REACTIONS OF DIAZOALKANES WITH UNSATURATED COMPOUNDS. 8.* CATALYTIC CYCLOPROPANATION OF ALLYL ALCOHOLS AND ALLYLAMINES WITH DIAZOMETHANE†

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Allyl alcohols and allylamines have been cyclopropanated directly with diazomethane in the presence of palladium compounds to give 60-88% of cyclopropylmethanols and cyclopropylmethylamines, respectively, almost free from the products of formal insertion of methylene into the heteroatom–hydrogen bond.

Palladium compounds have recently found extensive use as catalysts for the cyclopropanation of unsaturated compounds (UC) (hydrocarbons, ketones, and ethers) with diazomethane [3]. Least attention has been paid to UC containing functional groups with labile hydrogen (such as OH and NH), in which side reactions involving the formal insertion of methylene into the heteroatom–hydrogen bond are possible [4].

We have now examined the catalytic cyclopropanation with diazomethane of allyl alcohol (Ia), allyl ethers (Ib)-(Id) and esters (Ie), (If), allylamine (VIa), and its N-alkyl and N-aryl derivatives (VIb), (VIc), together with hexa-1,5-dien-3-ol (III) and acrolein diethyl acetal (VIII). The experiments were carried out at 0-10°C by rapid addition of an ethereal solution of diazomethane or continuous passage of mixture with an inert gas (nitrogen or argon) into a solution of the UC in dichloromethane containing 0.2-0.4 mole% of $(PhCN)_2PdCl_2$ or $Pd(acac)_2$. The cyclopropanation of the UC was followed by GLC and PMR spectroscopy. In most cases, the yields of cyclopropanation products were in accordance with the extent of conversion of the initial UC, increasing as the diazomethane was added. For example, the reaction between equimolar amounts of (Ia) and diazomethane in the presence of $(PhCN)_2PdCl_2$ gave cyclopropylmethanol (IIa) in ~47% yield, but when a two-molar excess of diazomethane was taken, the yield of (IIa) increased to 72%, without the formation of products of formal insertion of methylene into the O–H bond in either the starting or product alcohols.

$$\underset{\text{(I)}}{=\!-CH_2OR} + CH_2N_2 \xrightarrow[CH_2Cl_2,\ 0-10^\circ]{[Pd]} \underset{\text{(II)}}{\rangle\!-CH_2OR}$$

R = H(a), Me(b), Ph(c), C_6H_4Br-m(d), COMe(e), COCH=CHMe–E(f).

However, diazomethane under these conditions undergoes partial conversion into ethylene and cyclopropane, the proportions of which increase as the concentration of the starting UC is reduced.

The cyclopropanation of allyl ethers (Ib), (Ic) and allyl acetate (Ie) in the presence of $(PhCN)_2PdCl_2$ or $Pd(acac)_2$ is highly successful, the yields of cyclopropyl methyl ethers (IIb), (IIc), (IIe) when the UC:diazomethane ratios were ~1:2 amounting to 78-88% (Table 1). As a result of considerable decomposition of the diazomethane, the yield of the cyclopropanation product (IId) from allyl m-bromophenyl ether (Id) under these conditions was ~55%.

Cyclopropanation of allyl crotonate (If), which contains two different C=C bonds, occurred mainly at the monosubstituted (allyl) double bond to give ~50% of cyclopropylmethyl crotonate (IIf) (Table 1). There was also formed in this reaction 20-30% of high-boiling residue, apparently arising from 1,3-dipolar cycloaddition of diazomethane to the C=C bond of the acid moiety and subsequent reaction of this adduct.

*For previous communication, see [1].
†For preliminary report, see [2].

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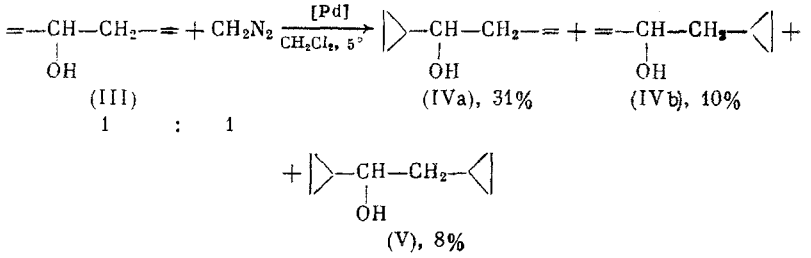
TABLE 1. Cyclopropanation of Allyl Alcohols and Allylamines with Diazomethane in the presence of $(PhCN)_2PdCl_2$

Starting UC	Molar ratio, UC:CH_2N_2	Reaction product	Yield, %	Bp, °C (p, mm Hg)	PMR spectrum, δ CH_2, ppm (in CCl_4)	
					=—CH_2	▷—CH_2
(Ia)	1:1 1:2	(IIa)	47 72	122–123	4.05 d.t	3.32 d
(Ib)	1:2	(IIb)	78	76–78	3.81 d.t	3,09 d
(Ic)	1:2	(IIc)	88	90–92(10)	4.40 d.t	3.68d
(Id)	1:2	(IId)	55	84–86(1)	4.42d.t	3.71d
(Ie)	1:1 1:2	(IIe)	49 81	131–133	4.49 d.t	3,80d
(If)	1:2	(IIf)	48	90–92(20)	4.51d.t	3,92d
(VIa)	1:2	(VIIa)	65	83–85	3.22d.t	2,52 d
(VIb)	1:2	(VIIb)	68	98–100	2.89 d.t	2,08 d
(VIc)	1:2	(VIIc)	62	68–71(2)	3,56 d.t	2,90 d

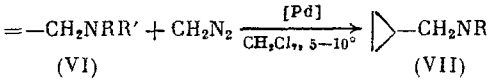
In order to compare the reactivities of the double bonds located in the allyl and homoallyl positions relative to the OH group, the cyclopropanation of hexa-1,5-dien-3-ol (III) with diazomethane in the presence of 0.2 mole% of $(PhCN)_2PdCl_2$ has been examined. Reaction of equimolar amounts of (III) and diazomethane afforded a mixture of the mono- (IV) and dicyclopropanation products (V), the principle product being, according to the PMR spectra of the compounds, the cyclopropylbuten-1-ol (IVa), isolated by preparative GLC (Carbowax 20M, 150°C), indicating that cyclopropanation occurs preferentially at the vinyl double bond in (III).



(III) 1 : 1 (IVa), 31% (IVb), 10%

(V), 8%

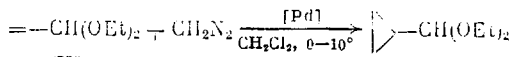
The allylamine (VIa) and its derivatives (VIb), (VIc) are also cyclopropanated with diazomethane in the presence of $(PhCN)_2PdCl_2$ to give the cyclopropylmethylamines (VII) in yields of 62-68%, using a twofold molar excess of diazomethane (Table 1). Under these conditions, however, the rate of decomposition of the diazomethane was somewhat lower than in the cyclopropanation of the oxygen-containing allyl compounds, evidently as a result of the further contribution of the amino group to the formation of a complex with the catalyst. For this reason, in order to ensure a moderate rate of decomposition of the diazomethane, a larger amount of catalyst was required (0.6-1.0 mole%).



(VI) (VII)

R = R' = H(a), Me(b); R = H, R' = Ph(c).

A convenient method for the preparation of formylcyclopropane acetals has also been developed, based on the catalytic cyclopropanation of unsaturated compounds. For example, the reaction of acrolein diethyl acetal (VIII) with a twofold excess of diazomethane in the presence of $(PhCN)_2PdCl_2$ gives formylcyclopropane diethyl acetal (IX) in a yield of 77-80% and, in this case as before, unreacted starting material can be recovered almost completely by fractionation of the reaction mixture.



(VIII) 1 : 2 (IX), 77–80%

This method of preparation of (X) is undoubtedly to be preferred over the synthesis involving the intermediate formation and subsequent thermal decomposition of the appropriate pyrazoline, obtained by prolonged keeping of a mixture of acrolein acetal and diazomethane in the absence of a catalyst [5].

EXPERIMENTAL

The reaction mixtures were analyzed by GLC on an LKhM-8MD chromatograph with an I-02 integrator (columns 300 × 0.3 cm with 5% SE-30 or 5% Carbowax 20M on Inerton AW-DMCS, 0.125-0.16 mm, carrier gas helium, 30 ml/min). Preparative separations were carried out on an LKhP-7I chromatograph (200 × 1.2 cm column with 10% Carbowax 20M on Inerton AW-DMCS, 0.25-0.315 mm, carrier gas argon, 340 ml/min). PMR spectra were obtained on Tesla BS-467 (60 MHz) as 0.6-0.7 M solutions in CCl_4 and Jeol-FX-90Q (90 MHz) spectrometers as 0.3-0.4 M solutions in $CDCl_3$, chemical shifts being given on the δ scale relative to TMS as internal standard.

Diazomethane was obtained by alkaline hydrolysis of nitrosomethylurea (NMU) and the reactions were carried out with a gaseous mixture of diazomethane and nitrogen or argon [6] or with a 0.6 M solution in ether. The unsaturated compounds (UC) used were first dried over Na_2SO_4, then distilled.

General Method of Cyclopropanation of Oxygen-Containing Allyl Compounds (I), (VI), (VIII). To a solution of 0.03 mole of the UC and 0.03-0.05 g of $(PhCN)_2PdCl_2$ or $Pd(acac)_2$ in 5 ml of dichloromethane was added at 0-10°C over 30-40 min an approximately equimolar amount of diazomethane, obtained from 5.1 g of NMU. In the case of allylamines, the catalyst was added in 4-5 portions of 0.15-0.2 g during the course of the reaction. The mixture was then filtered through a thin layer of silica gel, washed with ether, and fractionated. The yields and some properties of the resulting cyclopropylmethyl derivatives are given in Table 1.

The products cyclopropylmethanol (IIa) [7], methoxymethylcyclopropane (IIb) [8], phenoxymethylcyclopropane (IIc) [9], cyclopropylmethyl acetate (IIe) [7], aminomethylcyclopropane (VIIa) [10], dimethylaminomethylcyclopropane (VIIb) [11], and formylcyclopropane diethyl acetal (IX) [12] were identified by comparison of their properties with those reported in the literature.

m-Bromophenoxymethylcyclopropane (IId). PMR spectrum (δ, CCl_4): 6.98 and 6.70 m (4H, C_6H_4), 3.71 d (2H, J = 6.5 Hz, OCH_2), 1.12 m (1H, CH in cyclo-C_3H_5), 0.60 and 0.35 m (4H, CH_2CH_2).

E-Cyclopropylmethyl Crotonate (IIf). PMR spectrum (δ, $CDCl_3$): 6.96 d.q (1H, J_{trans} = 15.5 Hz, J = 6.7 Hz, =CH), 5.72 d.q (1H, J = 15.5 Hz and 1.6 Hz, =CHCO), 3.96 d (2H, J = 6.6 Hz, OCH_2), 1.88 d.d (3H, J = 6.7 Hz and 1.6 Hz, CH_3), 1.11 m (1H, CH in cyclo-C_3H_5), 0.58 and 0.34 m (4H, CH_2CH_2).

N-Cyclopropylmethylaniline (VIIc). PMR spectrum (δ, CCl_4): 7.0 and 6.49 m (2H and 3H, C_6H_5), 3.4 br. s (1H, NH), 2.90 d (2H, J = 6.6 Hz, NCH_2), 1.01 m (1H, CH in cyclo-C_3H_5), 0.50 and 0.25 m (4H, CH_2CH_2).

Cyclopropanation of Hexa-1,5-dien-3-ol (III). This was carried out as for the general method of cyclopropanation of allyl compounds, using equimolar amounts of the reactants. After removal of the solvents, the residue was distilled in vacuo and fractions with bp 70-75°C (40 mm) and 85-89°C (40 mm) containing the main mono- and dicyclopropanation products were separated by preparative GLC (Carbowax 20M, 150°C).

1-Cyclopropylbut-3-en-1-ol (IVa). PMR spectrum (δ, $CDCl_3$): 5.83 m (1H, =CH), 5.10 m (2H, $=CH_2$), 2.90 d.t (1H, J = 7.6 and 6.0 Hz, OCH), 2.34 m (2H, CH_2), 1.90 br. s (1H, OH), 0.86 m (1H, CH in cyclo-C_3H_5), 0.48 and 0.29 m (4H, CH_2CH_2).

1-Cyclopropylbut-3-en-2-ol (IVb). PMR spectrum (δ, $CDCl_3$): 5.90 d.d.d (1H, J_{trans} = 16.8 Hz, J_{cis} = 9.2 Hz, J = 6.0 Hz, =CH), 5.24 d.t and 5.10 d.t (2H, J = 16.8, 9.2, and 1.5 Hz, $=CH_2$), 4.20 br.q (1H, J = 6.2 Hz, OCH), 2.12 br.s (1H, OH), 1.47 t (2H, J = 6.5 Hz, CH_2), 0.78 m (1H, CH in cyclo-C_3H_5), 0.48 and 0.12 m (4H, CH_2CH_2).

1,2-Dicyclopropylethanol (V). PMR spectrum (δ, $CDCl_3$): 2.99 d.t (1H, J = 7.6 and 6.0 Hz, OCH), 1.80 br. s (1H, OH), 1.51 t (2H, J = 6.5 Hz, CH_2), 0.95 and 0.88 m (2H, CH in two cyclo-C_3H_5), 0.50, 0.29, and 0.12 m (8H, CH_2 in two cyclo-C_3H_5).

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DICOBALT HEXACARBONYL COMPLEXES OF CONJUGATED ENYNES AS EQUIVALENTS OF TETRADENTATE SYNTHONS FOR THE PREPARATION OF BICYCLO[3.3.0]OCTANES

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A method has been developed for the acylation of dicobalt hexacarbonyl (DCHC) complexes of conjugated enynes with α,β-unsaturated acylium salts as a general route to DCHC complexes of 3-keto-1,6-enynes. Conditions have been found for the selective Grignard reaction or hydride reduction of the carbonyl group of the latter. The method has been found to be applicable to [2+2+1]-cycloaddition at a sorbent surface for the DCHC complexes of a variety of functionally substituted 1,6-enyne substrates. A novel convergent strategy is proposed for the synthesis of substituted bicyclo[3.3.0]octanes by steps involving cationic acylation of the DCHC complexes of conjugated enynes with α,β-unsaturated acylium salts, modification of the carbonyl function in the resulting adducts and intramolecular [2+2+1]-cycloaddition.

Bicyclo[3.3.0]octanes (BCO) are key intermediates in the synthesis of naturally occurring polycyclopentanoids and their synthetic analogs [1]. Only a few such compounds, however, are readily accessible and, in most cases, the preparation of BCO with the required structure constitutes an independent synthetic problem [1].

One of the shortest routes to BCO derivatives is by intramolecular cyclization of dicobalt hexacarbonyl (DCHC) complexes of 1,6-enynes ([2+2+1]-cycloaddition, the Khand–Pauson reaction [2]), enabling the acyclic substrate to be converted in one step into a bicyclic product [3] (Scheme 1).

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