

## Simple Syntheses of Dihydrojasmane and *cis*-Jasmone *via* 1,4-Diketones

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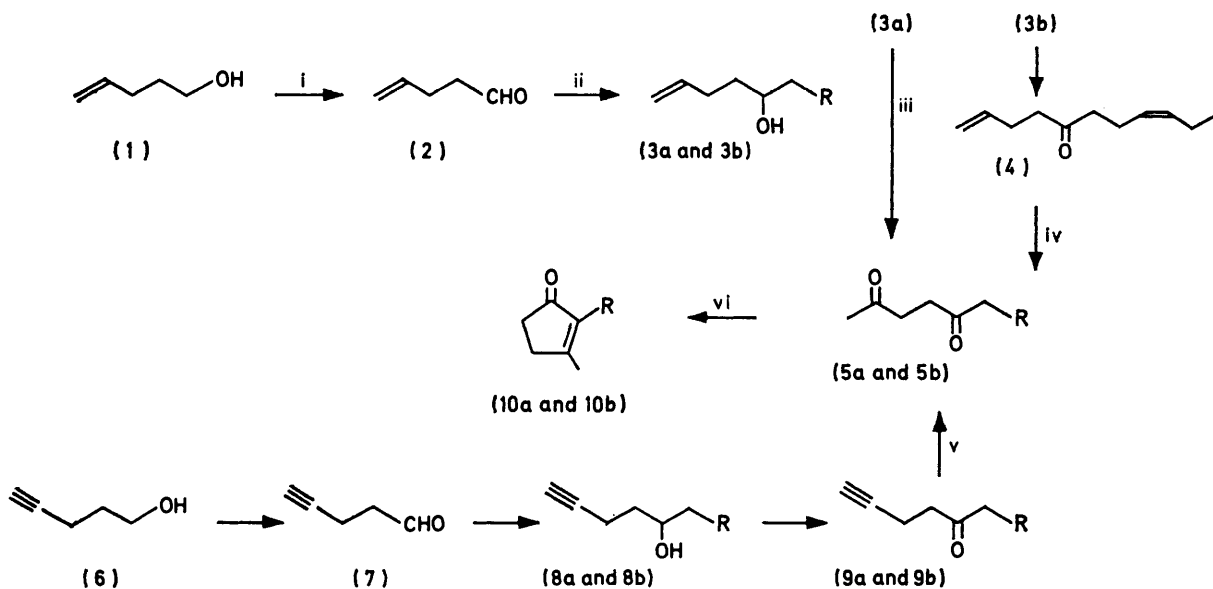
Two new routes for the synthesis of dihydrojasmane (10a) and *cis*-jasmone (10b) *via* 1,4-diketones (5a and b) are described. For the first route, pent-4-en-1-ol (1) was oxidised to the corresponding aldehyde (2), which on reaction with suitable Grignard reagents gave the olefinic alcohols (3a and b). The former (3a) was oxidised directly to the diketone (5a) by Jones reagent catalysed by  $\text{Hg}(\text{OAc})_2$ . The latter (3b) was oxidised stepwise, first by PCC to give (4), then by  $\text{PdCl}_2$  to yield (5b). For the second route, pent-4-yn-1-ol (6) was converted to the aldehyde (7), which on Grignard reaction using suitable reagents gave the hydroxy-acetylenes (8a and b). These were oxidised to the corresponding acetylenic ketones (9a and b), which in turn were converted by  $\text{Hg}^{2+}$  catalysed hydration to (5a and b). Base cyclisation of the diketones (5a and b) yielded (10a and b) respectively.

DIHYDROJASMONE (10a) and *cis*-jasmone (10b) are naturally occurring substances widely used as perfume ingredients. Because of their commercial importance and limited availability from natural sources, their syntheses have been carried out by a number of investigators and reviewed from time to time.<sup>1-3</sup> In many synthetic approaches, the efforts were focused on the preparation of appropriate 1,4-diketones (5a and b), which on base-catalysed cyclisation gave dihydrojasmane (10a) and *cis*-jasmone (10b), respectively. Several of the existing methods follow lengthy procedures and/or involve expensive chemicals. In this paper, two simple routes (see Scheme) for the syntheses of dihydrojasmane (10a) and *cis*-jasmone (10b) *via* 1,4-diketones (5a and b) from pent-4-en-1-ol (1) and pent-4-yn-1-ol (6) are discussed.

The compounds (1) and (6), obtained from tetrahydro-

furfuryl alcohol,<sup>4,5</sup> are attractive starting materials for the preparation of jasmonoid precursors as they have differential bifunctionalities in the correct positions in an appropriate skeleton. For dihydrojasmane (10a), in the first route, pent-4-en-1-ol was oxidised to the corresponding aldehyde (2) in 70% yield by treatment with pyridinium chlorochromate.<sup>6</sup> Reaction of this aldehyde (2) with the Grignard reagent prepared from *n*-hexyl bromide gave the hydroxy-olefin (3a) in 75% yield. Jones oxidation of (3a), in the presence of catalytic quantities of mercuric acetate,<sup>7</sup> converted the terminal olefin to a methyl ketone and simultaneously accomplished the oxidation of secondary hydroxy group to afford the required 1,4-diketone (5a) (85%).

For *cis*-jasmone, the dienol (3b) was synthesised in 70% yield by treatment of the aldehyde (2) with the Grignard reagent from *cis*-1-bromohex-3-ene.<sup>8</sup> In con-



For 'a' series :  $\text{R} = -\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_3$

For 'b' series :  $\text{R} = -\text{CH}_2-\overset{\text{Z}}{\text{C}}\text{H}=\text{CH}-\text{CH}_2-\text{CH}_3$

SCHEME Reagents: i,  $\text{C}_6\text{H}_5\text{NHCrO}_3\text{Cl}-\text{CH}_2\text{Cl}_2$  (PCC); ii,  $\text{RCH}_2\text{MgBr}$ -ether; iii,  $\text{Hg}(\text{OAc})_2$ -acetone-Jones reagent; iv,  $\text{PdCl}_2-\text{CuCl}_2-\text{DMF}-\text{O}_2-\text{H}_2\text{O}$ ; v,  $\text{Hg}^{2+}$ -aq.  $\text{MeOH}-\text{H}_2\text{SO}_4$ ; vi,  $\text{NaOH}-\text{EtOH}$

trast to the above case the functionalisation of the terminal olefin in (3b) to the methyl ketone could not be adopted due to the presence of an additional double bond. Hence an alternative approach was sought wherein the dienol (3b) was oxidised by pyridinium chlorochromate to the dienone (4) and then subjected to palladium chloride oxidation<sup>9,10</sup> to yield the desired 1,4-diketone (5b) (70%).

In the second route, pent-4-yn-1-ol (6) was oxidised to (7) and subsequently treated with Grignard reagents as above, to obtain the respective hydroxy-acetylenes (8a and b) in satisfactory yields. These were in turn oxidised to the corresponding oxo-acetylenes (9a and b) with pyridinium chlorochromate.<sup>6</sup> The functionalisation of these oxo-acetylenes to afford the desired 1,4-diketones (5a and b) was effected by catalytic quantities of mercuric sulphate-sulphuric acid<sup>11</sup> in aqueous methanol. The physical data of these 1,4-diketones are identical to those obtained by the first method.

Cyclisation of the above 1,4-diketones (5a and b) in the presence of alkali<sup>8</sup> yielded dihydrojasmane (10a) and *cis*-jasmane (10b), respectively. These products are identical (g.l.c. and u.v., i.r., and n.m.r. spectra) with authentic samples.\*

#### EXPERIMENTAL

I.r. spectra were recorded on a Perkin-Elmer Infracord spectrophotometer, model 137B, for liquid films. N.m.r. spectra were determined with a Varian-A-60A spectrometer for solutions in deuteriochloroform with Me<sub>4</sub>Si as internal standard. U.v. spectra were recorded on a Carl-Zeiss RPQ 20A recording spectrophotometer.

*Pent-4-enal* (2).—To a stirred mixture of dry pyridinium chlorochromate (24.2 g) in anhydrous methylene chloride (100 ml), pent-4-en-1-ol (1) (6.45 g) in anhydrous methylene chloride (10 ml) was added in one lot. Within a few minutes a black gum separated. The stirring, although difficult, was continued for an additional 2–3 h at ambient temperature. To the black gum, anhydrous ether (100 ml) was added and the supernatant solution decanted from the black gum. The residue was thoroughly washed with anhydrous ether and the combined extracts were passed through a bed of Florisil (40 g). Removal of the solvent gave pent-4-enal (2) (4.5 g, 70%), sufficiently pure for further reactions. A small portion was distilled for characterisation of the compound which had b.p. 103–104° (lit.<sup>12</sup> 103–104°),  $\nu_{\max}$  (film) 2 710, 1 720, 1 640, 990, and 910 cm<sup>-1</sup>,  $\tau$  0.20 (t, *J* 1.5 Hz, CHO) and 3.82–5.15 (m, CH<sub>2</sub>=CH).

*Undec-1-en-5-ol* (3a) and *Undeca-1,8-dien-5-ol* (3b).—To 200 ml of a well-stirred ethereal solution of hexylmagnesium bromide [from magnesium (1.44 g) and hexyl bromide (9.9 g)] under nitrogen, pent-4-enal (2) (4.2 g) in anhydrous ether (50 ml) was added dropwise with cooling over 1.5 h. On completion of addition, the mixture was refluxed for 2.5 h and the Grignard complex decomposed by careful addition of saturated ammonium chloride solution. The organic layer was separated, washed with brine, and dried (Na<sub>2</sub>SO<sub>4</sub>). Removal of the solvent followed by distillation afforded *undec-1-en-5-ol* (3a) (6.4 g, 75%), b.p. 70° at 4 mmHg,

\* Samples of dihydrojasmane and *cis*-jasmane were kindly provided by the National Chemical Laboratory, Poona, and International Flavours and Fragrances, U.S.A., respectively.

$\nu_{\max}$  (film) 3 340, 1 637, 995, and 910 cm<sup>-1</sup>,  $\tau$  3.80–5.19 (m, CH<sub>2</sub>=CH), 6.49 (m, CHOH), 7.94 (s, -CHOH), and 9.12 (t, *J* 5 Hz, CH<sub>2</sub>CH<sub>3</sub>) (Found: C, 77.25; H, 12.75. C<sub>11</sub>H<sub>22</sub>O requires C, 77.65; H, 12.95%).

Likewise, (*Z*)-hex-3-enylmagnesium bromide [from (*Z*)-1-bromohex-3-ene (2 g) and magnesium (0.30 g)] and pent-4-enal (2) (0.84 g) gave the *dienol* (3b) (1.17 g, 70%), b.p. 140–145° at 2 mmHg,  $\nu_{\max}$  (film) 3 360, 1 645, 995, and 910 cm<sup>-1</sup>,  $\tau$  3.79–5.16 (m, CH<sub>2</sub>=CH and CH=CH), 6.43 (m, CHOH), 7.78 (s, CHOH), and 9.04 (t, *J* 7 Hz, CH<sub>2</sub>CH<sub>3</sub>) (Found: C, 78.2; H, 12.1. C<sub>11</sub>H<sub>20</sub>O requires C, 78.55, H, 12.0%).

*Undecane-2,5-dione* (5a).—To a 250 ml round bottom flask were added acetone (80 ml), water (2 ml), and mercuric acetate (2.6 g) and the flask was placed on a water-bath. Undec-1-en-5-ol (3a) (6.8 g) was added with stirring to the bright yellow solution. To this solution, Jones reagent (0.7M; 75 ml) was added over 4 h while the bath temperature was maintained at 25 ± 5° by addition of ice. The dark green-brown solution was stirred for an additional 4 h and then poured into cold water and repeatedly extracted with ether. The combined ether extracts were washed with water, brine, and dried (Na<sub>2</sub>SO<sub>4</sub>). Removal of the solvent followed by distillation gave the diketone (5a) (6.25 g, 85%), b.p. 100–102° at 1 mmHg (lit.<sup>13</sup> 141° at 14 mmHg),  $\nu_{\max}$  (film) 1 710 cm<sup>-1</sup>,  $\tau$  7.30 (s, -COCH<sub>2</sub>CH<sub>2</sub>CO-), 7.80 (s, -COCH<sub>3</sub>), and 9.09 (t, *J* 5 Hz, CH<sub>2</sub>CH<sub>3</sub>) (Found: C, 71.6; H, 10.8. Calc. for C<sub>11</sub>H<sub>20</sub>O<sub>2</sub>: C, 71.7; H, 10.95%).

*Undeca-1,8-dien-5-one* (4).—By the same procedure as for (2), the dienol (3b) (0.84 g) and pyridinium chlorochromate (1.62 g) gave the dienone (4) (0.58 g, 70%), b.p. 120° at 2 mmHg,  $\nu_{\max}$  (film) 1710, 1 645, 990, and 910 cm<sup>-1</sup>,  $\tau$  3.85–5.15 (m, CH<sub>2</sub>=CH and CH=CH), and 9.05 (t, *J* 7 Hz, CH<sub>2</sub>CH<sub>3</sub>).

(*Z*)-*Undec-8-ene-2,5-dione* (5b).—To a mixture of palladium chloride (0.088 g) and cupric chloride (0.085 g) in aqueous dimethylformamide-water (2.1 ml, 20:1 v/v), the dienone (4) (0.50 g) was gradually added over 1 h while oxygen was passed through at a rate of 3.3 l h<sup>-1</sup>. The mixture was maintained at 60–70° C for 0.5 h after the introduction of (4), then poured into cold dilute hydrochloric acid (15 ml) and extracted with ether. The ether extract was washed with brine and dried (Na<sub>2</sub>SO<sub>4</sub>). Removal of the solvent followed by bulb-to-bulb distillation gave the diketone (5b) (0.38 g, 70%), b.p. 140° at 2 mmHg (lit.<sup>8</sup> 64–66° at 0.02 mmHg),  $\nu_{\max}$  (film) 1 715 cm<sup>-1</sup>,  $\tau$  4.35–4.87 (m, CH=CH), 7.32 (s, -COCH<sub>2</sub>CH<sub>2</sub>CO-), 7.82 (s, -COCH<sub>3</sub>), and 9.04 (t, *J* 7 Hz, CH<sub>2</sub>CH<sub>3</sub>) (Found: C, 72.3; H, 9.7. Calc. for C<sub>11</sub>H<sub>18</sub>O<sub>2</sub>: C, 72.45; H, 9.95%).

*Pent-4-ynal* (7).—By the same procedure as for (2), pent-4-yn-1-ol (6) (6.36 g) and pyridinium chlorochromate (24.22 g) gave the title compound (4.5 g, 72%),  $\nu_{\max}$  (film) 3 322, 2 137, 2 725, and 1 735 cm<sup>-1</sup>,  $\tau$  0.70 (t, *J* 1.5 Hz, CHO), which was used in the next step without further purification.

*Undec-1-yn-5-ol* (8a) and *Undec-8-en-1-yn-5-ol* (8b).—The compounds (8a and b) were prepared by the procedure described for (3a and b). Thus, pent-4-ynal (7) (4.1 g), magnesium (2.88 g), and hexyl bromide (20 g) gave *undec-1-yn-5-ol* (8a) (6.7 g, 80%), b.p. 140° at 2 mmHg,  $\nu_{\max}$  (film) 3 390, 3 322, and 2 120 cm<sup>-1</sup>,  $\tau$  6.50 (m, CHOH), 7.72 (s, -CHOH), and 9.10 (t, *J* 6 Hz, CH<sub>2</sub>CH<sub>3</sub>) (Found: C, 78.45; H, 11.8. C<sub>11</sub>H<sub>20</sub>O requires C, 78.55; H, 12.0%).

Likewise, pent-4-ynal (7) (0.41 g), magnesium (0.25 g), and *cis*-1-bromohex-3-ene<sup>8</sup> (1.63 g) gave *undec-8-en-1-yn-*

5-ol (8b) (0.58 g, 70%), b.p. 120—130° at 2 mmHg,  $\nu_{\max}$  (film) 3 390, 3 322, and 2 110  $\text{cm}^{-1}$ ,  $\tau$  4.60—4.80 (m,  $\text{CH}=\text{CH}$ ), 6.54 (m,  $\text{CHOH}$ ), 7.40 (s,  $\text{CHOH}$ ), and 9.05 (t,  $J$  7 Hz,  $\text{CH}_2\text{CH}_3$ ) (Found: C, 79.2; H, 10.8.  $\text{C}_{11}\text{H}_{18}\text{O}$  requires C, 79.5; H, 10.9%).

*Undec-1-yn-5-one* (9a) and *Undec-8-en-1-yn-5-one* (9b).—By the procedure described for (2), the title compounds were prepared. Thus (8a) (3.32 g) with pyridinium chlorochromate (6.48 g) gave the oxoacetylene (9a) (2.5 g, 71%), b.p. 98—100° at 3 mmHg,  $\nu_{\max}$  (film) 3 300, 2 120, and 1 720  $\text{cm}^{-1}$ .

Likewise, from (8b) (0.41 g) and pyridinium chlorochromate (0.8 g), (9b) was obtained (0.28 g, 68%), b.p. 120° at 2 mmHg,  $\nu_{\max}$  (film) 3 300, 2 120, and 1 715  $\text{cm}^{-1}$ .

*Undecane-2,5-dione* (5a).—To 70% v/v methanol-water (6 ml), mercuric sulphate (0.01 g) and concentrated sulphuric acid (0.01 g) were added followed by the oxoacetylene (9a) (0.83 g). The mixture was kept at 60—70 °C for 5 h, then cooled, diluted with cold water, and extracted with ether. The ether extract was washed with water and brine and then dried ( $\text{Na}_2\text{SO}_4$ ). Removal of the solvent followed by distillation gave the diketone (5a) (0.74 g, 80%), identical with the sample obtained from (3a).

(*Z*)-*Undec-8-ene-2,5-dione* (5b).—To 70% v/v methanol-water (2 ml), mercuric sulphate (0.01 g) and concentrated sulphuric acid (0.01 g) were added. The mixture was treated with the oxoacetylene (9b) (0.20 g) and stirred at room temperature for 2.5 h. Work-up as above furnished the diketone (5b) (0.13 g, 60%), identical with that obtained from (4).

*Dihydrojasmane* (10a).—A mixture of (5a) (9.2 g), ethanol (45 ml), and aqueous sodium hydroxide (0.5N; 90 ml) was refluxed for 5 h. The mixture was cooled, diluted with water, and extracted with ether. The extract was washed with water and brine and dried ( $\text{Na}_2\text{SO}_4$ ). Removal of the solvent gave crude dihydrojasmane (7.6 g) which was chromatographed on neutral alumina (Grade II, 80 g) with

light petroleum-ether (1 : 1) as eluant. Distillation afforded the pure dihydrojasmane (10a) (6.7 g, 75%), b.p. 88° at 3 mmHg (lit.,<sup>14</sup> 122—124 at 12 mmHg),  $\lambda_{\max}$  (MeOH) 235 nm ( $\epsilon$  11 220),  $\nu_{\max}$  1705 and 1 650  $\text{cm}^{-1}$ ,  $\tau$  7.92 (s,  $\text{C}=\text{CCH}_3$ ).

*cis-Jasmane* (10b).—A mixture of (5b) (0.45 g), ethanol (2 ml), and aqueous sodium hydroxide (0.5N; 5 ml) was refluxed under nitrogen for 5 h. The mixture was diluted with water, extracted with ether, and washed with brine. The organic layer was dried ( $\text{Na}_2\text{SO}_4$ ) and removal of the solvent gave crude *cis*-jasmane (10b) (0.3 g). The crude product was chromatographed on neutral alumina (grade II, 15 g) using light petroleum-ether (1 : 1) as eluant, yield 0.28 g (70%), b.p. 120—130° at 3 mmHg,  $\lambda_{\max}$  (MeOH) 234.5 nm ( $\epsilon$  12 880),  $\nu_{\max}$  1 705 and 1 645  $\text{cm}^{-1}$ ,  $\tau$  4.65 (m,  $\text{CH}=\text{CH}$ ), 7.02 (d,  $\text{C}=\text{CCH}_2$ ), 7.92 (s,  $\text{C}=\text{CCH}_3$ ), and 9.02 (t,  $J$  7 Hz,  $\text{CH}_2\text{CH}_3$ ).

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