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Naphthalene-Catalysed Lithiation of 3-Chloro-2-chloromethylpropene in a Barbier-Type Process with Carbonyl Compounds[1]

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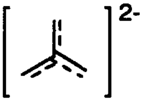
Abstract: The reaction of 3-chloro-2-chloromethylpropene (**1**) and carbonyl compounds (**2**) with an excess of lithium powder in the presence of a catalytic amount of naphthalene (6%) in tetrahydrofuran at -78 to 20°C leads, after hydrolysis, to the corresponding methylenic 1,5-diols **3** in a Barbier-type process. The treatment of the crude diols **3** with 12 M hydrochloric acid affords selectively the corresponding substituted dihydropyrans **6**.

Introduction

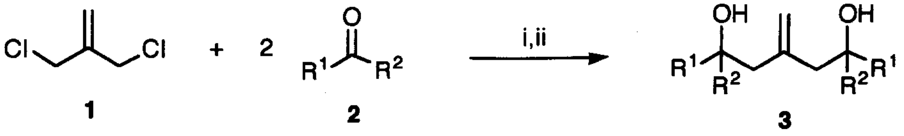
The trimethylenemethane dianion **I** has been subject of great attention not only due to its theoretical interest, in relation to the so-called acyclic "Y-aromacity", but also from a synthetic point of view: its reaction with electrophilic reagents yields directly polyfunctionalized molecules[2]. Thus, this intermediate **I** has been prepared by double deprotonation of isobutylene (using *n*-butyllithium/tetramethylethylenediamine[3] or *n*-butyllithium/potassium *t*-butoxide[4]) and used in the preparation of different functionalized compounds by reaction with electrophiles such as mono-[3a-c,4c] or di-haloalkanes[3d], carbonyl compounds[4c], epoxides[4c] and nitriles[4e]. However, when 3-chloro-2-chloromethylpropene was used as starting material for the preparation of the dianion **I** by chlorine-lithium exchange the reaction fails due to the decomposition of the monolithiated intermediate initially generated[4c]. On the other hand, and following our continous interest on functionalized organolithium compounds[5], we have recently developed a new procedure for the lithiation of different substrates at low temperature, which involves the use of an excess of lithium powder and a catalytic amount of an arene, naphthalene being the most commonly used[6], This methodology has made possible the obtention of very reactive organolithium intermediates by chlorine-lithium[6,7] or sulphur-lithium[6,8] exchange and other related processes, such as reductive cleavage of tetrahydrofuran[9a], sulfonates [9b] and sulfates[9c], aziridines[9d] or the obtention of *C,O*-dilithiated diarylmethanols[9e]. In this paper we describe a solution to the problem of preparing the dilithiated dianion of the type **I** from 3-chloro-2-chloromethylpropene[10] by combining the above described naphthalene-catalysed lithiation at low temperature with a Barbier-type process[11] in the presence of a carbonyl compound as electrophilic reagent[1,12].



I

Results and Discussion

The reaction of a mixture of 3-chloro-2-chloromethylpropene (**1**) and a carbonyl compound (**2**, 1:2 molar ratio) with an excess of lithium powder (1:6 molar ratio) and a catalytic amount of naphthalene (1:0.06 molar ratio) in tetrahydrofuran at -78 to 20°C led, after hydrolysis with water, to the corresponding methylenic 1,5-diols **3** (Scheme 1 and Table 1). When aldehydes were used as electrophiles, the corresponding mixture of the two possible diastereoisomers (*ca.* 1:1, by 300 MHz ^{1}H NMR) were obtained (Table 1, entries 1 and 2). In the case of carrying out the reaction as above but in absence of the carbonyl compound the only reaction product isolated was 1,4-dimethylenecyclohexane (**4**)[13] in 88% isolated yield[14].



Scheme 1. *Reagents and conditions*: i, Li powder (1:6)-$C_{10}H_8$ (1:0.06), THF, -78 to 20°C; iii, H_2O.

Table 1. Preparation of 1,5-Diols **3**

	Carbonyl compound		Product[a]		
Entry	R^1	R^2	no.	yield (%)[b]	m.p. (°C)[c]
1	H	*i*-Pr	**3a**[d]	64	-[e]
2	H	Ph	**3b**[d]	73	-[e]
3	Me	Me	**3c**	74	77-79
4	Et	Et	**3d**	72	57-59
5	*c*-C_3H_5	*c*-C_3H_5	**3e**	81	61-63
6	*i*-Pr	*i*-Pr	**3f**	75	78-80
7	-$[CH_2]_4$-		**3g**	89	75-77
8	-$[CH_2]_5$-		**3h**	67	78-80
9	-$[CH_2]_7$-		**3i**	78	107-109

[a] All products were >95% pure (GLC and ^{1}H NMR). [b] Isolated yield after flash chromatography (silica gel, hexane/ethyl acetate) based on the starting carbonyl compound **2**. [c] From hexane/ethyl acetate. [d] Mixture of two diastereoisomers (*ca.* 1:1 from ^{1}H NMR). [e] Oil.

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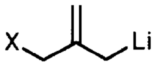
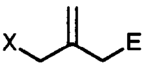
From a mechanistic point of view, the reaction described in the Scheme 1 can follow two possible ways: (a) after the first lithiation, the monolithiated intermediate **II** reacts with the electrophile to give the corresponding compound **V**, which in a new tandem lithiation-condensation, through the intermediate **III**, affords the final product **3** of the type **VI**; (b) the intermediate **II** suffers a second lithiation to the dilithiated intermediate **IV**, which reacts with the electrophile to give the same reaction product **VI**. At this point we do not know the actual mechanism for the reaction; an argument in favour of the way (b), through the dilithiated species **IV** could be that when the reaction is carried out with a deficiency of electrophile, for instance 3-pentanone (1:1 molar ratio), under the same reaction conditions, only a mixture (*ca.* 1:1 from GLC) of the corresponding products **3d**, of the type **VI**, and **4** was isolated (80-90% global yield); product of the type **VII**, resulting from **III** by the final hydrolysis, was never detected.



II: X=Cl
III: X=E
IV: X=Li



V : X=Cl
VI: X=E
VII: X=H

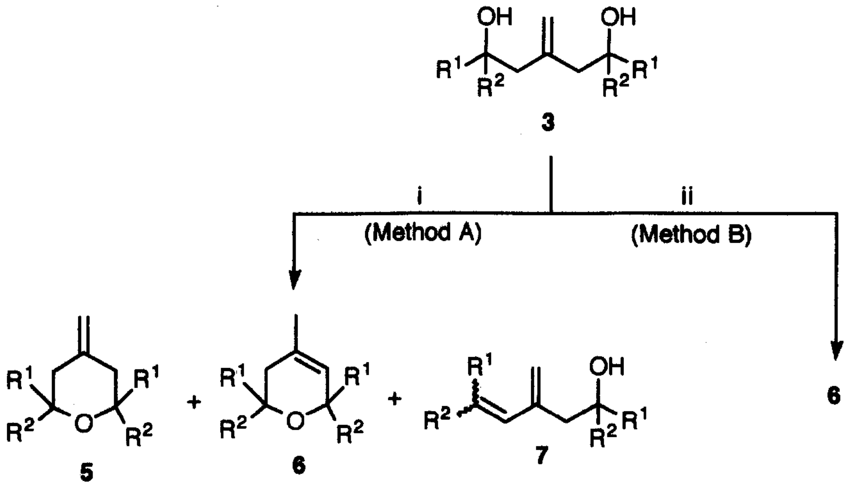
We also studied the preparation of other dianions of the type **I** derived from less electropositive metals than lithium, such as copper or zinc[15]. Thus, copper(I) bromide was treated at -78°C with an excess of lithium powder and a catalytic amount of naphthalene (*vide supra*) and after 10 min the starting material **1** was added (CuBr:**1**=2:1 molar ratio); after 30 min, 3-pentanone (1:2 molar ratio) was added and after the corresponding work-up compound **3d** was isolated in 51% yield (Table 2, entry 2); longer or shorter reaction times gave poorer yields (see, for instance, Table 2, entries 3 and 4). In absence of the metallic salt only coupling product **4** was isolated (Table 2, entry 1 and footnote c). On the other hand, the use of activated zinc (prepared from zinc dichloride under the above described reaction conditions) gave very poor yield (Table 2, entry 5).

In the last part of this paper we study the dehydration of the obtained crude 1,5-diols **3** under acidic conditions. The treatment of compounds **3** with 6 M hydrochloric acid (method A) afforded, in general, a mixture of products **5**-**7** (Scheme 2 and Table 3, entries 1, 3, 5, 7, 9, 10 and 12). However, when the same process was carried out with 12 M hydrochloric acid (method B) the products **6** were the only ones obtained, generally (Scheme 2 and Table 3, entries 2, 4, 6, 8, 11 and 13). Some interesting features of both processes are: (a) all products obtained have been separated in pure form by flash chromatography, except in the case of the mixture **5i**+**6i**, due to the small proportion of both components. (b) In all cases the thermodynamically most stable product (see method B) is the corresponding dihydropyran **6**, except in the case of the dicyclopropylketone and cyclooctanone derivatives, in which products **5e** and **8** were obtained, respectively, in an exclusive manner

Table 2. Use of Activated Copper or Zinc in the Reaction of Compound **1** with 3-Pentanone

Entry	Metallic salt	Reaction time[a]	Compound **3d** yield (%)[b]
1	-	1 h	0[c]
2	CuBr	30 min	51
3	CuBr	1 h	39[d]
4	CuBr	3 h	17
5	$ZnCl_2$	1 h	4

[a] Reaction time after addition of the starting material **1** and until the addition of 3-pentanone. [b] Isolated yield based on the amount of 3-pentanone used. [c] A 88% yield of compound **4** was obtained (see ref 14). [d] 0% yield when the temperature was allowed to rise to 20°C after addition of the starting material **1**.



Scheme 2. *Reagents and conditions*: i, 6 M HCl-Et_2O; ii, 12 M HCl-Et_2O.

(Table 3, entries 4 and 13). (c) It seems that compounds of the type **7** are initially formed: we could isolate products **7g** and **7h** only working by method A in short reaction times (Table 3, entries 7 and 9), but with longer reaction times only products **5** and **6** were obtained (compare Table 3, entries 9 and 10), so meaning that the transformation **7**→**5**+**6** takes place. (d) Under long reaction times and/or more concetrated hydrochloric acid the conversion of tetrahydropyrans **5** into the corresponding dihydropyrans **6** occurs (for instance, Table 3, entries 1 and 2); the exceptions to this behaviour are compounds **5e** and **8** (Table 3, entries 3, 4 and 12, 13); in the case of compound **6f**, it was exclusively obtained either by method A or B.

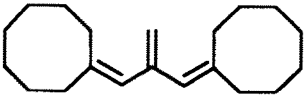


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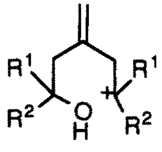
Table 3. Preparation of Compounds **5**-**8**

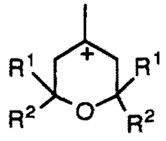
Entry	Diol **3**	Method	Reaction time (h)	Products [yield (%)][a]
1	**3d**	A	4	**5d** [25], **6d** [30]
2	**3d**	B	24	**6d** [75]
3	**3e**	A	1	**5e** [81]
4	**3e**	B	24	**5e** [80]
5	**3f**	A	24	**6f** [63]
6	**3f**	B	24	**6f** [65]
7	**3g**	A	2	**5g** [30], **6g** [14], **7g** [44]
8	**3g**	B	24	**6g** [84]
9	**3h**	A	5	**5h** [15], **6h** [5], **7h** [47]
10	**3h**	A	24	**5h** [28], **6h** [39]
11	**3h**	B	24	**6h** [66]
12	**3i**	A	24	**5i** [3][b]+**6i** [3][b], **8** [71]
13	**3i**	B	24	**8** [76]

[a] Isolated overall yields of pure compounds (>95%, GLC and ^{1}H NMR) after flash chromatography (silica gel, hexane/ethyl acetate) based on the starting carbonyl compound **2**, precursor of the crude diol **3** used in the dehydration process. [b] The mixture of compounds **5i**+**6i** could not be separated by flash chromatography.

With the above results in hand we think that the first carbenium ion generated **VIII** suffers rapid elimination of a proton to give the dienic alcohols **7**. However, this is a reversible process, so the carbocation **VIII** can also undergo intramolecular nucleophilic attack to give the first formed tetrahydropyran **5**. When the reaction time is long and/or the reaction conditions are more acidic, compound **5** suffers protonation to the intermediate carbenium ion of the type **IX**, which losses a proton again giving the most stable endocyclic olefin **6**.



VIII



IX

From the results described in this paper we conclude that the here described methodology is an adequate and easy way for methylenic 1,5-diols **3**. Moreover, the dehydration of these compounds affords tetra and dihydropyrans, which are common structural elements in many biologically active natural products[16].

Experimental Part

General.- M.p.s are uncorrected and were measured on a Reichert thermovar apparatus. IR spectra were determined with a Pye Unicam SP3-200 spectrometer. ^1H and ^{13}C NMR spectra were recorded in a Bruker AC-300 using $CDCl_3$ as solvent and $SiMe_4$ as internal standard; chemical shifts are given in δ (ppm) and the coupling constants (J) are measured in Hz. MS (EI) were recorded with a Hewlett Packard EM/CG HP-5988A spectrometer. The purity of volatile destilled products and the chromatographic analyses (GLC) were determined with a Hewlett Packard HP-5890 instrument equipped with a flame ionization detector (FID) and a 12 m HP-1 capillary column (0.2 mm diam., 0.33 µm film thickness), using nitrogen (2 ml/min) as the carrier gas, $T_{injector}$=270°C, T_{column}=60°C (3 min) and 60-270°C (15°C/min); retention times (t_r) are given under this condition. Thin layer chromatography (TLC) was carried out on Scheleicher & Schnell F1500/LS 254 plates coated with a 0.2 mm layer of silica gel, using hexane or a mixture of hexane/ethyl acetate as eluant; R_f values are given under these conditions. Microanalyses were performed by the Microanalyses Service of the University of Alicante. Solvents were dried by standard procedures[17]. Starting 3-chloro-2-chloromethylpropene, electrophiles as well as the other reagents were commercially available (Aldrich, Fluka) and were used as received.

Preparation of 1,5-Diols **3** *and 1,4-Dimethylenecyclohexane* **4**. *General Procedure*.- To a green suspension of lithium powder (14 mmol) and naphthalene (0.06 mmol) in tetrahydrofuran (10 ml) was added a mixture of the corresponding carbonyl compound **2** (5 mmol) and 3-chloro-2-chloromethylpropene **1** (2.5 mmol) at -78°C and the resulting solution was stirred for 2 h at the same temperature. Stirring was continued overnight allowing the temperature to rise to 20°C. The resulting mixture was then hydrolyzed with methanol, neutralized with 2 M HCl and extracted with diethylether (2 x 10 ml). The organic layer washed with water, dried over anhydrous Na_2SO_4 and evaporated (15 Torr). The resulting residue was purified by flash chromatography (silica gel, hexane/ethyl acetate) to afford the corresponding products **3**. In the case of performing the reaction with activated copper or zinc (see text) the corresponding salt (see Table 2) was added 10 min before the addition of the starting material **1** at -78°C; after 0.5-3 h (Table 2) 3-pentanone was added and the mixture worked-up as it was above described for compounds **3** giving the expected product. Compound **4** was isolated by the same procedure as for **3** but performing the reaction without the carbonyl compound. Yields and melting points are summarized in Tables 1 and 2. Other physical, analytical and spectral data follow. In the case of known compounds, their data are in full agreement with those reported in the literature.

2,8-Dimethyl-5-methylenenonan-3,7-diol (**3a**): t_r=10.68 min[18], R_f=0.47[18] (hexane/ethyl acetate: 3/2); ν_{max} (film) 3360 (OH), 3060, 1630 (CH_2=C) and 1050 cm^{-1} (C-O); δ_H 0.80-1.10 (12 H, m, 4xMe), 1,60-1.75 (2 H, m, 2xCH), 2.00-2.15, 2.20-2.35 (4 H, 2 m, 2xCH_2CO), 2.85 (2 H, s, 2xOH), 3.40-3.60 (2 H, m, 2xCHO), 4.98 and 4.99 (2 H, 2 s, CH_2=C); δ_C 17.3 (2 C), 17.7 (2 C), 18.4 (2 C), 18.55 (2C), 33.4 (2 C), 33.5 (2 C), 40.15 (2 C), 41.25 (2 C), 73.75, 74.85, 114.45, 114.95, 144.5 and 145.15; *m/z* 157 (M^+-43, 1%), 145 (33), 95 (100), 81 (20), 73 (68), 69 (17), 68 (23), 67 (15), 57 (11), 56 (12), 55 (45), 43 (31) and 41 (29). Anal calcd. for $C_{12}H_{24}O_2$·1/3 H_2O: C, 69.86; H, 12.05. Found: C, 69.7; H, 11.7.

3-Methylene-1,5-diphenylpentan-1,5-diol (**3b**)[4c]: t_r=17.21 min[18], R_f=0.40[18] (hexane/ethyl acetate: 3/2); ν_{max} (film) 3340 (OH), 3060, 1630 (CH_2=C), 3020, 1600 (Ph) and 1050 cm^{-1} (C-O); δ_H 2.35-2.55 (4 H, m, 2xCH_2CO), 2.90 (2 H, s, 2xOH), 4.60-4.85 (2 H, m, 2xCHO), 5.00, 5.10 (2 H, 2 s, CH_2=C) and 7.05-7.45

(10 H, m, 2xPh); δ_C 46.0 (2 C), 46.35 (2 C), 72.15 (2 C), 72.8 (2 C), 116.2, 116.4, 125.7 (4 C), 126.95 (2 C), 127.45 (4 C), 127.95 (2 C), 128.35 (4 C), 128.4 (4 C), 142.85, 143.1, 144.0 (2 C) and 144.05 (2 C); *m/z* 250 (M^+-18, 2%), 144 (72), 143 (10), 130 (12), 129 (100), 128 (10), 107 (81), 105 (20), 104 (18), 91 (10), 79 (66), 78 (11), 77 (63) and 51 (12).

2,6-Dimethyl-4-methyleneheptan-2,6-diol (**3c**)[4c]: t_r=8.13 min, R_f=0.20 (hexane/ethyl acetate: 3/2); ν_{max} (melted) 3300 (OH), 3060, 1630 (CH_2=C) and 1130 cm^{-1} (C-O); δ_H 1.22 (12 H, s, 4xMe), 2.39 (4 H, s, 2xCH_2CO), 3.25 (2 H, s, 2xOH) and 4.91 (2 H, s, CH_2=C); δ_C 29.85 (4 C), 49.75 (2 C), 70.83 (2 C), 117.65 and 144.25; *m/z* 142 (M^+-30, 1%), 123 (34), 98 (32), 85 (13), 83 (78), 81 (11), 70 (12), 59 (100), 58 (12), 57 (15), 56 (81), 55 (19), 43 (58) and 41 (21).

3,7-Diethyl-5-methylenenonan-3,7-diol (**3d**): t_r=12.06 min, R_f=0.44 (hexane/ethyl acetate: 4/1; ν_{max} (melted) 3320 (OH), 3060, 1630 (CH_2=C) and 960 cm^{-1} (C-O); δ_H 0.84 (12 H, t, *J*=7.45, 4xMe), 1.45 (8 H, q, *J*=7.45, 4xC*H*$_2$Me), 2.42 (4 H, s, 2xCH_2=CC*H*$_2$), 3.45 (2 H, s, 2xOH) and 4.85 (2 H, s, CH_2=C); δ_C 7.85 (4 C), 31.2 (4 C), 44.5 (2 C), 74.75 (2 C), 117.25 and 144.3; *m/z* 199 (M^+-29, 1%), 181 (20), 163 (66), 124 (39), 109 (52), 105 (17), 96 (10), 95 (92), 87 (97), 82 (11), 81 (12), 69 (29), 67 (15), 57 (100), 55 (15), 45 (45), 43 (19) and 41 (26). Anal cald. for $C_{14}H_{28}O_2 \cdot 1/4\ H_2O$: C, 72.21; H, 12.23. Found: C, 72.2; H, 11.8.

1,1,5,5-Tetracyclopropyl-3-methylenepentan-1,5-diol (**3e**): t_r=14.57 min, R_f=0.63 (hexane/ethyl acetate: 3/2); ν_{max} (melted) 3440 (OH), 3060, 1680 (CH_2=C) and 1020 cm^{-1} (C-O); δ_H 0.25-0.50 (16 H, m, 4xCH_2 ring), 0.75-0.90 (4 H, m, 4xCHCO), 1.91 (2 H, s, 2xOH), 2.57 (4 H, s, 2xCH_2CO) and 4.97 (2 H, s, CH_2=C); δ_C -0.35 (4 C), 0.8 (4 C), 18.95 (4 C), 49.15 (2 C), 70.85 (2 C), 117.65 and 144.2; *m/z* 240 (M^+-36, <1%), 148 (73), 111 (91), 107 (16), 106 (15), 105 (25), 93 (15), 92 (13), 91 (38), 79 (34), 77 (16), 69 (100), 67 (10), 55 (26), 53 (12) and 41 (81). Anal cald. for $C_{18}H_{28}O_2$: C, 78.21; H, 10.21. Found: C, 78.3; H, 10.1.

3,7-Diisopropyl-2,8-dimethyl-5-methylenenonan-3,7-diol (**3f**): t_r=14.34 min, R_f=0.30 (hexane/ethyl acetate: 9/1); ν_{max} (melted) 3400 (OH), 3060, 1620 (CH_2=C) and 1150 cm^{-1} (C-O); δ_H 0.96 (24 H, d, *J*=7.0, 8xMe), 1.90 (4 H, septet, *J*=7.0, 4xCH), 2.56 (4 H, s, 2xCH_2CO), 2.90 (2 H, s, 2xOH) and 4.88 (2 H, s, CH_2=C); δ_C 17.8 (4 C), 18.1 (4 C), 35.05 (4 C), 40.55 (2 C), 78.3 (2 C), 117.65 and 147.5; *m/z* 241 (M^+-41, <1%), 153 (17), 137 (17), 115 (20), 109 (24), 97 (14), 71 (100), 55 (15), 43 (87) and 41 (17). Anal cald. for $C_{18}H_{36}O_2$: C, 75.99; H, 12.76. Found: C, 76.0; H, 12.8.

1-[3-(1-Hydroxycyclopentyl)-2-methylenepropyl]cyclopentan-1-ol (**3g**): t_r=13.45 min, R_f=0.44 (hexane/ethyl acetate: 3/2); ν_{max} (melted) 3360 (OH), 3060, 1620 (CH_2=C) and 1000 cm^{-1} (C-O); δ_H 1.50-1.90 (16 H, m, 8xCH_2 ring), 2.48 (4 H, s, 2xC*H*$_2$C=CH_2), 3.14 (2 H, s, 2xOH) and 4.93 (2 H, s, CH_2=C); δ_C 23.25 (4 C), 39.75 (4 C), 47.5 (2 C), 81.75 (2 C), 116.65 and 144.95; *m/z* 206 (M^+-18, 2%), 177 (27), 149 (15), 122 (71), 108 (13), 107 (78), 103 (15), 94 (25), 93 (55), 91 (11), 85 (100), 81 (12), 80 (13), 79 (30), 77 (11), 67 (76), 57 (23), 56 (14), 55 (68), 53 (11), 43 (22) and 41 (46). Anal cald. for $C_{14}H_{24}O_2 \cdot 1/4\ H_2O$: C, 73.48; H, 10.79. Found: C, 73.5; H, 10.6.

1-[3-(1-Hydroxycyclohexyl)-2-methylenepropyl]cyclohexan-1-ol (**3h**): t_r=15.15 min, R_f=0.33 (hexane/ethyl acetate: 4/1); ν_{max}(melted) 3280 (OH), 3060, 1630 (CH_2=C) and 980 cm^{-1} (C-O); δ_H 1.15-1.75 (20 H, m, 10xCH_2 ring), 2.38 (4 H, s, 2xC*H*$_2$C=CH_2), 2.95 (2 H, s, 2xOH) and 4.91 (2 H, s, CH_2=C); δ_C 22.25 (4 C), 25.55 (2 C), 38.0 (4 C), 48.25 (2 C), 71.4 (2 C), 117.45 and 143.15; *m/z* 252 (M^+, <1%), 136 (71), 122 (16), 121 (67), 117 (20), 107 (16), 100 (12), 99 (100), 94 (24), 93 (20), 81 (80), 80 (12), 79 (24), 69 (16), 67 (11), 55 (46), 43 (19), 42 (10) and 41 (31). Anal cald. for $C_{16}H_{28}O_2 \cdot 1/4\ H_2O$: C, 74.81; H, 11.18. Found: C, 74.9; H, 11.0.

1-[3-(1-Hydroxycyclooctyl)-2-methylenepropyl]cyclooctan-1-ol (**3i**): t_r=17.34 min, R_f=0.36 (hexane/ethyl acetate: 9/1); ν_{max} (KBr) 3380 (OH), 3060, 1630 (CH_2=C) and 1020 cm^{-1} (C-O); δ_H 1.40-1.70 (28 H, m, 14xCH_2 ring), 2.32 (4 H, s, 2xC*H*$_2$C=CH_2), 2.43 (2 H, s, 2xOH) and 4.84 (2 H, s, CH_2=C); δ_C 22.25 (4 C), 24.9 (2 C), 28.25 (4 C), 36.5 (4 C), 47.7 (2 C), 75.25 (2 C), 118.05 and 144.15; *m/z* 290 (M^+-18, 1%), 149

(13), 136 (16), 127 (65), 121 (14), 109 (41), 108 (10), 107 (12), 94 (16), 93 (15), 83 (17), 82 (12), 81 (26), 69 (18), 67 (75), 57 (15), 56 (12), 55 (100), 53 (12), 43 (43), 42 (19) and 41 (69). Anal cald. for $C_{20}H_{36}O_2 \cdot 3/4\ H_2O$: C, 74.60; H, 11.74. Found: C, 74.8, H, 11.7.

1,4-Dimethylenecyclohexane (**4**)[13]: t_r=2.51 min, R_f=0.60 (hexane), b.p. 50°C (Kugelrohr, 100 Torr); ν_{max} (film) 3060 and 1630 cm^{-1} (CH_2=C); δ_H 2.18 [8 H, s, 2x(CH_2)$_2$] and 4.76 (4 H, s, 2xCH_2=C); δ_C 34.4 (4 C), 109.05 (2 C) and 149.05 (2 C); *m/z* 108 (M+, 12%), 87 (96), 69 (28), 57 (100), 55 (18), 53 (11), 45 (59), 43 (23) and 41 (31).

Treatment of 1,5-diols **3** *with Hydrocloric Acid. Isolation of Compounds* **5-8**. *General Procedure* .- The crude diol **3** obtained as above (2.5 mmol scale) was dissolved in diethylether (10 ml) and to the resulting solution was added 6 M (10 ml, method A) or 12 M (10 ml, method B) hydrochloric acid and the mixture was stirred for 1-24 h (see Table 3). Then, it was extracted with diethylether (2 x 10 ml), the organic layer was successively washed with a saturated aqueous solution of $NaHCO_3$ and water, dried over anhydrous Na_2SO_4 and evaporated (15 Torr). The resulting residue was chromatographied (silica gel, hexane/diethyl acetate) to yield pure compound **5-8**. Yields are included in Table 3. Physical, spectral, and analitycal data follow.

2,2,6,6-Tetraethyl-4-methylenetetrahydropyran (**5d**): t_r=9.67 min, R_f=0.52 (hexane); ν_{max} (film) 3060, 1640 (CH_2=C) and 1000 cm^{-1} (C-O); δ_H 0.75-0.85 (12 H, m, 4xMe), 1.20-1.60 (8 H, m, 4xCH_2Me), 2.09 (4 H, s, CH_2C=C) and 4.76 (2 H, s, CH_2=C); δ_C 8.2 (4 C), 31.35 (4 C), 41.05 (2 C), 77.4 (2 C), 110.0 and 142.4; *m/z* 182 (M+-28, 2%), 181 (17), 163 (25), 124 (21), 109 (39), 95 (71), 87 (30), 81 (10), 69 (18), 67 (16), 57 (100), 55 (13) and 41 (16).

2,2,6,6-Tetracyclopropyl-4-methylenetetrahydropyran (**5e**): t_r=13.62 min, R_f=0.91 (hexane/ethyl acetate: 19/1); ν_{max} (film) 3060, 1640 (CH_2=C) and 1020 cm^{-1}; δ_H 0.15-0.35, 0.35-0.45, 0.50-0.65 [8, 4, 4 H, 3 m, respectively, 4x(CH_2)$_2$CH], 0.85-1.00 (4 H, m, 4xCH), 2.15 [4 H, s, (CH_2)$_2$C=C] and 4.84 (2 H, s, CH_2=C); δ_C 1.05 (4 C), 2.35 (4 C), 20.0 (4 C), 42.5 (2 C), 72.35 (2 C), 110.45 and 142.6; *m/z* 217 (M+-41, 9%), 149 (11), 148 (100), 133 (17), 119 (11), 107 (17), 106 (16), 105 (36), 93 (19), 92 (16), 91 (58), 80 (11), 79 (48), 77 (19), 69 (56) and 41 (29). Anal cald. for: $C_{18}H_{26}O \cdot 1/2\ H_2O$: C, 80.84; H, 10.18. Found: C, 81.0; H, 9.8.

13-Methylene-6-oxadispiro[4.1.4.3]tetradecane (**5g**): t_r=10.91 min, R_f=0.34 (hexane); ν_{max} (film) 3060, 1650 (CH_2=C) and 1040 cm^{-1} (C-O); δ_H 1.10-1.75 [16 H, m, 2x(CH_2)$_4$CO], 2.08 [4 H, s, (CH_2)$_2$C=CH_2] and 4.69 (2 H, s, CH_2=C); δ_C 22.95 (4 C), 38.95 (4 C), 44.5 (2 C), 84.65 (2 C), 109.4 and 143.05; *m/z* 206 (M+, 8%), 177 (27), 149 (16), 122 (68), 121 (10), 107 (82), 94 (23), 93 (71), 91 (26), 85 (56), 81 (17), 80 (21), 79 (58), 78 (10), 77 (32), 68 (10), 67 (100), 66 (19), 65 (18), 57 (18), 56 (18), 55 (96), 54 (12), 53 (26), 43 (17), 42 (16) and 41 (84).

15-Methylene-7-oxadispiro[5.1.5.3]hexadecane (**5h**): t_r=12.71 min, R_f=0.43 (hexane); ν_{max} (film) 3040, 1640 (CH_2=C) and 1000 cm^{-1} (C-O); δ_H 1.20-1.80 [20 H, m, 2x(CH_2)$_5$CO], 2.15 [4 H, s, (CH_2)$_2$C=C] and 4.76 (2 H, s, CH_2=C); δ_C 22.9 (4 C), 26.05 (2 C), 39.25 (4 C), 44.2 (2 C), 74.65 (2 C), 109.8 and 142.2; *m/z* 234 (M+, 7%), 137 (10), 136 (100), 135 (16), 122 (11), 121 (68), 107 (15), 99 (68), 94 (20), 93 (20), 91 (10), 81 (49), 80 (12), 79 (25), 77 (11), 69 (12), 67 (13), 55 (26) and 41 (20).

19-Methylene-9-oxadispiro[7.1.7.3]icosane (**5i**) and *19-methyl-9-oxadispiro[7.1.7.3]icos-19-ene* (**6i**): t_r=16.04 min (**6i**) and 16.40 min (**5i**), R_f=0.70[18] (hexane); ν_{max} (film) 3060, 1640 (CH=C), 1020 and 1000 cm^{-1} (C-O); δ_H 1.10-1.90, 2.05-2.15 (65 H, m, 31xCH_2 aliphatic and Me), 4.72 (2 H, s, CH_2=C) and 5.45 (1 H, s, CH=C); δ_C 21.9 (2 C), 21.95 (2 C), 22.05 (4 C), 23.95, 24.85 (2 C), 24.9 (2 C), 25.0 (2 C), 28.4 (4 C), 28.45 (2 C), 28.5 (2 C), 35.8 (2 C), 37.0 (4 C), 37.15 (2 C), 40.28, 45.65 (2 C), 74.9, 74.95, 76.57 (2 C), 110.0, 127.2, 127.8 and 142.7; *m/z* for **5i**[19] 290 (M+, 2%), 164 (25), 163 (20), 149 (21), 136 (27), 135 (12), 127 (69), 122 (10), 121 (19), 109 (36), 108 (16), 107 (23), 98 (20), 97 (12), 96 (11), 95 (17), 94 (22), 93 (34), 91 (22), 83(26), 82 (18), 81 (45), 80 (14), 79 (43), 77 (19), 69 (21), 68 (14), 67 (79), 57 (12), 56 (14), 55 (100), 54 (12), 53 (15), 43 (21), 42 (18) and 41 (66); *m/z* for **6i**[19] 291 (M++1, 2%), 290 (M+, 10%), 219 (45), 191 (13), 167 (12), 163 (13), 149 (13), 136 (16), 135 (37), 123 (10), 122 (28), 121 (33), 109 (38), 107 (20), 105 (10), 97 (12), 96 (32), 95 (23), 93 (17), 91 (22), 83 (15), 82 (17), 81 (38), 79 (40), 77 (23), 69 (38), 67 (41), 57 (12), 56 (12), 55 (100), 53 (16), 43 (33), 42 (21) and 41 (70).

2,2,6,6-Tetraethyl-4-methyldihydropyran (**6d**): t_r=9.45 min, R_f=0.52 (hexane); ν_{max} (film) 3060, 1680 (CH=C), 1050 and 1010 cm^{-1} (C-O); δ_H 0.80-0.85 (12 H, m, 4x*Me*CH_2), 1.40-1.60 (8 H, m, 4xCH_2Me), 1.72 (3 H, s, MeC=C), 1.81 (2 H, s, CH_2C=C) and 5.25 (1 H, s, CH=C); δ_C 8.05 (2 C), 8.15 (2 C), 23.75, 30.15 (2 C), 32.75 (2 C), 37.15, 75.15, 76.15, 124.55 and 129.9; *m/z* 183 (M^+-27, 1%), 182 (17), 181 (100), 163 (50), 151 (10), 123 (17), 111 (29), 109 (21), 67 (11), 57 (90), 55 (12), 43 (16) and 41 (14).

2,2,6,6-Tetraisopropyl-4-methyldihydropyran (**6f**): t_r=12.41 min, R_f=0.85 (hexane); ν_{max} (film) 3020, 1680 (CH=C), 1020 and 1010 cm^{-1} (C-O); δ_H 0.80-1.20 [24 H, m, 4x(*Me*)$_2$CH], 1.26 (3 H, s, MeC=C), 1.79 (2 H, s, CH_2C=C) 1.90, 2.07 [4 H, 2 septet, *J*=7, 4xC*H*(Me)$_2$] and 5.52 (1 H, s, CH=C); δ_C 18.6 (2 C), 18.8 (2 C), 19.0 (2 C), 19.75 (2 C), 23.8, 31.05, 34.45 (2 C), 36.2 (2 C), 79.4, 80.4, 124.15 and 130.4; *m/z* 225 (M^+-41, 1%), 224 (12), 223 (65), 153 (15), 137 (45), 109 (10), 97 (33), 71 (77), 67 (10), 57 (20), 55 (15), 43 (100) and 41 (32).

13-Methyl-6-oxadispiro[4.1.4.3]tetradec-13-ene (**6g**): t_r=10.74 min, R_f=0.38 (hexane); ν_{max} (film) 3060, 1630 (CH=C), 1050 and 1010 cm^{-1} (C-O); δ_H 1.15-2.10 (21 H, m, 9xCH_2 and Me) and 5.34 (1 H, s, CH=C); δ_C 23.05 (2 C), 23.55, 23.65 (2 C), 38.35 (2 C), 39.2, 40.55 (2 C), 81.9, 82.65, 126.65 and 128.7; *m/z* 207 (M^++1, 3%), 206 (M^+, 19%), 177 (53), 149 (11), 135 (15), 126 (10), 125 (100), 109 (36), 108 (25), 107 (42), 105 (12), 95 (13), 93 (32), 91 (34), 83 (10), 81 (20), 80 (12), 79 (49), 77 (38), 69 (11), 67 (54), 65 (20), 56 (11), 55 (82), 53 (26), 51 (12), 43 (21), 42 (28) and 41 (79).

15-Methyl-7-oxadispiro[5.1.5.3]hexadec-15-ene (**6h**): t_r=12.42 min, R_f=0.54 (hexane); ν_{max} (film) 3020, 1680 (CH=C), 1040 and 990 cm^{-1} (C-O); δ_H 1.20-1.90 (25 H, m, 11xCH_2 and Me) and 5.38 (1 H, s, CH); δ_C 22.4 (2 C), 22.45 (2 C), 23.9, 25.85, 26.35, 37.95 (2 C), 39.15 (2 C), 40.35, 71.65, 72.1, 126.6 and 128.4;*m/z* 235 (M^++1, 5%), 234 (M^+, 32%), 192 (14), 191 (100), 163 (14), 139 (40), 136 (12), 135 (23), 122 (21), 121 (29), 109 (24), 107 (11), 93 (15), 91 (15), 83 (10), 81 (15), 79 (22), 77 (13), 69 (10), 67 (12), 55 (29) and 41 (21).

1-(3-Cyclopentylidene-2-methylene)propylcyclopentan-1-ol (**7g**): t_r=11.93 min, R_f=0.37 (hexane/ethyl acetate: 9/1); ν_{max} (film) 3440 (OH), 3070, 3040, 1640 (CH=C) and 1020 cm^{-1} (C-O); δ_H 1.55-1.90 [12 H, m, $(CH_2)_4CO$ and (C*H*$_2$)$_2$$CH_2$=CH], 2.16-2.35 [5 H, m, $(CH_2)_2C$=C and OH], 2.91 (2 H, s, $OCCH_2C$=C), 4.91, 4.95 (2 H, 2 s, CH_2=C) and 5.40 (1 H, s, CH=C); δ_C 23.5, 23.55 (2 C), 32.5, 34.7, 39.8, 40.0 (2 C), 46.3, 81.1, 115.0, 126.15, 142.35 and 144.85; *m/z* 188 (M^+-18, 21%), 173 (14), 159 (20), 146 (11), 145 (37), 131 (35), 122 (37), 120 (10), 119(12), 107 (55), 106 (27), 105 (16), 95 (12), 94 (20), 93 (44), 92 (15), 91 (44), 85 (90), 81 (11), 80 (11), 79 (51), 78 (12), 77 (29), 67 (100), 65 (13), 57 (17), 55 (33), 53 (12), 43 (12) and 41 (37).

1-(3-Cyclohexylidene-2-methylene)propylcyclohexan-1-ol (**7h**): t_r=13.91 min, R_f=0.85 (hexane/ethyl acetate: 19/1); ν_{max} (film) 3440 (OH), 3060, 3040, 1630 (CH=C) and 1000 cm^{-1}; δ_H 1.30-1.75 [16 H, m, $(CH_2)_5CO$ and (C*H*$_2$)$_3$$CH_2C$=CH], 1.80-1.90, 1.90-2.05 [4 H, 2 m, $(CH_2)_2C$=C], 2.14 (1 H, s, OH), 2.74 (2 H, s, $OCCH_2C$=C), 4.87, 4.94 (2 H, 2 s, CH_2=C) and 5.46 (1 H, s, CH=C); δ_C 22.25 (2 C), 22.4, 22.9, 25.3, 25.75, 27.9, 37.85 (2 C), 47.0, 47.4, 71.0, 115.4, 123.65, 135.6 and 144.3; *m/z* 234 (M^+, <1%), 216 (14), 173 (11), 145 (13), 136 (48), 134 (12), 133 (14), 122 (25), 121 (47), 107 (15), 99 (97), 94 (16), 93 (19), 91 (19), 81 (100), 79 (34), 77 (14), 67 (12), 55 (26) and 41 (19).

2-Methylene-1,3-dicyclooctylidenepropane (**8**): t_r=16.05 min, R_f=0.95 (hexane); ν_{max} (film) 3060 and 1640 cm^{-1} (CH=C); δ_H 1.25-1.30 [20 H, m, 2x(C*H*$_2$)$_5$$CH_2C$=C], 2.00-2.20, 2.60-2.65 (8 H, 2 m, 4xCH_2C=C), 4.80 (2 H, s, CH_2=C) and 5.36 (2 H, t, *J*=8.0, 2xCH=C); δ_C 26.4 (2 C), 26.45 (2 C), 26.55 (2 C), 28.25 (2 C), 28.55 (2 C), 30.05 (2 C), 43.9 (2 C), 112.85, 126.0 (2 C), 138.55 (2 C) and 146.15; *m/z* 273 (M^++1, 5%), 272 (M^+, 21%), 134 (11), 119 (19), 107 (14), 106 (11), 105 (31), 95 (10), 93 (24), 92 (16), 91 (49), 81 (29), 80 (13), 79 (44), 77 (34), 69 (13), 68 (10), 67 (73), 65 (17), 56 (10), 55 (51), 53 (25), 43 (12) and 41 (100).

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