 6-hydroxycamphene nucleus. Hence, the rest of the study, aimed at delineating the scope of the reaction, was carried out with 6-hydroxycamphene itself. Fragmentation of 6-hydroxycamphene[8] **10** took place in high yields with various electrophilic reagents (Table 1). The tertiary alcohol **12** and cyanohydrin **13** were found to be equally amenable to cleavage.

The fragmentation discussed above, appears to be well-suited for the synthesis of certain substituted cyclopentanes which can serve as synthons for several cyclopentane-containing natural products. With a view to exploring this possibility, the fragmentation of 5-norbornen-2-ol[12] **23** was investigated. Reaction of **23** with Cl_2 or Br_2 led to a complex mixture of products but, gratifyingly, its treatment with mercuric acetate or mercuric trifluoroacetate directly gave lactol **25**.[14] The latter could be potentially useful for the syntheses of *cis*-jasamone[15] and some prostaglandin intermediates.[16,17] The structure of lactol **25** was further secured by its oxidation to the known lactone **26**.[18]

EXPERIMENTAL

All m.ps and b.ps are uncorrected. Light petroleum refers to the fraction b.p. 60–80°. All solvent extracts were finally washed with brine and dried (Na_2SO_4).

The following instruments were used for spectral/analytical data: Perkin–Elmer IR Spectrophotometer, model 267; Perkin–Elmer UV Spectrophotometer, model 402; Perkin–Elmer model R32 (90 MHz) PMR Spectrometer; Varian Mat CH7 Mass spectrometer (70 eV, direct inlet system); Hewlett–Packard 5712 A and 7624 A gas chromatographs (Al columns, 180 × 0.6 cm; support, 60–80 mesh chromosorb W; carrier gas, H_2). All PMR spectra were taken in 15–20% soln in CCl_4 (unless stated to the contrary) with TMS as internal reference; signals are reported in ppm (δ); while citing PMR data, the following abbreviations have been used: s, singlet; d, doublet; t, triplet, m, multiplet; sig, signal; br, broad. While summarising mass spectral data, besides the molecular ion, the nine most abundant ions (*m/e*) are reported with their relative intensities.

Silica gel for chromatography (−100 + 200 mesh) was washed with hot water till sulphate-free, dried and activated at 125–130° for 6 hr and standardised.[18] Tlc was carried out on SiO_2-gel layers (0.25 mm) containing 15% gypsum and activated at 110–115° (2 hr).

Reaction of 5-exo-hydroxyisolongifolene **1** *with* Cl_2. To a cooled soln (−5 ± 2°) of **1**[4] (0.66 g, 3 mmol) in CCl_4 (20 ml) containing Li_2CO_3 (0.61 g, 9 mmol) was introduced a cold soln of Cl_2 (4.2%, 5 ml ≡ 0.21 g of Cl_2, 3 mmol) over 5 min. The yellow colour of Cl_2 was discharged immediately after addition of Cl_2 was over. Li_2CO_3 was then filtered off and washed with CCl_4 (2 ml × 2). The solvent was removed at 10 ± 2° under reduced pressure to give a residue (0.78 g) of **2**. IR: CHO 2720, 1730 cm^{-1}; C=C 1650 cm^{-1}. PMR: C-Me's (singlets at 0.99, 1.0, 1.01 and 1.03 ppm), C$\underline{H}$Cl

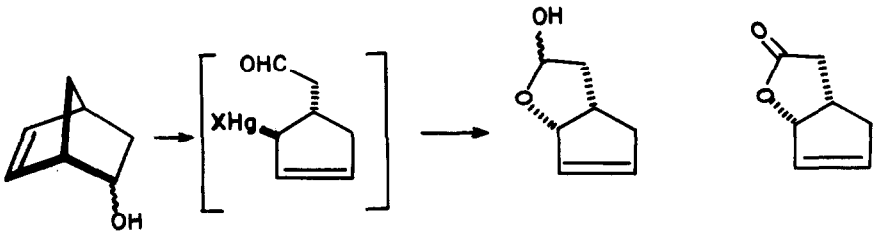
Table 1. Fragmentation of 6-hydroxycamphene derivatives

Entry	Substrate	Electrophilic reagent	Product	Yield %	Isolated* as
1	10: R_1=OH, R_2=H	Cl_2	14: R-H, X=Cl	>95	21†: R=H
2	10	Br_2	15: R=H, X=Br	95	21†
3	10	BrN_3	15	95	21†
4	10	$Hg(OAc)_2$	16: R=H, X=Hg(OAc)	95	21†
5	11: R_1=H, R_2=OH	$Hg(OAc)_2$	16	95	21†
6	12: R_1=Me, R_2=OH	ICl	17: R=Me, X=I	85	22§: R=Me
7	12	Br_2	18: R=Me, X=Br	>90	22§
8	12	$Hg(OAc)_2$	19: R=Me, X=Hg(OAc)	>95	
9	13: R_1=CN, R=OH	Br_2	20: R = CN, X=Br	90	21†

*The fragmentation product was reduced, without purification, with $NaBH_4$/LAH

†Identical with α-campholenic alcohol[9,10]

§The mixture of alcohols obtained was oxidised to a single ketone: 1-(2',2',3'-trimethylcyclopent-3'-en-1'-yl)-propan-2-one[11]



22 23: X = OAc, $OCOCF_3$ 24 25

(1H, br sig, 4.56 ppm, W_H = 7 Hz), CHO (1H, t, 9.78 ppm, J = 1.5 Hz).

5-endo-*Hydroxyisolongifolene and its fragmentation with* Cl_2. To a stirred slurry of LAH (300 mg) in ether (30 ml) was added dropwise, a soln of 5-*oxo*-isolongifolene[20] (1.2 g) in ether (25 ml). After usual work-up, the residue was chromatographed over SiO_2-gel (IIB, 1.5 cm × 45 cm): (i) 1:1 C_6H_6-light petroleum, 25 ml × 3, 950 mg (ii) 1:1 C_6H_6-light petroleum, 25 ml, 31 mg, mixture (iii) C_6H_6, 25 ml × 2, 100 mg, solid m.p. 82–85°, characterised as 1. Frac. (i) was distilled to give pure 5-*endo*-hydroxyisolongifolene (900 mg) which crystallised on standing, m.p. 48.5–49.5°. IR (liq. film): OH 3455, 1120, 1080 cm^{-1}; C=CH 870, 840 cm^{-1}. PMR: C-Me's (singlets at 0.79, 0.99, 1.03 and 1.11 ppm), CHOH (1H, dd, 4.05 ppm, J_1 = 8.5 Hz, J_2 = 3 Hz), C = CH (1H, t, 5.56 ppm, J = 3.5 Hz). (Found: C, 81.49; H, 10.59. $C_{15}H_{24}O$ requires: C, 81.76; H, 10.98%).

5-*endo*-Hydroxyisolongifolene (200 mg) was treated with Cl_2 soln in CCl_4 (4.2%, 1.25 ml) to give a product (210 mg) which was identical with 2 (IR, PMR).

Solvolysis of chlroaldehyde 2. The chloroaldehyde 2 (650 mg) was stirred (N_2, 3 hr) with Li_2CO_3 (580 mg) in 50% dioxane aq (20 ml) at 40 ± 1°. The contents were cooled to room temp. Li_2CO_3 was filtered and washed with ether (10 ml × 2). The filtrate was diluted with water (20 ml) and extracted with ether (10 ml × 3). The ether layer was washed, dried and concentrated to give a residue (613 mg) which was chromatographed over SiO_2-gel (IIIB, 1.0 cm × 25.0 cm). After elution with C_6H_6 (25 ml × 3) the column was eluted with 5% EtOAc in C_6H_6 (25 ml × 4) to give a mixture (434 mg) of alcohols 4 and 5 with the latter predominating. PMR: C-Me's (3H singlets at 0.79, 0.89, 1.05 and 1.13 ppm), CHOH (1H, br sig, 4.04 ppm, W_H = 8 Hz), CHO (1H, t, 9.76 ppm, J = 1.5 Hz).

Oxidation of **4/5** *to keto acid* **6**. The mixture of alcohols (**4/5**) obtained above (180 mg) was dissolved in acetone (1 ml), cooled (0°), and treated with Jones' reagent (0.5 ml). After stirring (0°) for 1 hr, the mixture was worked-up to give a solid residue (170 mg) which was crystallised from CH_3CN to give **6**, m.p. 162–164°. IR: C=O 1725, 1705 cm^{-1}. PMR: C-Me's (3H singlets at 0.96, 1.12, 1.18 and 1.28 ppm). UV (EtOH): λ_{max} 250.5 nm (ϵ 15150). (Found: C, 71.74; H, 8.87. $C_{15}H_{22}O_3$ requires: C, 71.97; H, 8.86%).

Epoxidation of **1**. To a soln of 5-*exo*-hydroxyisolongifolene **1** (490 mg) in 20% toluene in C_6H_6 (5 ml), cooled to 25°, was added a soln of perbenzoic acid (420 mg) in C_6H_6 (5 ml). The contents were set aside at $-5 \pm 1°$ for 48 hr. The mixture was diluted with ether (15 ml) and washed with 5% $NaHCO_3$ aq (10 ml × 3) and 10% $NaHSO_3$ aq (10 ml). After work-up, the residue was crystallised from light petroleum to yield **3** (400 mg), m.p. 102–103°. IR ($CHCl_3$): OH 3610, 3495, 1040 cm^{-1}; oxirane ring 3045, 1220, 880 cm^{-1}. PMR ($CDCl_3$): C-Me's (3H singlets at 0.68, 0.94, 1.03 and 1.10 ppm), CHOC (1H, t, 3.12 ppm, J = 4 Hz), CHOH (1H, ddd, 4.21 ppm, J_1 = 1.5 Hz, J_2 = 3 Hz, J_3 = 6.5 Hz). (Found: C, 75.94; H, 10.09. $C_{15}H_{24}O_2$ requires: 76.22; H, 10.24%).

Action of $HClO_4$ *on epoxide* **3**. To a soln of $HClO_4$ (0.35%) in 90% dioxane aq (10 ml) at 10° was added **3** (315 mg) in one lot. The contents were stirred at the same temp for 15 min and basified with 5% $NaHCO_3$ aq (15 ml). After dilution with water (30 ml), the mixture was extracted with ether (15 ml × 3). Work-up of the ether extracts gave a residue consisting of a mixture of **4** and **5** in which **4** predominated. IR ($CHCl_3$): CHO 2705, 1720 cm^{-1}; OH 3440, 1020 cm^{-1}. PMR ($CDCl_3$): C-Me's (3H singlets at 0.94, 0.97, 0.97 and 1.00 ppm), CHOH (1H, br sig, 4.21 ppm, W_H = 9 Hz), CHO (1H, t, 9.83 ppm, J = 1.5 Hz).

The oxidation of mixture of alcohols (**4, 5**) obtained above with Jones' reagent gave a product identical with **6** (*vide supra*).

Reaction of **7** *with* Cl_2. A soln of **7** (220 mg) in $CHCl_3$ (2 ml) was treated with Cl_2 in CCl_4 (3.6%, 2 ml) in the presence of Li_2CO_3 (210 mg) at −2°. Usual work-up provided **8** (235 mg). IR ($CHCl_3$): CHO 2705, 1705 cm^{-1}. PMR: C-Me's (singlets at 0.97, 1.05 and 1.28 ppm), CH_2Cl (2H, brs, 4.01 ppm, W_H = 5 Hz), C=CH (1H, br sig, 5.72 ppm, W_H = 9 Hz), CHO (1H, d, 9.80 ppm, J = 4 Hz).

Fragmentation of epoxide derived from **7**. The homoallylic alcohol **7** was treated with perbenzoic in toluene–benzene mixture (−5°, 100 hr) to give the corresponding epoxide. PMR: C-Me's (singlets at 0.89 and 1.08 ppm), oxirane CH_2 (1H, d, 2.23 ppm; 1H, d, 2.44 ppm; J = 5 Hz), CHOH (1H, d, 4.07 ppm, J = 6 Hz).

The above epoxide on treatment with 0.35% $HClO_4$ in 90% dioxane aq (5 ml) at 10° for 15 min gave **9**. PMR ($CDCl_3$): C-Me's (3H singlets at 0.97, 1.05 and 1.13 ppm), CH_2OH (2H, brs, 4.14 ppm, W_H = 6 Hz) C=CH (1H, br sig, 5.50 ppm, W_H = 7 Hz), CHO (1H, d, 9.91 ppm, J = 4 Hz).

Fragmentation of 6-*hydroxycamphene* **10**

(i) *With* Cl_2. A soln of **10**[8] (540 mg) in CCl_4 (10 ml) containing Li_2CO_3 (500 mg) on treatment with Cl_2 soln (4.2%, 6 ml) and work-up gave **14** (~635 mg). IR (CCl_4): CHO 2710, 1725 cm^{-1}; C=CH 885, 700 cm^{-1}. PMR: C-Me's (3H singlets at 0.92 and 1.12 ppm), CH_2Cl (2H, brs, 4.04 ppm, W_H = 4 Hz), C=CH (1H, br sig, 5.76 ppm, W_H = 6 Hz), CHO (1H, t, 9.75 ppm, J = 1.5 Hz).

Compound **14**, obtained above (350 mg) in THF (10 ml) was added dropwise to a stirred slurry of LAH (250 mg) in THF (10 ml) and stirred at ambient temp ($30 \pm 1°$) for 36 hr. Usual work-up gave a residue (300 mg) which was distilled to give **21**,[9,10] b.p. 110–115° (bath)/2.5 mm; n_D^{25} 1.4678. IR (liq. film): OH 3340, 1050 cm^{-1}; C=CH 800 cm^{-1}. PMR: C-Me's (3H singlets at 0.76 and 0.97 ppm), C=C-Me (3H, brs 1.61 ppm), CH_2OH (2H, m, 3.59 ppm), C=CH (1H, br sig, 5.20 ppm, W_H = 8 Hz) (lit.[9] IR: PMR).

(ii) *With* Br_2/BrN_3. Treatment of **10** (1 mmol) with either Br_2 (1 mmol) in CCl_4 or BrN_3 (1 mmol) in CH_2Cl_2 in presence of Li_2CO_3 (3 mmol) at $-5 \pm 2°$ gave almost quantitative yield of **15**. IR: CHO 2710, 1725 cm^{-1}; C=C 1650 cm^{-1}. PMR: C-Me's (3H singlets at 0.92 and 1.12 ppm), CH_2Br (2H, s, 3.92 ppm), C=CH (1H, br sig, 5.80 ppm, W_H = 6 Hz), CHO (1H, t, 9.72 ppm, J = 1.5 Hz).

Compound **15** on reduction with LAH gave α-campholenic alcohol **21**.

(iii) *With* $Hg(OAc)_2$. To a soln of $Hg(OAc)_2$ (318 mg, 1 mmol) in water (5 ml) and THF (2.5 ml) was added a soln of **10** (152 mg, 1 mmol) in THF (2.5 ml). The mixture was stirred at ambient temp (~30°) for 1 hr. The organomercurial acetate was reduced, without isolation, by stirring with 3N NaOH aq (5 ml) and 0.5 M $NaBH_4$ in 3N NaOH (5 ml) for 2 hr at ambient temp. (~30°). The mixture was extracted with ether (20 ml × 3). The combined ether extracts were washed with brine (5 ml), dried and solvent was distilled off. The residue was distilled to get **21** (150 mg, ~100%).

The *endo*-alcohol[8] **11** on similar treatment gave the same product (>95%).

6 - exo - *Methyl* - 6 - endo - *hydroxycamphene* **12**. A soln of 6-ketocamphene[8] (0.45 g, 3 mmol) in ether (10 ml) was added dropwise to a cooled (0–5°) soln of Grignard reagent, prepared from Mg turnings (0.15 g, 0.006 g atom) and CH_3I (0.85 g, 6 mmol) in ether. The reaction mixture was stirred at room temp (30°) for 4 hr and subsequently refluxed for 1 hr. It was then decomposed with a soln of NH_4Cl aq. Usual work up gave a residue which was distilled to give **12** (0.4 g, 81%), b.p. 120° (bath)/5 mm. IR (liq. film): OH 3530, 3480, 1060 cm^{-1}; $C=CH_2$ 1640, 940 cm^{-1}. PMR ($CDCl_3$): C-Me's (6H, s, 1.11 ppm), $-C(OH)CH_3$ (3H, s, 1.34 ppm) CH-C=CH_2 (1H, brs, 2.45 ppm, W_H = 4 Hz), C=CH_2 (2H, s, 4.98 ppm). Mass: *m/e* 166 (M^+, 2.5%), 151 (4%), 133 (4%), 123 (7%), 108 (100%), 107 (20%), 93 (52%), 91 (14%), 81 (8.5%) and 44 (35%). (Found: C, 79.21; H, 10.97. $C_{11}H_{18}O$ requires: C, 79.52; H, 10.84%).

Fragmentation of **12**

(i) *With* Br_2. A soln of **12** (0.1 g, 0.6 mmol) in CCl_4 (2 ml) was treated in presence of Na_2CO_3 (0.1 g) with a soln of Br_2 (0.096 g, 0.6 mmol) in CCl_4 at −5°. Usual work-up gave **18** which without isolation was dissolved in ether (10 ml) and treated with LAH (30 mg). The mixture was stirred at room temp (~30°) for 5 hr. Work-up and removal of solvent gave a residue which was distilled to give **22** (90 mg, 90%), b.p. 90°(bath)/5 mm. IR (liq. film): OH 3360 cm^{-1}, C=C 1645, 970 cm^{-1}. PMR ($CDCl_3$): C-Me's (3H singlets at 0.78 and 1.0 ppm), $C(OH)CH_3$ (3H doublets at 1.21 and 1.25 ppm, J = 6 Hz), C=C-CH_3 (3H singlets at 1.62 and 1.63 ppm), CHOH (1H, m, 3.7–4.06 ppm), HC=C (1H, brs, 5.28 ppm, W_H = 6 Hz). Mass: *m/e* 168 (M^+, 14%), 135 (28%), 120 (9%), 107 (100%), 93 (57%) and 91 (51%). (Found: C, 78.90; H, 12.11. $C_{11}H_{20}O$ requires: C, 78.57; H, 11.91%).

Oxidation of **22** *to* 1 - (2',2',3' - *trimethylcyclopent* - 3' - *en* - 1' - *yl*)*propan* - 2 - *one*

To a complex prepared[21] from CrO_3 (0.182 g, 1.8 mmol) and pyridine (1.8 lm) was added a soln of mixture of alcohols **22** (0.078 g, 0.5 mmol) in pyridine (0.45 ml) and stirred at room temp (~30°) for 24 hr. Usual work-up and distillation of the residue gave the title ketone (0.066 g, 85%), b.p. 90°(bath)/3.5 mm (lit. [11] b.p. 81–82.5/6 mm). IR (liq. film): C=O 1710 cm^{-1}. PMR: C-Me's (3H singlets at 0.78 and 1.0 ppm), C=C-CH_3 (3H, s, 1.62 ppm), $COCH_3$ (3H, s, 2.1 ppm), CH=C (1H, brs, 5.24 ppm, W_H = 6 Hz) (lit.[11] IR, PMR). Mass: *m/e* 166 (M^+, 6.4%), 123 (8.5%), 108 (100%), 93 (66%), 80 (30%) and 43 (74%). (Found: C, 79.38; H, 10.69. $C_{11}H_{18}O$ requires: C, 79.52; H, 10.84.)

(ii) *With* ICl. Treatment of **12** (100 ml) with ICl (98 mg) gave a product **17** which was too unstable and was immediately reduced with LAH to **22**.

(iii) *With* $Hg(OAc)_2$. To a soln of **12** (0.106 g, 0.64 mmol) in THF–H_2O (1:1, 5 ml) was added $Hg(OAc)_2$ (0.204 g, 0.64 mmol) and the reaction mixture was stirred at 20° for 5 hr. Usual work-up after dilution with water gave a gummy residue which was crystallised from light petroleum to give **19** (0.26 g, 98%), m.p. 104–106°. IR ($CHCl_3$): C=O 1705 cm^{-1}; Hg(OAc) 1600 cm^{-1}. PMR ($CDCl_3$): C-Me's (3H singlets at 0.92 and 1.12 ppm) Hg(OCO CH_3) (3H, s, 2.02 ppm), $COCH_3$ (3H, s, 2.15 ppm) C=CH (1H, brs, 5.4 ppm).

6 - exo - *Cyano* - 6 - endo - *hydroxycamphene* **13**. A mixture of 6-ketocamphene[8] (0.396 g, 2.7 mmol), acetone cyanohydrin (1.125 g, 13.2 mmol) and a drop of 10% K_2CO_3 aq was stirred at room temp (30°) for 2 hr. The mixture was poured in water and extracted with light petroleum (10 ml × 3). The combined petrol

extracts were washed and dried. The residue was chromatographed over SiO_2-gel (1.2 cm × 18.0 cm). After elution with $CHCl_3$, the column was eluted with EtOAc–$CHCl_3$ (1:9, 20 ml). The removal of solvents from the eluate provided **13** as a colourless oil (0.371 g, 80%), b.p. 150–155°(bath)/2.5 mm. IR (CCl_4): OH 3580, 3420, 1110 cm^{-1}; C≡N 2240 cm^{-1}; C=CH_2 1660, 900 cm^{-1}. PMR ($CDCl_3$): C-Me's (6H, s, 1.12 ppm), C<u>H</u>-C=C (1H, brs, 2.85 ppm, W_H = 4 Hz), C=C<u>H</u>$_2$ (1H, singlets at 4.98 and 5.21 ppm), Mass: *m/e* 177 (M^+, 8%), 162 (8%), 121 (21%), 118 (100%), 93 (91%), 79 (12%) and 77 (17%). (Found: C, 74.81; H, 8.19; N, 7.62. $C_{11}H_{15}NO$ requires: C, 74.57; H, 8.47; N, 7.91%).

Fragmentation of **13**. Treatment of **13** with Br_2 (1 mol eq.) followed by reduction with LAH gave **21**.

Cleavage of norborn - 4 - en - 2 - ol. A soln of norborn - 5 - en - 2 - ol[12] (2.0 g, 18.2 mmol) in THF aq (1:1, 50 ml) was cooled to 20° and $Hg(OAc)_2$ (5.8 g, 18.2 mmol) was added in portions over 20 min. Stirring at 20° was continued for 5 hr. The mixture was diluted with water (50 ml) and worked-up to give a viscous liquid (1.99 g) which was chromatographed over Al_2O_3 (II, 2.5 cm × 19 cm); (i) 0.5% MeOH in $CHCl_3$, 10 ml × 10, 60 mg, mixture; (ii) 1% MeOH in $CHCl_3$, 15 ml × 15, 1.05 g. Frac. (ii) was distilled to furnish **25** (1.05 g, 45%), b.p. 120–125°/5 mm. IR (liq. film): OH 3400, 1070 cm^{-1}; C=C 1625, 895 cm^{-1}. PMR ($CDCl_3$): C<u>H</u>OC (1H, m, 5.15–5.38 ppm), C<u>H</u>OH (1H, m, 5.43–5.63 ppm), C<u>H</u>=C<u>H</u> (2H, m, 5.72–5.98 ppm). Mass: *m/e* 126 (M^+, 1.3%), 125 (3%), 108 (13%), 80 (100%), 79 (91%), 70 (13%), 66 (28%), 57 (12%), 55 (16%) and 41 (25%). (Found: C, 66.73; H, 8.00. $C_7H_{10}O_2$ requires: C, 66.67; H, 7.94%).

Oxidaion of lactol **25**. A soln of the lactol **25** (75 mg, 0.6 mmol) in annhydrous CH_2Cl_2 (4 ml) was added in one lot to a suspension of pyridinium chlorochromate[22] (257 mg, 1.2 mmol) in CH_2Cl_2 (4 ml) and the contents were stirred (~28°) for 1.5 hr. Anhyd ether (20 ml) was then added and the supernatant liquid was decanted from the black gummy residue. The latter was washed with ether (10 ml × 3). The combined ether extracts were passed through a small bed of deactivated Al_2O_3. Removal of solvent followed by distillation gave **26** (47 mg, 64%). b.p. 120–5° (bath)/5 mm (lit.[18] b.p. 95–100°/4 mm). IR (CCl_4): γ-lactone 1770 cm^{-1}. PMR: C<u>H</u>-O- (1H, dd, 5.45 ppm, J_1 = 6.5 Hz, J_2 = 1.5 Hz), C=C<u>H</u>-CH_2 (1H, m, 5.82–5.95 ppm), C=C<u>H</u>-CHO- (1H, m, 6.01–6.17 ppm) (lit.[23] PMR).

REFERENCES

[1]See *e.g.*: P. S. Wharton and G. A. Hiegel, *J. Org. Chem.* **30**, 3254 (1965); G. Ohloff, J. Becker, K. H. Schulte-Elte, *Helv. Chim. Acta* **50**, 705 (1967); C. A. Grob and P. W. Schiess, *Angew. Chem. Int. Ed.* **6**, 1 (1967); W. Kraus and W. Rothenwohrer, *Tetrahedron Letters* 1007, 1013 (1968); P. G. Gassman and J. M. Hornback, *J. Am. Chem. Soc.* **91**, 5817 (1969); C. A. Grob, *Angew. Chem. Int. Ed.* **8**, 535 (1969); J. A. Marshall, *Synthesis* **5**, 229 (1971); J. A. Marshall and J. L. Belletire, *Tetrahedron Letters* 871 (1971); C. A. Grob, B. Schmitz, A. Sutter and A. H. Weber, *Ibid.* 3551 (1975); A. Fischli, Q. Branca and J. Daly, *Helv. Chim. Acta* **59**, 2443 (1976); H. D. House and V. L. Thomas, *J. Org. Chem.* **44**, 2819 (1979); H. C. Brown, G. L. Buchanan and J. O'Donnell, *J. Chem. Soc. Perkin I* 1740 (1979); L. F. Tietze, G. Kinast and H. C. Uzar, *Angew. Chem. Int. Ed.* **18**, 541 (1979); L. F. Tietze and U. Reichert, *Ibid.* **19**, 830 (1980).

[2]*Inter alia* see: E. J. Corey, R. B. Mitra and H. Uda, *J. Am. Chem. Soc.* **86**, 485 (1964); R. Zurfluh, E. N. Wall, J. B. Siddall and J. A. Edwards, *Ibid.* **90**, 6224 (1968); S. Julia and G. Linstrumelle, *Bull. Soc. Chim. Fr.* 3490 (1966); K. Sisido, S. Kurozumi and K. Utimoto, *J. Org. Chem.* **34**, 2661 (1969); B. D. Challand, H. Hikino, G. Kornis, G. Lange and P. deMayo, *Ibid.* **34**, 794 (1969); J. E. McMurray and S. J. Isser, *J. Am. Chem. Soc.* **94**, 7132 (1972); G. Stork, T. M. Tabak and J. Blount, *Ibid.* **94**, 4735 (1972); K. P. Dastur, *Ibid.* **96**, 2605 (1974); G. Mehta and S. K. Kapoor, *J. Org. Chem.* **35**, 2618 (1974); G. Kinast and L. F. Tietze, *Chem. Ber.* **109**, 3626 (1976); B. M. Trost, M. J. Bogdanowicz, W. J. Frazee and T. N. Salzmann, *J. Am. Chem. Soc.* **100**, 5512 (1978); T. Kalya, N. Shirai and J. Sakakibara, *J. Chem. Soc. Chem. Comm.* 431 (1979); D. Sternbach, M. Shibuya, F. Jaisli, M. Bonetti and A. Eschenmoser, *Angew. Chem. Int. Ed.* **18**, 636 (1979).

[3]J. S. Yadav, H. P. S. Chawla and Sukh Dev, *Tetrahedron Letters* 1149 (1977).

[4]E. H. Eschinasi, G. W. Shaffer and A. P. Bartels, *Ibid.* 3523 (1970).

[5]J. A. McMillan, I. C. Paul, U. R. Nayak and Sukh Dev, *Ibid.* 419 (1974).

[6]R. G. Curtis, I. Heilbron, E. R. H. Jones and G. F. Woods, *J. Chem. Soc.* 457 (1953).

[7]This compound has been synthesised from longicyclene; the details will be reported elsewhere.

[8]M. Gaitonde, P. A. Vatakenchery and Sukh Dev, *Tetrahedron Letters* 2007 (1964); Also see: M. Julia, D. Mansuy and P. Detraz, *Ibid.* 2141 (1976); N. Darby, N. Lamb and T. Money, *Can. J. Chem.* **57**, 742 (1979).

[9]V. S. Joshi, N. P. Damodaran and Sukh Dev, *Tetrahedron* **24**, 5817 (1968).

[10]A. F. Thomas, *Helv. Chim. Acta* **55**, 815 (1972).

[11]The ketone serves as a synthon for a group of juvenile hormone analogues; A. Siewinski, J. Dmochowska-Gladysz, T. Kolch, A. Zabra and K. Derdzinski, *Tetrahedron* **35**, 1409 (1979).

[12]A mixture of *exo* and *endo* isomers (1:3) was used for fragmentation. This mixture was prepared by saponification of the corresponding acetates obtained by a modification of a known procedure.[13] Instead of cyclopentadiene monomer, commercially available dicyclopentadiene itself was used (for Diels–Alder reaction with vinyl acetate) resulting in ~10% inprovement in the overall yield. The mixture of alcohols **23** is also available from Aldrich Chemical Co.

[13]D. A. Lightner and W. A. Beavers, *J. Am. Chem. Soc.* **93**, 2677 (1971).

[14]The allylic mercuric acetate/trifluoroacetate **24** undergoes facile solvolytic "demercuration" under the experimental conditions; see, e.g. P. D. Sleezer, S. Winstein and W. G. Young, *J. Am. Chem. Soc.* **85**, 1890 (1963).

[15]See *e.g.*: P. A. Grieco, *J. Org. Chem.* **37**, 2363 (1972). Also see: E. J. Corey, Z. Arnold and J. Hutton, *Tetrahedron Letters* 307 (1970).

[16]See *e.g.* P. A. Grieco and J. J. Reap, *J. Org. Chem.* **38**, 3413 (1973).

[17]See e.g.: W. Bartmann, G. Beck and U. Lerch, *Tetrahedron Letters* 2441 (1974); L .Novak, J. Rohaly, C. Szantay and M. Kajtar, *Acta Chim Acad. Sci. Hung.* **102**, 91 (1979); *Chem. Abstr.* **93**, 7691 (1980).

[18]J. Meinwald and B. C. Cadoff, *J. Org. Chem.* **27**, 1539 (1962).

[19]R. Hernandez, R. Hernandez Jr. and L. R. Axelrod, *Analyt. Chem.* **13**, 370 (1961).

[20]J. S. Yadav, U. R. Nayak and Sukh Dev, *Tetrahedron* **36**, 309 (1980).

[21]J. C. Collins, W. W. Hess and F. J. Frank, *Tetrahedron Letters* 3363 (1968); R. Ratcliffe and R. Rodehorst, *J. Org. Chem.* **35**, 4000 (1970).

[22]E. J. Corey and J. W. Suggs, *Tetrahedron Letters* 2647 (1975).

[23]T. K. Dasgupta, D. Felix, U. M. Kempe and A. Eschenmoser, *Helv. Chim. Acta* **55**, 2198 (1972).