

## Diterpenes. Part XI.<sup>1</sup> Iodocarboxylations of Phyllocladene (8 $\beta$ ,13 $\beta$ -Kaur-16-ene) and Isophyllocladene (8 $\beta$ ,13 $\beta$ -Kaur-15-ene)

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16-Acetoxy-17-iodo- (15) and 17-acetoxy-16-hydroxy-8 $\beta$ ,13 $\beta$ -kaurane (16) have been isolated from the reaction of phyllocladene (8 $\beta$ ,13 $\beta$ -kaur-16-ene) (1) with thallium(i) acetate-iodine, and 17-iodo-8 $\beta$ ,13 $\beta$ -kaur-15-ene (10) has been obtained from the reaction with thallium(i) tosylate. Treatment of phyllocladene or isophyllocladene (8 $\beta$ ,13 $\beta$ -kaur-15-ene) (6) with thallium(i) benzoate-iodine gives 8 $\beta$ ,13 $\beta$ -kaur-15-en-17-yl benzoate (7) and 8 $\beta$ ,13 $\beta$ -kaur-16-en-15 $\alpha$ -yl benzoate (2), which are also obtained using silver benzoate-iodine. Formation of the products is discussed and an S<sub>N</sub>2' type mechanism is proposed for the solvolysis of the allylic iodide (10) with thallium(i) acetate.

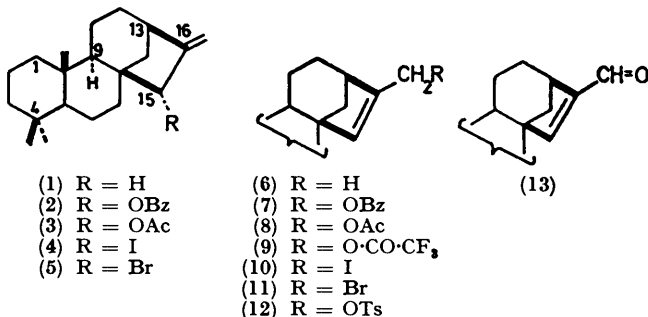
In a previous paper we reported<sup>2</sup> that treatment of either phyllocladene (8 $\beta$ ,13 $\beta$ -kaur-16-ene) (1) or isophyllocladene (8 $\beta$ ,13 $\beta$ -kaur-15-ene) (6) with silver benzoate and iodine in dry benzene under the usual Prévost conditions<sup>3</sup> gave a single product, *viz.* the allylic benzoate (7). A re-investigation of this reaction has now shown that contrary to the earlier report, both phyllocladene and isophyllocladene consistently afford a mixture of the isomeric benzoates (7) and (2)<sup>4</sup> in a ratio of *ca.* 67 : 33. Treatment of phyllocladene or isophyllocladene with

† A mixture of the allylic acetates (8) and (3) could also be conveniently prepared by oxidation of either phyllocladene or isophyllocladene with freshly sublimed selenium dioxide in acetic acid-acetic anhydride. The aldehyde (13) was obtained<sup>2,6</sup> when an excess of selenium dioxide was used in the presence of water, while the ketone (14) was isolated<sup>7</sup> in low yield when the reaction was carried out in refluxing benzene. The allylic acetates (8) and (3) were also obtained from isophyllocladene in 56% yield in a ratio of 4 : 1 using the reagent, palladium(ii) chloride-copper(i) chloride-sodium acetate in acetic acid.<sup>8</sup>

<sup>1</sup> Part X, K. M. Baker, L. H. Briggs, J. G. St. C. Buchanan, R. C. Cambie, B. R. Davis, R. C. Hayward, G. A. S. Long, and P. S. Rutledge, *J.C.S. Perkin I*, 1972, 190.

<sup>2</sup> L. H. Briggs, B. F. Cain, R. C. Cambie, B. R. Davis, and P. S. Rutledge, *J. Chem. Soc.*, 1962, 1850.

silver acetate-iodine in benzene or moist acetic acid (Woodward-Prévost reaction<sup>5</sup>) also affords a mixture of the allylic acetates (8) and (3).†



<sup>3</sup> C. V. Wilson, *Org. Reactions*, 1957, **9**, 332.

<sup>4</sup> L. H. Briggs, B. F. Cain, R. C. Cambie, and B. R. Davis, *J. Chem. Soc.*, 1962, 1840.

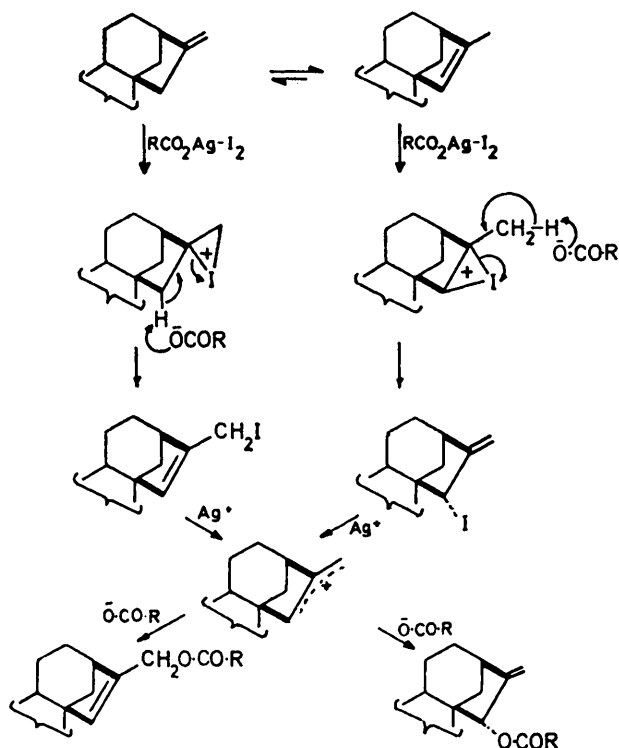
<sup>5</sup> R. B. Woodward and V. F. Brutter, *J. Amer. Chem. Soc.*, 1958, **80**, 209.

<sup>6</sup> R. Henderson and R. Hodges, *Tetrahedron*, 1960, **11**, 226.

<sup>7</sup> L. H. Briggs, R. C. Cambie, and D. W. Stanton, *Chem. and Ind.*, 1965, 515.

<sup>8</sup> W. C. Baird, *J. Org. Chem.*, 1966, **31**, 2411; R. Jira and W. Friessleben, *Organometallic Reactions*, 1970, **3**, 1.

Previously<sup>2</sup> it was suggested that the allylic esters might be formed by a free radical reaction. However, the results above suggest that they arise by heterolytic processes involving iodonium ions which undergo elimination and carbon-iodine bond cleavage as indicated in Scheme 1. Since the ratio of products from either



SCHEME 1

phyllocladene or isophyllocladene was the same a common intermediate is indicated. From a study of the products from 2-methylcholest-2-ene and 3-methylcholest-2-ene, Mangoni and Dovinola<sup>9</sup> have already rejected a free radical mechanism for the Prévost reaction.

In a preliminary communication<sup>10</sup> we reported that thallium(I) carboxylates may be used in place of silver carboxylates for the Prévost reaction. Treatment of phyllocladene or isophyllocladene with thallium(I) benzoate and iodine in a stoichiometric ratio of 1 : 2 : 1 at 20° gave a high yield of the allylic benzoates (7) and (2) in a ratio of 46 : 54.†

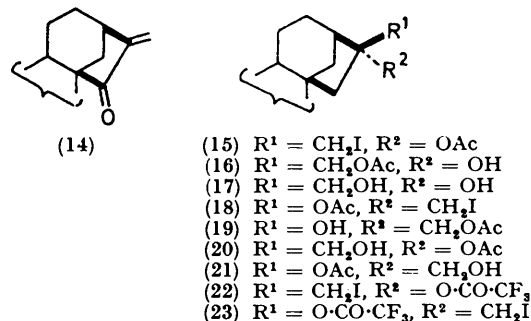
When thallium(I) benzoate was replaced by thallium(I) acetate the corresponding allylic acetates (8) and (3) were formed in yields of 50 and 40%, together with a trace of a third product. When isolated by preparative t.l.c., the latter was found to contain two compounds in 9 and <1% yield respectively. Both were of low stability but crystallisation gave the major component while the mother liquors afforded a fraction enriched in the

† When the reactants were heated under reflux for 1 h (conditions under which the products were stable) the yields of the benzoates (7) and (2) were changed to 31 and 69% respectively.

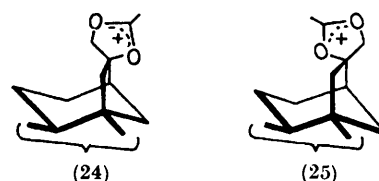
<sup>9</sup> L. Mangoni and V. Dovinola, *Gazzetta*, 1969, **99**, 176, 195.

<sup>10</sup> R. C. Cambie, R. C. Hayward, J. L. Roberts, and P. S. Rutledge, *J.C.S. Chem. Comm.*, 1973, 359.

minor component. The major product was identified as the iodoacetate (15) and its stereochemistry was assigned on the basis of its solvolysis with silver acetate in acetic acid to the  $\alpha$ -hydroxyacetate (16), identical with that obtained by monoacetylation of the *cis*-diol (17).<sup>4</sup>



The n.m.r. spectrum of the minor component showed two doublets at  $\delta$  3.57 and 3.97 ( $J$  10 Hz) [cf.  $\delta$  3.69 and 4.18 ( $J$  11 Hz) for (15)] due to protons on an iodine-substituted carbon atom, and the compound was tentatively assigned the structure (18). Solvolysis of the fraction enriched in (18) with silver acetate in wet acetic acid afforded the hydroxy-acetate (16) (30%) and a further hydroxy-acetate (45%) which was assigned the structure (19) on the basis of its spectral parameters. None of the expected isomeric hydroxy-acetates (20) and (21) were detected in the crude product. Formation of the hydroxy-acetates (16) and (19) is assumed to involve neighbouring group participation to give the 1,3-dioxolan-2-ylum<sup>11</sup> cations (24) and (25) which then undergo stereoselective hydrolysis.<sup>12</sup>



In contrast to the reaction of silver acetate-iodine with phyllocladene, that of thallium(I) acetate-iodine showed a marked solvent dependence (Table). Use of

Effect of solvents on product distribution *			
Solvent	(15) + (18) (%)	(8) (%)	(3) (%)
Silver acetate-I <sub>2</sub>			
CCl <sub>4</sub>	27	54	20
PhH	17	55	28
CHCl <sub>3</sub>	14	56	28
CH <sub>2</sub> Cl <sub>2</sub>	14	59	27
HOAc	25	50	25
Thallium(I) acetate-I <sub>2</sub>			
CCl <sub>4</sub>	0	35	65
PhH	10	40	50
CHCl <sub>3</sub>	8	32	60
CH <sub>2</sub> Cl <sub>2</sub>	15	30	55
HOAc	30	40	30

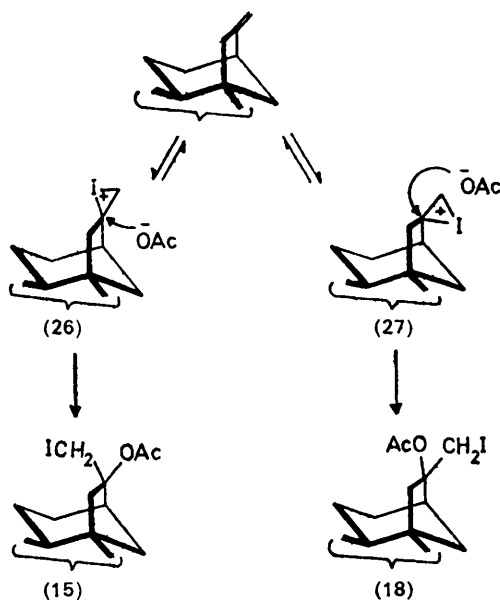
\* Relative percentages are estimated from analysis of the n.m.r. spectrum of the crude product.

<sup>11</sup> C. U. Pittman, S. P. McManus, and J. W. Larsen, *Chem. Rev.*, 1972, **72**, 357.

<sup>12</sup> J. F. King and A. D. Allbutt, *Canad. J. Chem.*, 1970, **48**, 1754.

solvents more polar than benzene not only greatly facilitated the reaction but also affected the product ratios. The solvent effects may be rationalised by assuming that the iodoacetates arise *via* an intermediate iodonium ion whose formation is aided by solvation by the more polar solvents.<sup>13</sup> In non-polar solvents such as carbon tetrachloride the allylic acetates (8) or (3) or their precursors are probably formed by a more concerted process.

Formation of both iodoacetates (15) and (18) was unexpected. Although alternative pathways can be envisaged, the most direct rationalisation of their formation is to invoke the intermediacy of  $\alpha$ - and  $\beta$ -iodonium ions \* which undergo nucleophilic attack as indicated in Scheme 2. Electrophilic attack on the double bond of



phyllocladene and subsequent nucleophilic attack on the iodonium ion would appear to have a measure of steric control.† Attack by  $I^+$  from the more hindered  $\beta$ -face would not be especially easy. However, this could be compensated by the ease of attack by  $^-OAc$  on the intermediate (26) and the difficulty of  $\beta$ -attack by  $^-OAc$  on the intermediate (27). Thus, although the product of kinetic control of nucleophilic attack, *viz.* (15), might be expected to predominate, significant quantities of the iodocarboxylate (18) could be formed due to the preponderance of the intermediate (27). Although iodoacetates corresponding to the iodoacetates (15) and (18) could not be detected from the reaction of thallium(I) benzoate–iodine with phyllocladene this was not because of steric factors since thallium(I) *p*-nitrobenzoate and thallium(I) trifluoroacetate gave iodo-*p*-nitrobenzo-

\* Cf. the formation of  $\alpha$ - and  $\beta$ -dihydro-derivatives of phyllocladene.<sup>14</sup>

† Cf. the suggestion of steric control for brominations of all phyllocladene and kaurene derivatives leading to dibromocompounds *via* bromonium ions.<sup>15</sup>

‡ Reaction of phyllocladene with silver trifluoroacetate–iodine afforded the iodotrifluoroacetates (22) and (23) as the only identified products.

ates and iodotrifluoroacetates respectively. In addition to the compounds (22) and (23) the latter reagent also afforded the allylic trifluoroacetate (9).‡ No evidence was obtained for the formation of iodoacetates from the reaction of isophyllocladene with thallium(I) acetate–iodine indicating that they are primary products from phyllocladene alone.

As indicated above, the allylic esters (8) and (3) probably arise *via* allylic iodides. Indeed, the formation of an allylic iodide was indicated when a more detailed t.l.c. investigation of the products from the action of thallium(I) acetate–iodine on phyllocladene revealed the presence of a further compound which was slightly more polar than the starting material and which was converted into the allylic acetates (8) and (3) when the reaction was heated or prolonged. We could not isolate the compound as it decomposed during work-up. However, treatment of either phyllocladene or isophyllocladene with thallium(I) tosylate<sup>16</sup>–iodine in dry dichloromethane gave a high yield of the allylic iodide (10). The latter was stable at 0° but decomposed at 20° when exposed to the atmosphere. Its stability was sufficient, however, to allow confirmation of its structure by an unambiguous synthesis from the allylic bromide (11)<sup>17</sup> by a Finkelstein reaction<sup>18</sup> using sodium iodide in anhydrous acetone. No reaction of phyllocladene occurred with thallium(I) tosylate–iodine in the less polar solvent carbon tetrachloride. However, reaction of phyllocladene with silver tosylate<sup>19</sup>–iodine in dry carbon tetrachloride gave the allylic tosylate as the sole product, while reaction in warm benzene gave the  $\alpha\beta$ -unsaturated aldehyde (13) in addition to unidentified non-polar compounds. Formation of the aldehyde (13) is not without precedent<sup>4</sup> but is unusual because its formation requires cleavage of a sulphur–oxygen bond. Formation of a single allylic iodide (10) from both phyllocladene and isophyllocladene is probably due to allylic rearrangement of the isomeric iodide (4) to the thermodynamically more stable isomer (10). Even so, although Mangoni and Dovinola<sup>9</sup> have postulated the intermediacy of more than one allylic iodide in the Prévost reaction with substituted steroidal alkenes, it would be unwise to generalise to other cases from the present example. Steric crowding of the C-15 position by the C-10 angular methyl group in phyllocladene derivatives may produce atypical results since processes such as migration or proton elimination which relieve this compression occur very readily.<sup>1,20,21</sup>

<sup>13</sup> A. Balsamo, P. Crotti, B. Macchia, and F. Macchia, *Tetrahedron*, 1973, **29**, 199; G. Heublein, *Angew. Chem. Internat. Edn.*, 1965, **4**, 881.

<sup>14</sup> L. H. Briggs, *J. Chem. Soc.*, 1937, **79**, 1035.

<sup>15</sup> F. Piozzi, G. Savona, and M. L. Marino, *Gazzetta*, 1973, **103**, 211.

<sup>16</sup> H. Gilman and R. K. Abbott, *J. Amer. Chem. Soc.*, 1943, **65**, 123.

<sup>17</sup> L. H. Briggs, R. C. Cambie, P. S. Rutledge, and D. W. Stanton, *J. Chem. Soc.*, 1965, 6212.

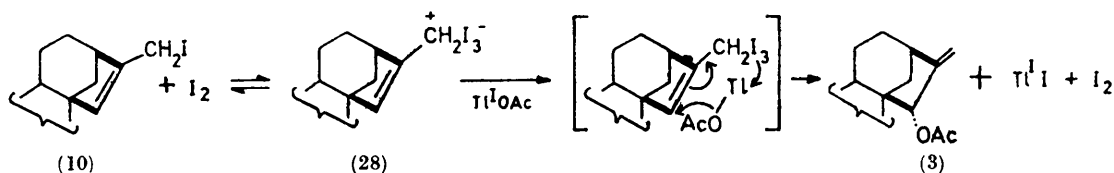
<sup>18</sup> H. Finkelstein, *Ber.*, 1910, **43**, 1528; R. S. Tipson, *Adv. Carbohydrate Chem.*, 1953, **8**, 107.

<sup>19</sup> H. M. R. Hoffmann, *J. Chem. Soc.*, 1965, 6748.

<sup>20</sup> J. MacMillan and M. F. Barnes, *J. Chem. Soc. (C)*, 1967, 361; MacMillan and E. R. H. Walker, *J.C.S. Perkin I*, 1972, 981.

<sup>21</sup> L. H. Briggs, R. C. Cambie, and P. S. Rutledge, *J. Chem. Soc.*, 1963, 5374.

Attempts to solvolyse the allylic iodide (10) in acetic acid with or without potassium acetate, or with potassium acetate and added iodine, gave only traces of the allylic acetates (8) and (3). However, as expected, use of silver acetate in acetic acid or dichloromethane gave high yields of the allylic acetates (8) and (3). Initial attempts to effect solvolysis with thallium(I) acetate in acetic acid were unsuccessful but when a catalytic amount of iodine was added rapid solvolysis occurred. The relative yields of the allylic acetates obtained from each of the thallium(I) acetate and silver(I) acetate solvolyses paralleled those obtained from Prévost reactions where phyllocladene was the starting material thereby suggesting the intermediacy of an allylic iodide in the latter reactions. With silver acetate the ratio of allylic acetates from the allylic iodide (10) was solvent invariant with the thermodynamically more stable allylic acetate (8) predominating. This is presumably because the silver-mediated reaction involves an  $S_N1$  pathway in which steric crowding between the C-15 $\beta$  proton and the C-10 angular methyl group makes formation of the acetate (8) more energetically favourable. Although the



product ratio with thallium(I) acetate in acetic acid resembled that obtained with silver acetate, the less thermodynamically stable acetate (3) predominated when dichloromethane was the solvent. This implies that the reaction does not proceed exclusively *via* an allylic cation and that a different mechanism may operate with thallium(I) carboxylates. Indeed, the predominance of the acetate (3) in the product suggests that the thallium(I) reagent may react in part *via* an  $S_N2'$  type pathway. Thallium(I) is a weak 'soft acid' and does not appear to interact with the iodine atom of the allylic iodide to cause polarisation of the carbon-iodine bond. However, with iodine present, extensive polarisation of this bond must occur in order to explain the ready reaction. In aprotic solvents, allyl iodide has been shown<sup>22</sup> to undergo rapid exchange of iodine by a polar mechanism with a transition state resembling the ion pair  $\text{C}_3\text{H}_5^+\text{I}_3^-$ . The interception by thallium(I) acetate of a similar species formed from the allylic iodide (10) could lead to the allylic acetate (3) by an  $S_N2'$  type pathway as follows. Since the species (28) probably resembles the intermediate for isomerisation of the allylic iodide (4) to the iodide (10) it is not surprising that phyllocladene and isophyllocladene each give similar yields of the allylic acetates (8) and (3) when treated with thallium(I) acetate and iodine.

A pathway analogous to that proposed above for the formation of the allylic iodide (10) from isophyllocladene has been put forward by Mangoni and Dovinola<sup>9</sup> to explain the abnormal bromination of isophyllocladene

to the allylic bromide (11).<sup>17</sup> It was suggested that the initial bromination product was the allylic bromide (5) which underwent rearrangement during chromatography to give the observed product. However, during the present work, n.m.r. analysis of the products from bromination of isophyllocladene or of phyllocladene in carbon tetrachloride gave no evidence for the formation of the allylic bromide (5).

#### EXPERIMENTAL

General experimental details are given in Part X.<sup>1</sup>

**Oxidation of Phyllocladene (8 $\beta$ ,13 $\beta$ -Kaur-16-ene) (1) with Silver Benzoate and Iodine.**—Phyllocladene (2.0 g) and silver benzoate (3.84 g; dried at 100°) in benzene (150 ml) were dried by azeotropic distillation under nitrogen, iodine (1.93 g) in dry benzene was added slowly with cooling, and the mixture was stirred at 20° for 2 h and heated under reflux for 3 h. Silver salts were removed and washed with hot benzene. The combined benzene solutions were concentrated *in vacuo* to a gum which was chromatographed on silica gel. Elution with hexane gave a mixture (0.74 g) of phyllocladene and isophyllocladene while elution with hexane-benzene (1:1) gave a mixture (1.06 g) of the

allylic benzoates (7) (67%) and (2) (33%). Preparative t.l.c. (p.l.c.) using benzene-hexane (1:2) gave 8 $\beta$ ,13 $\beta$ -kaur-16-en-15 $\alpha$ -yl benzoate<sup>4</sup> (2), m.p. and mixed m.p. 130–132° (identical i.r. spectrum),  $\delta$  0.80 (s, *gem*-Me<sub>2</sub>), 1.10 (s, 10-Me), 2.63 (m,  $W_{\frac{1}{2}}$  8 Hz, 13-H), 4.98, 5.12 (2s, 17-H<sub>2</sub>), 5.97 (s, 15-H), and 7.20–8.00 (s, aryl-H), and 8 $\beta$ ,13 $\beta$ -kaur-15-en-17-yl benzoate<sup>2</sup> (7), m.p. and mixed m.p. 161–163° (identical i.r. spectrum),  $\delta$  0.70 (s, 10-Me), 0.78, 0.81 (2s, *gem*-Me<sub>2</sub>), 2.41 (m,  $W_{\frac{1}{2}}$  10 Hz, 13-H), 4.80 (s, 17-H<sub>2</sub>), 5.70 (s, 15-H), and 7.30–8.00 (m, aryl-H). The allylic benzoates (7) and (2) were also prepared in identical yields from isophyllocladene.

The allylic acetates (8) and (3) were prepared in a similar manner using silver acetate.

**Oxidation of Phyllocladene with Selenium Dioxide.**—Freshly sublimed selenium dioxide (0.40 g) was added to a stirred solution of phyllocladene (2.0 g) in acetic acid (25 ml) and acetic anhydride (25 ml) at 20°. The solution was heated under reflux with stirring for 5 h, the selenium was removed, and the mixture was worked up to give a gum which was chromatographed (dry column) on silica gel. Elution with hexane-benzene (1:1) gave isophyllocladene (0.35 g) and then a 1:1 mixture (2.0 g) of the allylic acetates (8) and (3). P.l.c. using benzene-hexane (1:2) gave 8 $\beta$ ,13 $\beta$ -kaur-16-en-15 $\alpha$ -yl acetate (3), needles (from methanol), m.p. 65–67°, identical (i.r. and n.m.r. spectra) with a sample prepared by acetylation of 8 $\beta$ ,13 $\beta$ -kaur-16-en-15 $\alpha$ -ol<sup>1</sup> (Found: C, 80.2; H, 10.4. C<sub>22</sub>H<sub>34</sub>O<sub>2</sub> requires C, 79.95; H, 10.4%),  $\nu_{\text{max}}$  (CCl<sub>4</sub>) 1735 (CO) and 1245 cm<sup>-1</sup> (OAc),  $\delta$  0.77, 0.83 (2s, *gem*-Me<sub>2</sub>), 1.00 (s, 10-Me), 2.02 (s, OAc), 2.59 (m,  $W_{\frac{1}{2}}$  10 Hz, 13-H), 4.99, 5.06 (2d,  $J$  0.5 Hz, 17-H<sub>2</sub>), and 5.79 (s, 15-H) and 8 $\beta$ ,13 $\beta$ -kaur-15-en-17-yl acetate<sup>2</sup>

<sup>22</sup> R. M. Noyes and E. Körös, *Accounts Chem. Res.*, 1971, 4, 233.

(8), m.p. and mixed m.p. 36—37° (identical i.r. spectrum),  $\delta$  0.79 (s, 10-Me), 0.84, 0.86 (2s, *gem*-Me<sub>2</sub>), 2.08 (s, OAc), 2.38 (m,  $W_{\frac{1}{2}}$  9 Hz, 13-H), 4.63 (d,  $J$  1 Hz, 17-H<sub>2</sub>), and 5.72 (s, 15-H).

The same products were formed in similar yields from isophyllocladene.

**Oxidation of Isophyllocladene (6) with Palladium(II) Chloride.**—A solution of isophyllocladene (0.50 g), anhydrous potassium acetate (0.38 g), anhydrous copper(II) chloride (0.52 g), and palladium(II) chloride (50 mg) in glacial acetic acid (30 ml) was stirred at 80° for 48 h. Work-up as described<sup>8</sup> gave an oil which was chromatographed (dry column) on silica gel. Elution with hexane–benzene (2 : 1) gave isophyllocladene (0.12 g) and then an oil (0.33 g) containing the allylic acetates (8) and (3) in a ratio of 4 : 1 (n.m.r.).

**Thallium(I) Carboxylates.**—Thallium(I) ethoxide was prepared as described.<sup>23</sup> For successful oxidation of the metal it was necessary to remove carbon dioxide from industrial oxygen.

A stoichiometric amount of the pure ethoxide was added to the carboxylic acid in a dry organic solvent. When an ethanolic solution of the ethoxide was used, hexane was added to precipitate completely the thallium(I) carboxylate. Thallium(I) benzoate was obtained in 89% yield as a microcrystalline solid, m.p. 335—340° (lit.,<sup>24</sup> 340—345°).

**Oxidation of Phyllocladene with Thallium(I) Carboxylates and Iodine in Benzene.**—(a) *With thallium(I) benzoate.* A solution of iodine (0.46 g) in dry benzene (20 ml) was added slowly to a stirred suspension of thallium(I) benzoate (1.19 g) in a solution of phyllocladene (0.50 g) in dry benzene at 20°. The rate of addition had to be such that iodine was never in large excess since then reaction occurred between the iodine and precipitated thallium(I) iodide to give complex iodides, e.g. Tl<sub>3</sub>I<sub>4</sub> [Tl(I)<sub>5</sub>Tl(III)I<sub>8</sub> or Tl(I)<sub>6</sub>I<sub>5</sub>+I<sub>3</sub>]<sup>25</sup> and TlI<sub>3</sub>.<sup>26</sup> The mixture was stirred at 20° for 30 h, thallium(I) iodide was removed, and the filtrate was concentrated to give a solid (0.70 g) which was chromatographed on silica gel. Elution with hexane–benzene (1 : 1) gave a mixture of 8 $\beta$ ,13 $\beta$ -kaur-16-en-15 $\alpha$ -yl benzoate (2) (46%) and 8 $\beta$ ,13 $\beta$ -kaur-15-en-17-yl benzoate (7) (54%).

(b) *With thallium(I) acetate.* A suspension of thallium(I) acetate (0.48 g) in a solution of phyllocladene (0.25 g) in benzene (50 ml) was treated with iodine (0.23 g) as in (a). Work-up as above gave a gum (0.23 g) which after chromatography on silica gel afforded the allylic esters (8) (40%) and (3) (50%).

P.l.c. (benzene–hexane, 1 : 3) of the crude product gave 17-iodo-8 $\beta$ ,13 $\beta$ -kauran-16 $\alpha$ -yl acetate (15) which crystallised from methanol as needles, m.p. 147—150°, *m/e* 398 ( $M^{+}$  –60) and 271.2427 ( $M^{+}$  –60 –127),  $\nu_{\max}$  1725 (CO) and 1240 cm<sup>-1</sup> (OAc),  $\delta$  0.80 (s, 10-Me), 0.89, 0.91 (2s, *gem*-Me<sub>2</sub>), 2.04 (s, OAc), 2.35 (m, 13-H), and 3.69 and 4.18 (2d,  $J$  11 Hz, 17-H<sub>2</sub>).

The mother liquors from crystallisation of the acetate (15) gave 17-iodo-8 $\beta$ ,13 $\beta$ -kauran-16 $\beta$ -yl acetate (18) as a viscous oil,  $\nu_{\max}$  1722 (CO) and 1240 cm<sup>-1</sup> (OAc),  $\delta$  0.80 (s, 10-Me), 0.89, 0.91 (2s, *gem*-Me<sub>2</sub>), 2.08 (s, OAc), 2.37 (m, 13-H), and 3.57 and 3.97 (2d,  $J$  10 Hz, 17-H<sub>2</sub>).

**Solvolysis of 17-Iodo-8 $\beta$ ,13 $\beta$ -kauran-16 $\alpha$ -yl Acetate.**—A solution of the iodoacetate (15) (35 mg) in acetic acid (2 ml) containing water (0.02 ml) was stirred at 70—80° with

silver acetate (13 mg) for 1 h. Work-up gave 16 $\alpha$ -hydroxy-8 $\beta$ ,13 $\beta$ -kauran-17-yl acetate<sup>4</sup> (16) (20 mg, 77%) which crystallised from chloroform–pentane as needles, m.p. and mixed m.p. 139—141° (identical i.r. spectrum),  $\delta$  0.83 (s, 10-Me), 0.91 (s, *gem*-Me<sub>2</sub>), 2.07 (s, OAc), and 4.19 (s, 17-H<sub>2</sub>).

**Solvolysis of 17-Iodo-8 $\beta$ ,13 $\beta$ -kauran-16 $\beta$ -yl Acetate.**—A solution of the crude iodoacetate (18) (25 mg) was solvolysed in wet acetic acid (2 ml) with silver acetate (10 mg) as described above. Work-up followed by p.l.c. (chloroform) gave 16 $\alpha$ -hydroxy-8 $\beta$ ,13 $\beta$ -kauran-17-yl acetate (7 mg), m.p. and mixed m.p. 139—141°, and 16 $\beta$ -hydroxy-8 $\beta$ ,13 $\beta$ -kauran-17-yl acetate (19) (12 mg), m.p. 116—119°, *m/e* 348 ( $M^{+}$ ), 333 ( $M$  – 15), 330 ( $M$  – 18), 315 ( $M$  – 15 – 18), and 275.2382 ( $M$  – C<sub>3</sub>H<sub>5</sub>O<sub>2</sub>),  $\nu_{\max}$  3448 (OH) and 1720 cm<sup>-1</sup> (CO),  $\delta$  0.84, 0.86 (2s, *gem*-Me<sub>2</sub>), 0.92 (s, 10-Me), 2.06 (s, OAc), and 3.80 and 4.15 (2d,  $J$  11 Hz, 17-H<sub>2</sub>).

**Reaction of Thallium(I) Acetate and Iodine in Acetic Acid.**—(a) *With phyllocladene.* Iodine (0.23 g) in acetic acid (15 ml) was added dropwise to a stirred solution of phyllocladene (0.25 g) and thallium(I) acetate (0.48 g) in acetic acid (50 ml) containing water (0.3 ml). The mixture was stirred at 20° for 1 h and then heated at 50° for 3 h. Work-up and chromatography gave a solid (0.36 g) which from the n.m.r. spectrum contained the acetates (8) (40%), (3) (30%), (15) (26%), and (18) (4%).

Reactions of phyllocladene (1 mmol) with thallium(I) acetate or silver acetate (2 mmol) and iodine (1 mmol) were carried out in various solvents (see the Table).

(b) *With isophyllocladene.* Isophyllocladene (0.27 g) was treated with iodine (0.50 g) and thallium(I) acetate (0.52 g) as in (a). N.m.r. analysis of the crude product (0.29 g, 88%) showed the presence of (8) (59%) and (3) (41%).

**Oxidation of Phyllocladene with Thallium(I) Trifluoroacetate and Iodine.**—A solution of iodine (0.25 g) in dry dichloromethane (10 ml) was added dropwise at 20° under nitrogen to a stirred solution of phyllocladene (0.27 g) and thallium(I) trifluoroacetate<sup>27</sup> (0.63 g) in dry dichloromethane. The mixture was stirred for 3 h and worked up to give a solid (0.50 g) which was shown by n.m.r. to contain the iodotrifluoroacetates (22) and (23) in a ratio of 1.2 : 1. P.l.c. of a portion of the product gave 17-iodo-8 $\beta$ ,13 $\beta$ -kauran-16 $\alpha$ -yl trifluoroacetate (22), needles (from methanol), m.p. 108—110° (Found:  $M^{+}$ , 512.1465. C<sub>22</sub>H<sub>32</sub>F<sub>3</sub>O<sub>2</sub> requires  $M$ , 512.1400),  $\nu_{\max}$  1780 cm<sup>-1</sup> (COCF<sub>3</sub>),  $\delta$  0.78, 0.81, 0.85 (3s, 10-Me and *gem*-Me<sub>2</sub>), 2.51 (m,  $W_{\frac{1}{2}}$  18 Hz, 10-H), and 3.55 and 3.91 (2d,  $J$  12 Hz, 17-H<sub>2</sub>), and 8 $\beta$ ,13 $\beta$ -kaur-15-en-17-yl trifluoroacetate (9) as an oil,  $\nu_{\max}$  1780 cm<sup>-1</sup> (COCF<sub>3</sub>),  $\delta$  0.83, 0.87 (2s, *gem*-Me<sub>2</sub>), 1.04 (s, 10-Me), 2.70 (m,  $W_{\frac{1}{2}}$  11 Hz, 13-H), 5.20 (m,  $W_{\frac{1}{2}}$  5 Hz, 17-H<sub>2</sub>), and 6.00 (s, 15-H). Hydrolysis with methanolic potassium hydroxide gave 8 $\beta$ ,13 $\beta$ -kaur-15-en-17-ol which crystallised from chloroform–pentane as needles, m.p. 120—122° (lit.,<sup>2</sup> 126—127°) (Found:  $M^{+}$ , 288.2506. Calc. for C<sub>20</sub>H<sub>32</sub>O:  $M$ , 288.2553),  $\nu_{\max}$  (KBr) 3250 cm<sup>-1</sup> (OH),  $\delta$  0.74 (10-Me), 0.79, 0.83 (*gem*-Me<sub>2</sub>), 2.37 (m,  $W_{\frac{1}{2}}$  10 Hz, 13-H), 4.13 (d,  $J$  1.5 Hz, 17-H<sub>2</sub>), and 5.59 (s, 15-H).

The iodotrifluoroacetates (22) and (23) were also obtained (n.m.r. and t.l.c.) using silver trifluoroacetate.

**Reaction of Phyllocladene with Thallium(I) Tosylate and Iodine.**—A solution of iodine (0.13 g) in dry dichloromethane (5 ml) was added dropwise to a stirred suspension of thallium-

<sup>23</sup> L. F. Fieser and M. Fieser, 'Reagents for Organic Synthesis,' Wiley, New York, 1969, vol. 2, p. 407.

<sup>24</sup> R. Walter, *Ber.*, 1926, **59**, 962.

<sup>25</sup> M. B. Robin and P. Day, *Adv. Inorg. Chem. Radiochem.*, 1967, **10**, 371.

<sup>26</sup> W. Maitland and R. Abegg, *Z. anorg. Chem.*, 1906, **49**, 341.

<sup>27</sup> F. Swarts, *Bull. Soc. chim. belges*, 1939, **48**, 176.

(1) tosylate <sup>16</sup> (0.37 g) in dichloromethane (5 ml) containing phyllocladene (0.14 g). The mixture was stirred at 20° for 18 h whereupon t.l.c. (hexane) of the dark solution indicated that only a trace of phyllocladene remained. The mixture was chromatographed from dichloromethane on silica gel to give 17-iodo-8 $\beta$ ,13 $\beta$ -kaur-15-ene (10) as a pale yellow oil (0.16 g, 80%) which crystallised from dry ethanol as needles, m.p. 48—49°, which decomposed at 20° when exposed to the atmosphere;  $\nu_{\max}$  1615 and 840  $\text{cm}^{-1}$  (C=C),  $\delta$  0.72 (s, 10-Me), 0.81, 0.84 (2s, *gem*-Me<sub>2</sub>), 2.43 (m,  $W_{\frac{1}{2}}$  8 Hz, 13-H), 3.93 (s, 17-H<sub>2</sub>), and 5.77 (s, 15-H). The product was identical (mixed m.p., t.l.c., and i.r. and n.m.r. spectra) with that prepared by stirring the allylic bromide <sup>17</sup> (11) with sodium iodide in anhydrous acetone at 20° for 18 h.

The allylic iodide (10) was prepared in 85% yield from similar treatment of isophyllocladene.

*Reaction of Phyllocladene with Silver Tosylate and Iodine.*—

(a) *In carbon tetrachloride.* Iodine (0.25 g) was added to a suspension of silver tosylate <sup>28</sup> (0.56 g) in dry carbon tetrachloride (5 ml) containing phyllocladene (0.27 g). The mixture was stirred for 6 h and worked up to give 8 $\beta$ ,13 $\beta$ -kaur-15-en-17-yl tosylate (12) as an unstable oil (0.13 g),  $\nu_{\max}$  1380 and 1190  $\text{cm}^{-1}$  (OTs),  $\delta$  0.80, 0.81 (2s, 10-Me and *gem*-Me<sub>2</sub>), 2.42 (s, aryl Me), 4.48 (d,  $J$  0.5 Hz, 17-H<sub>2</sub>), 5.65 (s, 15-H), and 7.20 and 7.65 (2d,  $J$  8 Hz, aryl H).

(b) *In benzene.* A solution of iodine (0.50 g) in dry benzene (25 ml) was added dropwise to a stirred suspension of silver tosylate (1.12 g) in dry benzene (25 ml) containing phyllocladene (0.54 g). The mixture was warmed to *ca.* 50° for 30 min, cooled, and worked up to give a product which contained a number of components. P.l.c. (benzene) gave 8 $\beta$ ,13 $\beta$ -kaur-15-en-17-al (13) (0.11 g) which crystallised

from aqueous ethanol as needles, m.p. 124—126° (lit.,<sup>2</sup> 125—127°),  $\nu_{\max}$  1715 (CO) and 1655  $\text{cm}^{-1}$  (C=C),  $\delta$  0.75 (s, 10-Me), 0.84, 0.87 (2s, *gem*-Me<sub>2</sub>), 2.89 (m,  $W_{\frac{1}{2}}$  10 Hz, 13-H), 6.80 (s, 15-H), and 8.43 (CHO).

*Solvolyses of 17-Iodo-8 $\beta$ ,13 $\beta$ -kaur-15-ene.*—*General procedure.* A solution of the allylic iodide (10) was treated at 20° with an equimolar quantity of the metallic acetate and a trace of iodine. After 1 h the mixture was washed with water, 5% aqueous sodium hydrogen carbonate, and aqueous sodium thiosulphate. Work-up at <30° gave the crude product which was analysed by n.m.r.

M(t)OAc	Solvent	(8) (%)	(3) (%)
KOAc	Aq. HOAc		
TIOAc	CH <sub>2</sub> Cl <sub>2</sub>	26	74
TIOAc	Aq. HOAc	55	45
AgOAc	CH <sub>2</sub> Cl <sub>2</sub>	65	35
AgOAc	Aq. HOAc	65	35

*Bromination of Phyllocladene and Isophyllocladene.*—A solution of the alkene (0.27 g) in dry carbon tetrachloride (2.5 ml) was treated with a solution of bromine (0.16 g) in carbon tetrachloride (2.5 ml) at 0°. As noted previously <sup>21</sup> the reactions were characterised by the immediate evolution of hydrogen bromide. Product ratios were determined by n.m.r. analysis of the crude product.

Alkene	(31)	Yields (%)			
		(32)	(33)	(34)	(11)
(1)	28	33	22	9	7
(6)	28	38	12	16	5

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<sup>28</sup> Ref. 23, p. 370.