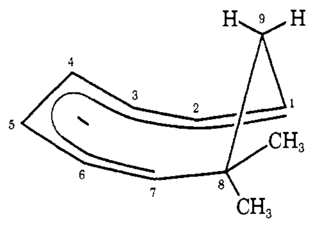

6

2,[9] (3) the π bonds between C_1 and C_4 are more twisted than those between C_4 and C_7 because they are adjacent to the "out-of-plane" C_9 rather than to the "in-plane" C_8, and (4) H_7 is located across the ring from the more twisted portion of the π system (particularly C_1) and is therefore substantially more shielded (or less deshielded) than H_1.[10] A perturbation in the counterion does not seem to have a large effect on the spectral parameters discussed above since the cesium and potassium salts of **3** have nearly identical spectra.

Interestingly, treatment of 1,2-cyclononadiene with potassium amide in liquid ammonia in an nmr tube at room temperature affords 1,5-cyclononadiene[11] with no evidence of anion formation. This presumably is due to the large strain in the latter species.[12]

In summary, the nmr spectra of anions **2** and **3** provide the most detailed information to date regarding the conformation of sterically strained anions. It is clear from this study that the need to minimize angle and torsional strain can compete effectively with the requirement for maximum overlap in the π system.[13] Furthermore, substantial delocalization of charge can occur even in a relatively highly twisted π system.

Acknowledgment. We gratefully acknowledge the support of this work by the National Science Foundation.

[9] This is estimated from the value of J_{19} in **3** (8.5 Hz) and the average value of J_{19} and J_{78} in **2** (<6.5 Hz).

[10] The fact that H_7 is >0.6 ppm upfield from H_1 is probably due to an anisotropy effect rather than to the influence of excess negative charge since the effect of a twist in the C_1–C_4 portion of the ring is to increase the negative charge at C_1 relative to C_7.

[11] G. Nagendrappa and D. Devaprabhakara, *J. Organometal. Chem.*, **15**, 225 (1968). This is the most stable cyclononadiene isomer: D. Devaprabhakara, C. G. Cardenas, and P. D. Gardner, *J. Amer. Chem. Soc.*, **85**, 1553 (1963).

[12] The cyclooctadienyl anion is nonplanar but nevertheless is generated rapidly and essentially completely in potassium amide–liquid ammonia: H. Kloosterziel and J. A. A. van Drunen, *Recl. Trav. Chim. Pays-Bas*, **89**, 368 (1970).

[13] The conformation of anions **2** and **3** leads us to suggest that the *all-cis*-cyclononatetraenyl anion may be nonplanar. See (a) T. J. Katz and P. J. Garratt, *J. Amer. Chem. Soc.*, **85**, 2852 (1963); (b) E. A. LaLancette and R. E. Benson, *ibid.*, **85**, 2853 (1963); (c) see also G. Boche, D. Martens, and W. Danzer, *Angew. Chem., Int. Ed. Engl.*, **8**, 984 (1969).

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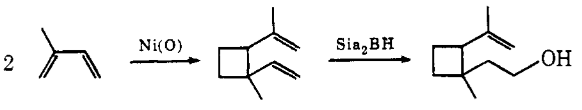
A Synthesis of (±)-Grandisol

Sir:

The limited supply of insect pheromones from natural sources places their synthesis into a strategic position with regard to procurement.[1] We wish to report a novel two-step synthesis[2] of the important monoterpene, grandisol (**2**), a key constituent of the male boll weevil pheromone (eq 1).



(1)

1 **2** (grandisol)

A salient feature of the synthesis we report is based upon the remarkable discovery by Heimbach[4] that certain zero-valent nickel complexes are useful for the catalytic production of *cis*-1,2-divinylcyclobutanes from 1,3-dienes.[5]

Thus, 10.0 g (0.0364 mol) of nickel bisacetylacetonate monohydrate was dried overnight at 85° (0.5 mm) and then brought to room temperature and atmospheric pressure with rigorous exclusion of atmospheric oxygen and moisture. To this were added 30 ml of dry toluene (freshly distilled under N_2) and 25.0 g (0.23 mol) of freshly distilled 1,5-cyclooctadiene (COD). After the solid had dissolved, the solution was stirred an additional hour and cooled to $-10°$, and about 3 g of butadiene was added. This was followed by the dropwise addition (6 hr) of 26% $Al(C_2H_5)_3$ in toluene (19.7 ml, 0.038 mol) at -5 to $-10°$. After the addition was completed, the mixture was stirred an additional 4 hr, and the bright yellow crystals of $Ni(COD)_2$ were filtered in a drybox, washed with toluene, and dried *in vacuo*. Yields obtained by this method ranged from 60 to 85%.

The dimerization was carried out by addition of isoprene to a 1:1 mixture of the $Ni(COD)_2$ and tris(2-biphenylyl) phosphite.[6] Best results were obtained when isoprene was present in about a 70:1 molar ratio to nickel. The reaction vessel was sealed with a serum stopper, and the solution was magnetically stirred at room temperature until glpc monitoring indicated a maximization of product formation. The reaction was terminated by addition of 4 mol of triphenyl phosphite/mol of nickel, stirring an additional 30 min and filtering. The filtrate was distilled at 0° (100 mm) into a Dry Ice–acetone trap. After the major portion of the isoprene was removed by distillation, other fractions were collected by successively decreasing the pressure. From these crude distillates the material could be further purified.[7] Thus, the desired cyclobutane **1** was produced in 12–15% efficiency based on reacted isoprene, along with two other compounds identified as 1,5-dimethylcyclooctadiene (**3**) and the vinylcyclohexene (**4**) with the indicated uncertainty about the position of the methyl group. Above room temperature **1** undergoes a Cope rearrangement to give **3**. Surprisingly, no other cyclobutanes were produced in yields exceeding 1%.

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[1] M. Jacobson, "Insect Sex Attractants," Interscience, New York, N. Y., 1965.

[2] Previous syntheses[3] of grandisol have relied upon photochemical formation of the cyclobutane ring.

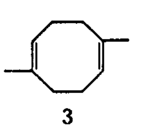
[3] J. H. Tumlinson, D. D, Hardee, R. C. Gueldner, A. C. Thompson, P. A. Hedin, and J. P. Minyard, *Science*, **166**, 1010 (1969); see also *Chem. Eng. News*, **48**, 40 (Jan 26, 1970).

[4] P. Heimbach and W. Brenner, *Angew. Chem., Int. Ed. Engl.*, **6**, 800 (1967).

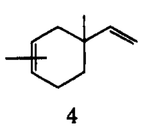
[5] We thank Dr. Heimbach for making available the details of the catalyst preparation.

[6] C. L. Moyle, U. S. Patent 2,220,845 (1940).

[7] Spinning band distillation gave a fraction enriched in 1. Preparative glpc on a 15% Carbowax 20M on 80–100 Chromosorb W column operated at 65° gave pure 1. Its proton nmr spectrum shows signals at δ 1.25 (s, 3 H, methyl), 1.56 (s, 3 H, isopropenyl methyl), ~1.6–2.5 (m, 4 H, cyclopropyl), 2.27 (t, 1 H, allylic), 4.55–5.20 (m, 4 H, terminal methylene), 5.85–6.38 (m, 1 H, vinyl).



3



4

The conversion **1** → **2** was carried out by hydroboration with 1 *M* disiamylborane in THF at 0°. Alkaline peroxide oxidation of the organoborane gave the desired product in 52% yield. Purification was accomplished by preparative glpc on a 6 ft × 0.25 in. 30% SE-30 on 80–100 Chromosorb W column at 120°. The material isolated by this method proved to be identical with an authentic sample.[8]

Finally, the method promises to be useful for the syntheses of various analogs of **2**. Thus, *cis*-2-vinyl-1-cyclobutaneethanol was produced from *cis*-1,2-divinylcyclobutane with disiamylborane.

Acknowledgment. We gratefully acknowledge the Research Corporation for financial support of this work.

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(8) We thank Dr. R. C. Gueldner for providing spectral data and a sample of grandisol. The following 60-MHz nmr spectrum in CCl_4 with a TMS internal reference was observed: δ 1.18 (s, 3 H), ~1.3–2.2 (m, 6 H), 1.68 (s, 3 H), 2.53 (t, 1 H), 2.67 (s, 1 H, a concentration dependent OH), 3.55 (t, 2 H), 6.62 (s, 1 H), and 6.8 (s, 1 H). The identity of this substance was confirmed by comparison of this spectrum with the one provided by Dr. Gueldner and by comparison of its glpc retention time with an authentic sample on an SE-30 column. The structure **1** was further confirmed by bioassaying, which showed activity equal to natural grandisol.

(9) National Defense Education Act Fellow, 1970–present.

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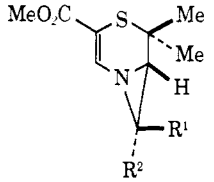
Stereochemical Outcome of a 1,3-Sulfur Migration

Sir:

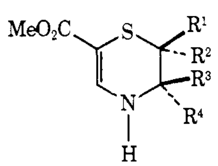
Rearrangements involving novel 1,3-sulfur migrations have recently been observed with certain dihydro-1,4-thiazines.[1] For example, methyl (6*S*)-5,5-dimethyl-4-thia-1-azabicyclo[4.1.0]hept-2-ene-3-carboxylate (**1**) was converted into methyl (3*R*)-3,4-dihydro-3-isopropenyl-2*H*-1,4-thiazine-6-carboxylate (**3**) in boiling toluene. A study of the rearrangement of **1**, specifically monodeuterated at the 7-methylene group, is expected to provide insight into the mechanism of the reaction. We now describe the results of this investigation.

One approach to the synthesis of the specifically labeled aziridine, *e.g.*, **2**, involves the stereoselective reduction of **7** to **10**. A preliminary experiment established that **9**,[2] mp 81–82°, $[\alpha]_D$ +158° ($CHCl_3$), which was prepared (24%) from **11** by the method of Perron, *et al.*,[3] underwent rearrangement[4] to **5** (85%) in the presence of methanolic sodium methoxide. Derivative **5** can be converted into **1** by way of **6**.[1]

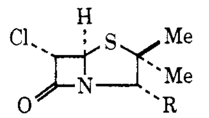
Attempts to prepare **7** by oxidation[5] of **9** and by reduction[6] of **11** were unsuccessful. However, the following route proved to be satisfactory. 6α-Chloropenicillanoyldiazomethane[2] (**12**), mp 93–95° dec, $[\alpha]_D$ +400° ($CHCl_3$), was prepared (76%) from **11** in the usual manner.[7] When heated with 1 *N* sulfuric acid in dioxane, **12** afforded (52% after silica gel chromatography) the syrupy ketol[2] **13**, $[\alpha]_D$ +235° ($CHCl_3$), which was reduced by sodium borohydride to a mixture (3:2 by nmr spectroscopy) of diols **14** (21%). The mixture was fractionated by silica gel chromatography to give the major diol[2] as a syrup, $[\alpha]_D$ +137° ($CHCl_3$), and the minor diol,[2] mp 76–77°, $[\alpha]_D$ +129° ($CHCl_3$). The diols (individually or as a mixture) were oxidatively cleaved by 1 mol equiv of sodium periodate in aqueous dioxane to the syrupy aldehyde **7** (71%), which was reduced to **9** (29%) by actively fermenting yeast.[8]



1, $R^1 = R^2 = H$
2, $R^1 = D; R^2 = H$



3, $R^1 = R^2 = R^4 = H; R^3 = CMe{=}CH_2$
4, $R^1 = R^4 = H; R^2 = D; R^3 = CMe{=}CH_2$
5, $R^1 = R^2 = Me; R^3 = H; R^4 = CH_2OH$
6, $R^1 = R^2 = Me; R^3 = H; R^4 = CH_2OTs$



7, R = CHO
8, R = CDO
9, $R = CH_2OH$
10, R = CHDOH
11, $R = CO_2H$
12, $R = COCHN_2$
13, $R = COCH_2OH$
14, $R = CHOHCH_2OH$
15, $R = CDOHCH_2OH$

Sodium borodeuteride reduction of **13** gave a mixture of the monodeuterated diols **15**, which was converted into **8** by sodium periodate. The last derivative was reduced by Mosher's procedure[8] to **10**, which was transformed into **2**. The aziridine was *ca.* 77% monodeuterated and *ca.* 23% undeuterated on the basis of mass spectroscopy. Nmr spectroscopy corroborated this result (*ca.* 73% monodeuterated) and indicated that the deuterium resided at the 7-exo position[9] [τ ($CDCl_3$) 8.18 (d, 1 H, $J_{6,7\text{-endo}}$ = 3.5 Hz, 7-*endo*-H), 7.70 (d, 0.27 H, $J_{6,7\text{-exo}}$ = 4.6 Hz, 7-*exo*-H), 7.25 (d, 1 H, separation = 3.4 Hz, 6-H)]. On the assumption that the configuration of the exocyclic methylene group of **6** is inverted[10] during the formation of **1**, **10** possesses the *S* configuration, in accord with previous work.[11]

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(1) A. R. Dunn and R. J. Stoodley, *Chem. Commun.*, 1169, 1368 (1969); *J. Chem. Soc., Perkin Trans. 1*, 2509 (1972).

(2) The composition of all new compounds was confirmed by elemental analysis or by mass spectroscopy. Structural assignments are based on ir and nmr evidence.

(3) Y. G. Perron, L. B. Crast, J. M. Essery, R. R. Fraser, J. C. Godfrey, G. T. Holdrege, W. F. Minor, M. E. Neubert, R. A. Partyka, and L. C. Cheney, *J. Med. Chem.*, 7, 483 (1964).

(4) I. McMillan and R. J. Stoodley, *Tetrahedron Lett.*, 1205 (1966); *J. Chem. Soc. C*, 2533 (1968).

(5) C. W. Rees and R. C. Storr, *Chem. Commun.*, 1305 (1968); R. E. Partch, *Tetrahedron Lett.*, 3071 (1964); J. D. Albright and L. Goldman, *J. Amer. Chem. Soc.*, **87**, 4214 (1965); K. E. Pfitzner and J. G. Moffat, *J. Amer. Chem. Soc.*, **87**, 5670 (1965); M. M. Baizer, *J. Org. Chem.*, **25**, 670 (1960).

(6) W. J. Gottstein, G. E. Bocian, L. B. Crast, K. Dadabo, J. M. Essery, J. C. Godfrey, and L. C. Cheney, *J. Org. Chem.*, 31, 1922 (1966).

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(8) V. E. Althouse, K. Veda, and H. S. Mosher, *J. Amer. Chem. Soc.*, **82**, 5938 (1960).

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(11) D. Arigoni and E. L. Eliel, *Top. Stereochem.*, **4**, 127 (1969).