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THE REVISED STEREOSTRUCTURES OF THE DIELS-ALDER ADDUCTS OF 1-CARVONE WITH BUTADIENE

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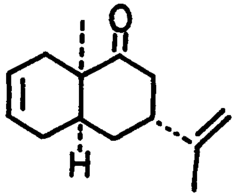
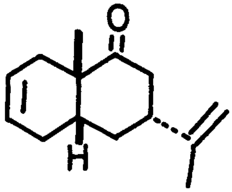
On the Diels-Alder reaction of carvone with butadiene under heating conditions, Nerdel et al. reported that the stereostructure of the major product (in 6% yield) was shown by the formula (Ib) and that of the minor product (in 2% yield) by the formula (Ia).1) This result suggested that addition of butadiene to the dienophile took place predominantly from the same side as that of an isopropenyl group. Recently, we examined the Diels-Alder reaction of 5-methyl-2-cyclohexene-1-one with butadiene in the presence of BF_3 etherate and it was ascertained that addition of butadiene to the dienophile occurred opposite to a secondary methyl group.2) The former result is, therefore, in conflicting with our conclusion prompting us to re-examine the stereostructures of the Diels-Alder adducts reported in the literature.1) The contradiction has now been resolved by revision of the formulas reported in such a way that the structure (Ib) for the major product is replaced by the formula (Ia) and the structure (Ia) for the minor product by the formula (Ib).

Using optically active 1-carvone, the Diels-Alder reaction was carried out under the same reaction condition reported in the literature and two adducts were obtained in the same yield and ratio as those reported.1)

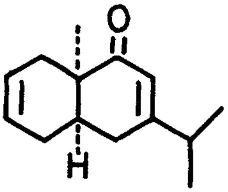
On the other hand, reaction of 1-carvone with butadiene in the presence of $AlCl_3$ (0.1 eq.) provided (Ia)*1 and the α,β-unsaturated ketone (Ic), ν: 1655; δ: 1.10 (6H, d., J=7 Hz), 1.20 (3H, s.) and 5.55-5.85 (3H, m.) in 40% and 3% yields, respectively. In this reaction condition, the compound corresponding to the minor product in the literature1) was not obtained and the



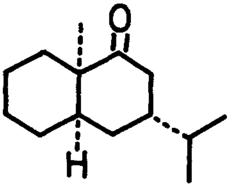
(Ia)



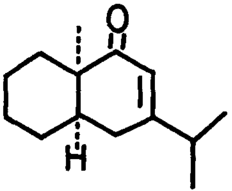
(Ib)



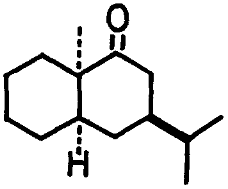
(Ic)



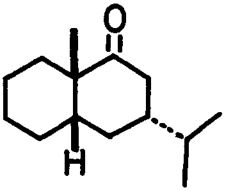
(II)



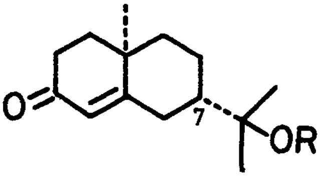
(III)



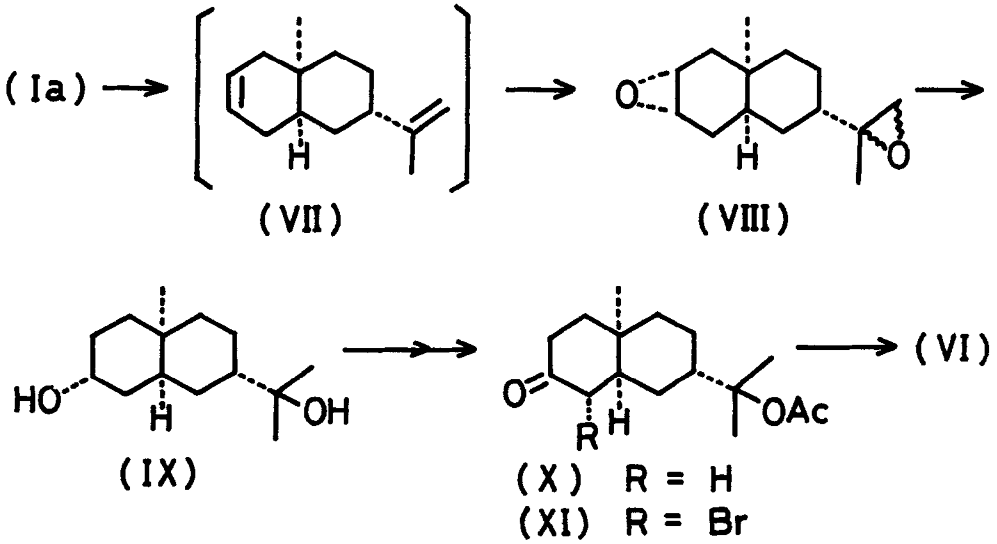
(IV)



(V)



(VI) R = Ac
(XII) R = H



yield of the compound (Ia) corresponding to the major product was improved.

Catalytic hydrogenation of the major product (Ia) over PtO_2 gave the ketone (II), ν: 1690; $[\alpha]_D^{28}$=+57.1° (c=1.0, EtOH), in an 80% yield. Bromination of (II), followed by dehydrobromination with $LiBr-Li_2CO_3$ afforded the α,β-unsaturated ketone (III), ν: 1655; δ: 5.77 (1H, m.); $[\alpha]_D^{26}$=-31.6° (c=1.0, EtOH) in a 61% yield. Catalytic reduction of (III) over PtO_2 provided the ketone (IV), ν: 1690; $[\alpha]_D^{23}$=-79.8° (c=1.0, EtOH) in a good yield. The minor product (Ib) was catalytically hydrogenated over PtO_2 to give the ketone (V), $[\alpha]_D^{25}$= +84.3° (c=0.91, EtOH) in a quantitative yield, which was an antipode of the ketone (IV). It is well known that hydrogen attacks a double bond from the less hindered "convex" face in the cis-decalin derivatives. On the basis of this generally accepted principle, the ketone (IV) could be represented by the formula (IV). Therefore, it seems reasonable to assume that the stereostructure of the major product is represented by the formula (Ia) and that of the minor product by the formula (Ib). On the other hand, the absolute structure of (Ic) was established by conversion of (Ic) to the ketone (IV).

In order to confirm more definitely the above deduction, an attempt was made to convert the major product (Ia) to the compound (VI), the stereostructure of which had been unequivocally established. Tosylhydrazone of (Ia) was reduced to the hydrocarbon (VII), which without isolation was oxidized with m-chloroperbenzoic acid to afford the diepoxide (VIII) in a 25% yield from (Ia). The epoxy ring opening of (VIII) with $LiAlH_4$ gave the diol (IX), mp 141-142°, ν: 3580 and 3430; δ: 0.99 (3H, s.), 1.15 (6H, s.) and 4.11 (1H, m., $W_{1/2}$=7 Hz) in a 60% yield. Oxidation of (IX) with Jones' reagent, followed by acetylation with isopropenyl acetate-p-TsOH provided the acetoxy-ketone (X), mp 75-76°, ν: 1710; δ: 1.04 (3H, s.), 1.41 (3H, s.), 1.43 (3H, s.) and 1.95 (3H, s.), in a 78% yield. Bromination of (X) with Br_2-MgCO_3 afforded the bromo-ketone (XI), mp 122-125°, ν: 1720; δ: 4.83 (1H, d., J=12.5 Hz) in a 40% yield, which was dehydrobrominated to yield the α,β-unsaturated keto-acetate (VI), ν: 1720, 1662 and 1620; δ: 5.75 (1H, broad s.); $[\alpha]_D^{28}$=-94.3° (c=2.0, benzene) in a 41% yield. 2,4-Dinitrophenylhydrazone of (VI) was identical in all respects with an authentic sample.[*2] This fact led us to conclude that the structures of the major product and the minor product should be represented by the formulas, (Ia) and (Ib), respectively. From this conclusion, the Diels-Alder reaction of 2,5-dialkyl-2-cyclohexene-1-one with butadiene will serve as a route for synthesis of the eudesman type sesquiterpenes, in which an angular methyl and an alkyl side chain at C_7 bear a cis relationship.

Moreover, the α,β-unsaturated keto-acetate (VI) was converted to the α,β-unsaturated ketone (XII)[3)], an antipode of which had been transformed to (+)-β-eudesmol.[4)] Synthesis of the α,β-unsaturated keto-acetate (VI), therefore, amounts to a formal synthesis of (-)-β-eudesmol.

Footnotes and References

[*1] All new compounds gave satisfactory analytical and spectroscopic data to support the structures. IR and NMR spectra were measured in $CHCl_3$ and $CDCl_3$, respectively.

[*2] The authors are indebted to Professor F. Fringuelli, Università di Perugia, Perugia, Italy, for providing us with an authentic sample of 2,4-dinitrophenylhydrazone of (VI).

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