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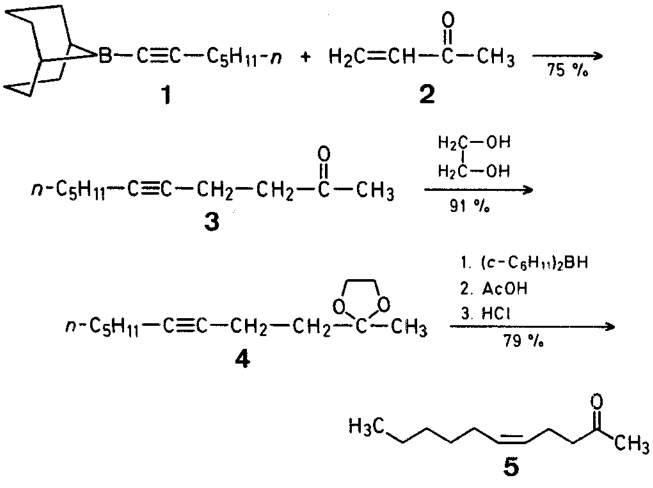
Pheromone Synthesis via Organoboranes: A Simple Synthesis of (*Z*)-5-Undecen-2-one, A Ketone from the Pedal Gland of the Bontebok (*Damaliscus dorcas dorcas*)

Herbert C. Brown*, Uday S. Racherla, D. Basavaiah

Richard B. Wetherill Laboratory, Purdue University,
West Lafayette, Indiana 47907, U.S.A.

The significance of pheromones in olfactory communication in mammals and the possibility of using synthetic pheromones to influence the behavior of problem animals have been recently studied[1]. (*Z*)-5-Undecen-2-one (**5**) was isolated[1] as the principal volatile component of the pedal gland exudate of the bontebok, *Damaliscus dorcas dorcas*. This ketone **5** was prepared and intense interest was shown by two captive animals when it was subjected to the preliminary biological test as a mammalian pheromone of the bontebok[1]. However, the method involves six steps. The only other synthesis known to date used dihydrojasmone as the starting material[2,3]. Overall yields in both of these methods are low. Therefore, a simple facile synthesis of **5** from easily accessible starting materials would be of great interest. In continuation of our interest[4-8] in the synthesis of insect pheromones and other biologically active molecules, we herein report a very facile, convenient synthesis of **5** in 54% overall yield via organoborane chemistry.

Stereo- and regio-construction of carbon-carbon bonds via organoborane chemistry has been well documented in the literature[9,10]. We have recently reported the conjugate addition of *B*-(1-alkynyl)-9-borabicyclo[3.3.1]nonanes to α, β-unsaturated ketones providing a convenient procedure for the preparation of γ, δ-acetylenic ketones[11]. We now have demonstrated the synthetic applicability of this method, thus providing a convenient synthesis of **5**.



Treatment of *B*-(1-heptynyl)-9-borabicyclo[3.3.1]nonane[12] (**1**) with methyl vinyl ketone (**2**), followed by hydrolysis, produced 5-undecyn-2-one (**3**). The carbonyl group of **3** was protected as ethylene acetal to give **4**. The formation of the (*Z*)-alkene in the hydroboration of internal alkynes, followed by protonolysis, has been well established[9]. Hydroboration of **4** with dicyclohexylborane, followed by protonolysis (acetic acid) and acid hydrolysis (hydrochloric acid), afforded the desired (*Z*)-5-undecen-2-one (**5**) in high overall yield, starting from 1-heptyne, the precursor of **1**.

Thus, this procedure represents a very simple, highly efficient three-step synthesis of **5** in 54% overall yield. Now we are continuing our efforts in exploring the application of organoboranes in synthetic transformations.

Boiling points are uncorrected. The G.L.C. analyses are carried out on a Hewlett Packard 5750 research chromatograph (column 6 ft × 0.25 in packed with 10% SE-30 on Chromosorb W AW DMCS). I.R. spectra are recorded on a Perkin Elmer 1420 ratio recording infrared spectrophotometer. ^{1}H-N.M.R. and ^{13}C-N.M.R. spectra are recorded on Perkin Elmer Model R-32 (90 MHz) and Varian FT-80A spectrometers, respectively. 1-Heptyne is obtained from Farchan Acetylenes and 9-borabicyclo[3.3.1]nonane and methyl vinyl ketone (**2**) are obtained from the Aldrich Chemical Company. General procedures for the manipulation of air-sensitive materials have been described elsewhere[9].

5-Undecyn-2-one (3):
B-(1-Heptynyl)-9-borabicyclo[3.3.1]nonane[12] (**1**; 50 mmol), prepared from 1-heptyne (4.8 g, 50 mmol) and *B*-(methoxy)-9-borabicyclo[3.3.1]nonane (7.6 g, 50 mmol), is treated with methyl vinyl ketone (**2**; 4.2 g, 60 mmol) according to a known procedure[11] to give **3**; yield: 6.22 g (75%); b.p. 58–59 °C/0.2 torr (Ref.[2], b.p. 104–106 °C/10 torr); n_D^{20}: 1.4496 (Ref.[2], n_D^{22}: 1.4495). G.L.C. analysis indicates > 99% chemical purity.

I.R. (neat): ν = 1718 cm^{-1}.

^{1}H-N.M.R. (CDCl$_3$): δ = 0.92 (distorted t, 3H); 1.2–1.6 (m, 6H); 2.08–2.76 ppm (m + s, 9H).

2,2-Ethanediyldioxyundec-5-yne (4):
5-Undecyn-2-one (**3**; 4.98 g, 30 mmol) is treated with ethylene glycol (3.72 g, 60 mmol) in the presence of a catalytic amount of *p*-toluenesulfonic acid (1%, 60 mg) in benzene (22 ml) under reflux using a Dean and Stark water separator for 3 h. Work-up by ether gives **4**; yield: 5.73 g (91%); b.p. 78–79 °C/0.2 torr (Ref.[1], b.p. 88–89 °C/1.2 torr); n_D^{20}: 1.4567. G.L.C. analysis shows > 99% chemical purity.

^{1}H-N.M.R. (CDCl$_3$/TMS): δ = 0.91 (deformed t, 3H); 1.21–2.45 (m + s, 15H); 3.91 ppm (s, 4H).

(*Z*)-5-Undecen-2-one (5):
2,2-Ethanediyldioxyundec-5-yne (**4**; 4.20 g, 20 mmol) is hydroborated with dicyclohexylborane (20 mmol) for 1 h at 0 °C, followed by 2 h at room temperature. Solvent tetrahydrofuran is removed under reduced pressure, acetic acid (20 ml) is added and the mixture is heated under reflux for 3 h. G.L.C. analysis of the crude product after the usual workup[9] shows that it is a mixture of **5** and (*Z*)-2,2-ethanediyldioxyundec-5-ene (45 : 55). The crude product is then treated with 6 normal hydrochloric acid (7 ml) in acetone (25 ml) at room temperature for 3 h. Work-up by ether provides **5**; yield: 2.65 g (79%); b.p. 79–80 °C/0.8 torr (Ref.[2], b.p. 97–99 °C/12 torr); n_D^{20}: 1.4425 (Ref.[2], n_D^{22}: 1.4420). G.L.C. analysis indicates 100% chemical purity.

I.R. (neat): $\nu = 1718\ cm^{-1}$.

^{1}H-N.M.R. ($CDCl_3$/TMS): $\delta = 0.88$ (deformed t, 3H); 1.12–1.61 (m, 6H); 1.81–2.59 (m + s, 9H); 5.14–5.53 ppm (m, 2H).

^{13}C-N.M.R. ($CDCl_3$/TMS): $\delta = 13.76$; 21.54; 22.36; 26.95; 29.16; 29.47; 31.32; 43.31 (alkyl C); 127.58; 130.86 (C=C); 204.93 ppm (carbonyl). The only two vinylic carbon signals reveal the absence of any significant amount of the corresponding (*E*)-isomer[13].

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[*] Address for correspondence.

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