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ON THE REGIOSELECTIVITY OF ELIMINATION REACTIONS IN TERPENE DERIVATIVES.

B. BADET, M. JULIA, J.M. MALLET and C. SCHMITZ.

ECOLE NORMALE SUPERIEURE, LABORATOIRE DE CHIMIE
24, rue Lhomond, 75231 PARIS CEDEX 05 - FRANCE.

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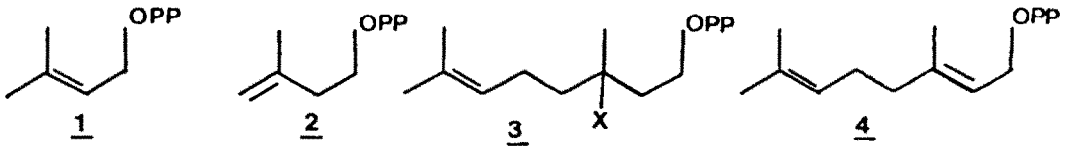
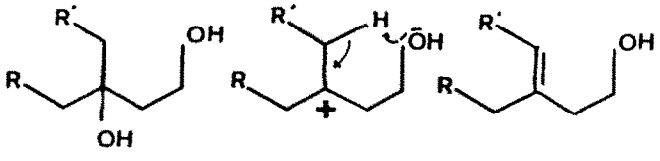
ABSTRACT : *Tertiary alcohols with prenyl or geranyl moities, bearing a second oxygen function in the 3, 4 or 5 position were dehydrated under various conditions : the composition of the olefinic mixture obtained was accounted for, by an intramolecular base relay effect.*
Basic elimination of analogous dimethylsulfonium salts gave results that could be related to the inductive effect : a correlation between regioselectivity and the Taft constant σ_I *of the second oxygen function was found, except for the very basic alkoxide groups where an alternative regioselective elimination took place.*

The stereochemistry of the biosynthesis of geranyl (and farnesyl) pyrophosphate catalysed by prenyl-transferase has been beautifully elucidated and several suggestions have been made towards its rationalisation [1].
Much less attention has been given to the problem of the direction of the elimination ; although it is not obvious that the final deprotonation of 3 formed by condensation of 1 with 2 where X is a nucleofugal substituent or a positive charge should produce a double bond in the 2,3-position (natural) as in 4 instead of the 3,4- (retro) or exo positions.



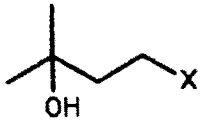
1 2 3 4

In fact some apparently similar systems undergo elimination reactions in the opposite direction. Over fifty years ago Pfau and Plattner reported the formation of homoallylic -and not allylic- alcohols in the acid promoted dehydration of 1,3-diols [2] 5. The suggestion [3] made by Arnold that the hydroxyl group was acting as an intramolecular base and removed the proton from the intermediate carbocation 5a accounted for the facts. In alkaline solutions, cases are known where suitably placed oxygen atoms in the molecule direct elimination reactions [4-5].



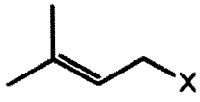
5 5a 5b

In the present investigation [6], a series of tertiary alcohols has been prepared with another oxygen function in the 1,3 position (6a : OH, 6b : OAc, 6c : OnBu, 6d : OCF_2-CFClH) and their dehydration under various conditions compared with that of the reference alcohol 6e with regard to the proportions of the natural 7 and retro product 8.



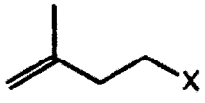
6

a X= OH
b OAc
c OnBu
d OCF_2CHFCl
e nBu



7

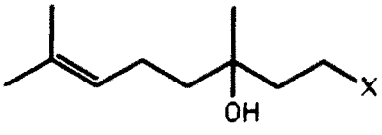
f CH_2OH
g CH_2OAc
h CH_2-$CH(CH_3)OH$
i CH_2-$CH(CH_3)OAc$



8

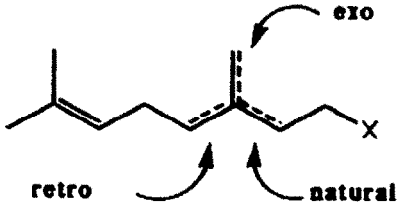
j OPh
k CH_2OPh
l CH_2-$CH(CH_3)OPh$

The isoprenologs 9a, 9b, 9e were similarly prepared and treated. In the homologous alcohols 6f (and acetate 6g) and their isoprenologs 9f (acetate 9h) the second oxygen function is in the 1,4-position with respect to the first one. In the next homologous one 6h (and acetate 6i) and their isoprenologs 9h (resp. 9i), the oxygen functions are in the 1,5-position.



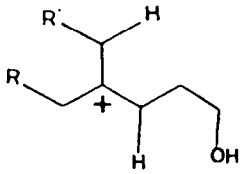
9

a X= OH
b OAc
e nBu
f CH_2OH
g CH_2OAc
h CH_2-$CH(CH_3)OH$
i CH_2-$CH(CH_3)OAc$

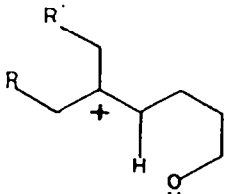


10

These compounds have been selected in order to gather information about the Arnold factor illustrated in 5a from two points of view. First, the relative position of the oxygen function : it will be seen that in the situations pictured as 5f and particularly 5h this factor should favour the formation of the natural products in the elimination. In fact, it is known [7] that dehydration of 4-methyl-1,4-pentane diol takes place in the natural direction. Second, the basicity of the oxygen group : this led to select oxygen functions a,b,c,d of widely varying basicity [8].



5f



5h

The dehydration reactions were carried out either with potassium hydrogen sulfate or with phosphorus oxychloride-pyridine. The results are shown in Tables 1 and 2. It appears that the basicity 6a,b,c,d of the oxygen atom has little influence on the direction of the elimination.

TABLE 1 : Dehydration with potassium hydrogen sulfate (10% w/w)140°C A(4h) B(45mn).

	Substrate	Total yield%	Natural isomers% in the mixture	Composition of 10				
				natural		retro		
				Z	E	exo Z		E
diols	6a	33[a]	7a 4					
	9a	40						
	6f	30[b]	7f 78					
B	9f	20[c]						
	6h	57[e]	7h 78					
	9h	62[f]	77	19	58	7[d]		16
hydroxy-	6b	70	7b 20					
acetates	6c	50	7c 18					
and -ethers	6d	0						
	9b	60	24	7	17	42	9	25
A	6g	60	7g 63					
	9g	40						
	6i	50	7i 65					
	9i	60	53	17	36	33[d]		14
	6e	70	7e 48					
	9e	65	49	16	33	35[d]		16

a) Isoprene 30% and dimethylvinylcarbinol 8% were also found. b) Reaction time 5mn, 2,2-dimethyltetrahydrofuran 65% was also found. c) 2-methyl-2-(4-methyl-3-pentene-1-yl)tetrahydrofuran 25% was found. d) Isomers not separated by glc on a capillary colomn SE52. e) 2,2-Dimethyltetrahydropyran 7% was found. f) 2-Methyl-2-(4-methyl)-3-pentane-1-yl)tetrahydropyran 7% was found.

Table 2 : Dehydration with $POCl_3$(1.5eq.)/py(3ml) of 1mmol of substrate, 15h, rt.

6 → 7 + 8 ; 9 → 10

Substrate	Total yield%	Natural isomers %in the mixture		Composition of 10 natural Z	E	exo retro Z	E
6a	0[a]						
6b	70[b]	7b	40				
6c	60	7c	20				
6d	80	7d	35				
9b	50		29	10	19	22 17	32
6g	69	7g	68				
9g	89		52	17	35	25	23
6i	73	7i	65				
9i	77		49	17	32	27	24
6e	70	7e	70				
9e	80		47	16	31	29	24

a) complex mixture.
b) compounds 7, 8, 10 bcdegi are stable under these conditions

Table 3 : Prenylation of isopentenyl derivatives.

8 + DMVC $\xrightarrow{TFA}$ 9 + 10

In dichloromethane (5ml), 20min, 0°C, 8(1mmol), DMVC(2mmol), TFA(5.2mmol).

Substrate	alcohols 9 %	olefins 10 %	natural isomers % in the mixture 10	Composition of 10 natural Z	E	exo retro Z	E
8a	15 (45)	4 (12)	2	1	1	13 18	67
8c	33 (69)	4 (8)	8	2	6	15 18	59
8g	27 (50)	10 (19)	67	23	44	17	16
8i	24 (34)	8 (11)	86	28	58	7	7
8e	21 (22)	5 (5)	52	16	36	25	23

In nitromethane (2.5ml), 1.5h, 0°C, 8(4mmol), DMVC(1mmol), TFA(2.6mmol).

8b	39	7	28	9	19	27	15	30
8g	29	39	46	13	33	23		31
8i	28	42	71	18	53	14		15

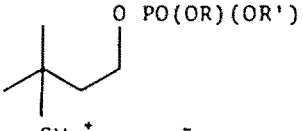
With potassium hydrogen sulfate, control experiments have shown that some decomposition and isomerisation of the products took place under the reaction conditions. The distribution of products has been therefore disregarded in those cases when the total recovery was small. The relative position of the second oxygen function has a strong influence : compare glycols 6a, 6f and 6h or 9h; the prenyl residue does not make much difference. For hydroxy-acetates the effect is less pronounced (see 6b, 6g, 6i or 9b, 9i)

With phosphorus oxychloride-pyridine the same trend is apparent. The orientation effect is noticeable with 6b, 6c, 6d and 9b. However with 6i the natural isomer should have been favoured, which was not the case. In this technique, the isoprenologs 9b, 9g, 9i gave definitely lower proportions of natural elimination.

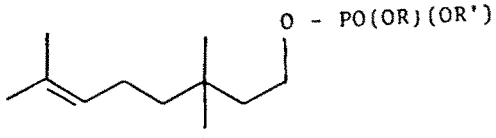
A similar influence of the nature and the position of the oxygen function was to be expected in the prenylation of isopentenyl derivatives and homologs. Table 3 gives the results of a series of prenylation reactions run with dimethyl vinyl carbinol (DMVC) and trifluoroacetic acid (TFA) in dichloromethane [8] and nitromethane [10] respectively leading to substituted ene-ols 9 (main products) and substituted dienes 10. Whereas the nature of the terminal group in 8a,b,c is of little consequence, the position of the oxygen function strongly influences the result. In the homoallylic derivative 8g and bis-homoallylic 8i the total yield of olefins 10 in the mixture increases, particularly in $MeNO_2$, and the proportion of the natural ones also increases from 2-4% to 70% in $MeNO_2$ and 86% in CH_2Cl_2.

There is a good agreement between these results and those of the dehydration experiments above and both can be accounted for by the Arnold effect.

In another investigation of the chemical factors involved in the biosynthesis of geranyl pyrophosphate, a series of phosphoric esters 11 - 14 with a prenyl or a geranyl skeleton and a dimethylsulfonium leaving group have been prepared and submitted to basic elimination conditions [15].

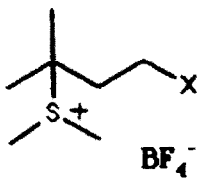


11 R = Me, R' = Me
12 R = Me, R' = H



13 R = Me, R' = Me
14 R = Me, R' = H

Very high proportions of "natural" elimination were observed. In a first series of experiments a number of sulfonium salts were prepared, with a prenyl skeleton bearing OH 15a, OAc 15b or OPh 15j substituents as well as the homologs 15f,g,k and bis homologs 15h,i,l. The sulfonium salt 15e without any other function was included for comparison.



15

a	X= OH	h	CH_2-CH(CH_3)OH
b	OAc	i	CH_2-CH(CH_3)OAc
c	OnBu	j	OPh
d	OCF_2CHFCl	k	CH_2OPh
e	nBu	l	CH_2-CH(CH_3)OPh
f	CH_2OH	m	CH_2COOMe
g	CH_2OAc		

These salts were prepared by reaction of the corresponding terminal olefins with dimethylsulfide and tetrafluoroboric acid. This technique [11] appears to be more efficient than the reaction with the corresponding alcohols even in simple cases (see experimental part).

With the sulfonium salts in hand we carried out elimination reactions under two sets of reaction conditions : potassium t-butoxide in dimethyl sulfoxide (conditions A) or sodium hydroxide in dichloromethane/methanol [15], (conditions B).

The results are shown in Table 4.

Table 4 : Elimination reactions of sulfoniums salts 24h at 20°C.

A : 0.1N in DMSO with t-BuOK(1eq)

B : 0.1N in CH_2Cl_2/MeOH (4/1 vol.) with 10N aq NaOH (1eq)

15 ⟶ 7 natural + 8 retro

	Conditions A		Conditions B	
Substrate	Total yield 7+8%	7/8	Total yield 7+8%	7/8
15e	82	9/91	86	12/88
15a	45	1/99	37	1/99
15f	35	11/89	45	4/96
15h	35	41/59	37	12/88
15b	55	54/46		as above
15g	50	33/67		
15i	60	17/83		
15j	94	52/48	99	82/18
15k	91	25/75	99	17/83
15l	93	18/82	83	14/86

The reference compound 15e shows a strong tendency towards the Hofmann elimination under conditions A. A hydroxyl group in the 3 position as in 15a increases this orientation as expected from an Arnold-like situation. When the hydroxyl group is further away (15f,15h), the proportion of the natural olefin formed increased markedly but only up to 41%. The situation is analogous to 5h and a still higher proportion might have been expected ; intermolecular elimination probably accounts for half of the products formed. The effect is much less apparent under conditions B where the weaker external base would not induce as much intramolecular basic relay.

In the phenoxysulfonium derivatives 15j,k,l, where no such intramolecular basic relay is possible the opposite trend is apparent, i.e. whereas the prenyl derivative 15j gave a sizeable (52%) amount of natural elimination under conditions A, the homologs 15k and 15l behaved more like the reference compound 15e and showed Hofmann type elimination. Under conditions B, 15j gave as much as 82% of natural elimination (see before).

The acetoxy derivatives 15b,g,i, behaved like the phenoxy analogs under conditions A

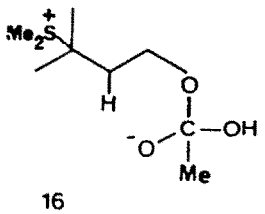
but like the alcohols 15a,f,h, under conditions B, due probably to rapid hydrolysis of the ester group.

The remarkable orientation effect of the phenoxy group points to some electronic effect. The elimination of bad leaving groups such as SMe_2 involves transition states with considerable accumulation of negative charge of the β-carbon atom (a ρ value of 2.75 has been measured [13]). It thus should be facilitated by electron attracting groups on the γ- carbon atom. This effect should favour the formation of the natural product and, if strong enough, might counterbalance the statistical effect (3/1 in favour of the retro elimination). This effect would of course diminish as the electron attracting group is moved away from the sulfonium group.

The phenoxy and the acetoxy groups have similar Taft σ_I values (0.38 and 0.39 respectively) [12]. In fact, they gave very similar distributions of elimination products.

In order to gather more evidence in this point, a few more derivatives 15 with a prenylskeleton and various groups in 3-position with respect to the sulfonium group were prepared and treated under conditions A and B. The results are shown in Table 5 together with the σ_I values of the various X groups. A very clear trend appears : the proportion of natural elimination increases with the electron attracting power of the X group. The hydroxy group gives an abnormally high proportion of retroelimination due to the base-relay phenomenon mentioned above.

With the acetoxy group 15b another possibility was considered :
a tetrahedral intermediate 16 formed by nucleophilic attack of the base on the carbonyl group would have an alkoxide function situated as in Scheme 5h which might favour the natural elimination.



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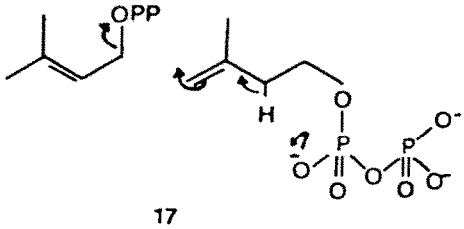


17

A similar role 17 has been suggested for the pyrophosphate group in the biosynthesis [16]. The sulfonium salt 15m was therefore prepared with an ester carbonyl group in the same situation as in the acetate. The σ_I value is now 0.15. Under conditions A a ratio of natural/retro elimination of 31/69 was found, that is almost exactly in line with the other results in Table 5 and much less than the value 54/46 found with the acetoxy group 15b : the base relay effect does not appear to be important.

On the other hand, a sulfonium salt bearing a strongly electron attracting group $OCF_2CClF\ H$ 15d was prepared and led to very high proportions of natural elimination particularly under conditions B, Table 5.

In two kinetically controlled elimination reactions the ratio of the amounts of products formed should equal the rate ratio. The rate of the retro elimination might be assumed to be roughly independant of the X groups. (The inductive effect will be reduced to 0.36x0.36=0.1 times its value for the natural elimination since the site of action is two carbon atoms further away from X). It might therefore be used as a reference rate in a Hammett-like treatment and the proportions of isomers would reflect the usual kX/kH ratio. In fact its

logarithm when plotted against the σ_I values of the X groups falls indeed on a straight line for conditions A (and another of course for conditions B) which is quite remarkable with such a crude treatment.

Table 5 : Attempted correlation of the direction of elimination with the inductive effect σ_I of the X group in C_5 derivatives.

		Conditions A		Conditions B	
Substrate	σ_I	Total yield 7 + 8 %	7/8	Total yield 7 + 8 %	7/8
15e	-0.04	82	9/91	86	12/88
15m	0.15	64	31/69		
15a	0.25	45	1/99	37	1/99
15c	0.27	58	43/57	87	63/37
15j	0.38	94	52/48	99	82/18
15b	0.39	55	54/46	43	1/99 [a]
15d	0.55 [b]	24	71/29	99	97/3

a) hydrolysis of the ester group. b) this is the value for OCF_3 assumed to be similar.

It thus appears that the relative position of X and SMe_2 and the electronic effect of the X groups account for the results. This might be of use when designing regioselective elimination reaction [17].

Our thanks are due to the CNRS for financial support (LA32) and the Rhone-Poulenc Company for a scholarship (to C.S.). We also thank Miss Michon, Miss Derouet and Mrs Morin for the spectral data and the Laboratoire de Microanalyse of University P&M. Curie for the analytical data.

EXPERIMENTAL

For general indications, see ref.10. Compounds 6a,b,c,d,e,g,i have been prepared previously [8], so have 6f [22], 6h [23].

Dehydrations with $KHSO_4$: Compounds 6 or 9 (4mmol) were treated under reflux with $KHSO_4$ (10% by weight) at 140°C with stirring. The cooled mixture was diluted with acetone (10ml), excess sodium bicarbonate, an internal standard (linear C_9 - C_{12} alcane) added and compared by glc with authentic samples.

Dehydrations with $POCl_3$-Py: Phosphorus oxychloride (1.5mmol) was added to a solution of alcohol 6 or 9 (1mmol) in pyridine (3ml) at 0°C. After standing for 15h at r.t. the mixture was poured in ice-HCl, after extraction the mixture was analyzed by glc as above.

Prenylation of isopentenyl derivatives and homologs 8 was carried out as described : ref. 8 in CH_2Cl_2 ; ref. 10 in $MeNO_2$.

Prenyl derivatives and homologs : Compounds 7a-e have been prepared [8]. So have 7f,g [9], 7h [24], 7i [25], 7j [26].

4-Methyl-1-phenoxy-3-pentene 7k

was prepared from the corresponding alcohol [9] and phenol with carbodiimide, technique of ref.14, 48%, bp : 101°C/4mm.

Found % : C, 81.95 ; H, 9.33 ; $C_{12}H_{16}O$ requires % : C, 81.77 ; H, 9.15.
^{1}H NMR 80MHz (TMS) : 7.45-6.85(5H,m,arom) ; 5.25(1H,t,J=7.0Hz, vinylic) ; 3.95(2H,t,J_2=7.0Hz, CH_2O) ; 2.45(2H,dt,J_1=J_2=7.0Hz,CH_2) ; 1.75 and 1.67(6H,2s,allylic).

6-Methyl-2-phenoxy-5-heptene 7l

was prepared from the corresponding alcohol [2], dicyclohexyl carbodiimide, phenol and cuprous chloride (technique of ref.14), and purified by flash chromatography, 52%.
Found : C, 82.09 ; H, 9.83 ; $C_{14}H_{20}O$ requires % : C, 82.30 ; H, 9.87.

^{1}H NMR 80MHz (TMS): 7.4-6.75(5H,m,arom) ; 5.08(1H,t,vinylic) ; 4.37(1H,m,CH-OPh) ; 2.17-1.90(2H, m,CH_2) ; 1.8-1.5(4H,m,CH_2) ; 1.67-1.55(6H,2s,CH_3,vinylic) ; 1.27(3H,d,J=6.0Hz,CH_3-CH).

Methyl 5-methyl-4-hexenoate 7m

was prepared from 1-bromo-3-methyl-2-butene [9] and dimethyl malonate followed by decarbomethoxylation, bp : 80°C/22mm ; 49%. bp_{lit} 54-55°C/10mm [27].

^{1}H NMR 80MHz (TMS) : 5.09(1H,t,vinylic) ; 3.74(3H,s,CH_3O-) ; 2.25-1.70(4H,m,CH_2CH_2) ; 1.68 and 1.59(6H,2s,allylic).

Isopentenyl derivatives and homologs 8

4-Methyl-1-phenoxy-4-pentene 8k

was prepared as 7k (48%); bp : 90°C/1.8mm.
Found % : C, 81.92 ; H, 9.31 ; $C_{12}H_{16}O$ requires % : C, 81.8 ; H, 9.1.

^{1}H NMR 80MHz (TMS) : 7.4-6.8(5H,m,arom) ; 4.75(2H,s,vinylic) ; 3.95(2H,t,J=6.0Hz,CH_2O) ; 2.3-1.75(4H,m,CH_2) ; 1.75(3H,s,allylic).

6-Methyl-2-phenoxy-6-heptene 8l

was prepared as 7k, and purified by flash chromatography, 52%.

Found : C, 82.39 ; H, 9.95 ; $C_{14}H_{20}O$ requires % : C, 82.30 ; H, 9.87.

^{1}H NMR 80MHz (TMS) : 7.35-6.7(5H,m,arom.) ; 4.90(2H,s,vinylic) ; 4.30(1H,m,CHO-) ; 2.16-1.90(2H, m,CH_2) ; 1.69(3H,s,allylic) ; 1.75-1.45(4H,m,CH_2CH_2) ; 1.26 (3H,d,J=6.0Hz,CH_3-C-O).

Methyl 5-methyl-5-hexenoate 8m

was prepared from isopentenyl-tosylate and dimethyl malonate followed by decarbomethoxylation according to Krapcho [18], bp : 69°C/11mm. 62% ; bp_{lit} [27] 67-70°C/15mm.

^{1}H NMR 80MHz (TMS) : 4.76(2H,s,vinylic) ; 3.73(3H,s,CH_3O) ; 2.35(2H,t,J=7.0Hz,CH_2) ; 2.20-1.70 (4H,m,CH_2CH_2) ; 1.75(3H,s,allylic).

Diols and homologs 9

Alcohols 9a-e have been prepared in ref.8.

4,8-Dimethyl-7-nonene-1,4-diol, 9f and monoacetate 9g

Technique of ref.19. To a solution of 3-chloro-1-propanol(40g, 0.425mol) in THF (400ml) at -20°C was added n-propylmagnesium chloride (2,5M in THF, 170ml). After warming up to room temperature, magnesium turnings (13g, 0.54mol) and 1,2-dibromoethane(0.4ml) were added and the mixture refluxed for 3h. After cooling, titration with benzyl alcohol showed the solution to be 0.5M in grignard. 100ml of this solution were placed in a flask under argon and cooled to 0°C ; 6-methyl-5-hepten-2-one (5g, 0.05mol) was added and the mixture allowed to stand another hour at 0°C. After the usual workup the diol was obtained as a viscous colourless oil (6.5g, 88%).

The acetate 9g was obtained from 9f above with Ac_2O-Pyridine, and purified by flash chromatography.

Found % : C, 68.28 ; H, 10.85 ; $C_{13}H_{24}O_3$ requires % : C, 68.38 ; H, 10.59.

^{1}H NMR 250MHz (TMS) : 5.17(1H,t,vinyl) ; 4.11(2H,t,J=6.5Hz, CH_2O) ; 2.04(3H,s,CH_3-COO) ; 2.05 (2H,t,allylic CH_2) ; 1.71 and 1.64(6H,2s,allylic) ; 1.77-1.47(6H,m,methylenes) ; 1.20(3H,s, CH_3-C-O).

^{13}C NMR ($CDCl_3$) (TMS): 170.1(-CO) ; 130.4(-C=) ; 123.9(-CH=) ; 71.4(-C-) ; 64.5 (OCH_2) ; 41.4 (CH_2) ; 37.5(CH_2) ; 26.3(CH_3) ; 25.2(CH_3) ; 23.0(CH_2) ; 22.4 (CH_2) ; 20.4(CH_3) ; 17.2(CH_3).

6,10-Dimethyl-9-undecene-2,6-diol, 9h and monoacetate, 9i

The preceding technique with methylheptenone and the grignard of 5-chloro-2-pentanol gave 9h (81%). This was converted into the acetate 9i purified by flash chromatography, 89%.

Found % : C, 70.32 ; H, 10.91 ; $C_{15}H_{28}O_3$ required % : C, 70.27 ; H, 11.01.

^{1}H NMR 250MHz : 5.18(1H,t,vinylic) ; 4.96(1H,m,-CHOAc) ; 2.06(3H,s,CH_3CO_2) ; 2.05(2H,m,CH_2 allylic) ; 1.71 and 1.64(6H,2s,CH_3 allylic) ; 1.65-1.36(8H,m,methylenes) ; 1.23(3H,d,J=6.0Hz, CH_3-CHO) ; 1.17(3H,s,CH_3-C-O).

^{13}C NMR ($CDCl_3$) : 170.1(C=O), 130.9(C=), 124.1(-CH=) ; 72.1(-C-O) ; 70.6 (-CH-O) ; 41.4(2xCH_2) ; 36.3(CH_2) ; 26.6(CH_3) ; 25.6(CH_3) ; 22.6(CH_2) ; 21.2(CH_3) ; 19.9(CH_3) ; 19.7(CH_2) ; 17.5(CH_3).

Dehydration and prenylation products 10

Compounds 10a-i have been obtained previously [8].

The compositions of the mixtures of isomers was determined by glc on a capillary column. Authentic samples were obtained on one hand starting with geraniol, nerol, homogeraniol, homonerol, geranylacetone and nerylacetone for the "natural" isomers. Mixtures of all 5 isomers were obtained by dehydration of the corresponding alcohols 9.

Preparation of sulfonium salts 15

A solution of olefin 8 (10mmol) and dimethylsulfide(0.8ml, 12mmol), in dichloromethane (10ml) was cooled to -30°C under nitrogen and tetrafluoroboric acid in ether (1.4ml, 10mmol) was added. After standing for 0.5h at -30°C the mixture was allowed to warm up to room temperature (1h) and sodium bicarbonate (1g) was added. After standing for 1h the mixture was filtered and washed with CH_2Cl_2. The usual workup gave an oil which crystallised when triturated with ether (2x20ml). The yields and physical data of the various 15 are shown in Table 6, 7 and 8. It was found preferable to use olefins 8 instead of alcohols 6 as starting material, as shown by model experiments on isobutene.

t-Butyldimethylsulfonium perchlorate

To a solution of isobutene (800mg, 14.3mmol) and Me_2S (2.2ml, 30mmol) in CH_2Cl_2(15ml), trifluoroacetic acid (TFA)(4.3ml, 55mmol) was added at -50°C and the mixture was allowed to stand at 20°C for 6 days. The solvent was evaporated i.v. and the residue was treated with 70% aqueous $HClO_4$ (3ml). 2.17g (99%) of sulfonium perchlorate was obtained : mp:191-3°C (aq MeOH) mp_{lit} : 196-7 [20] ; 193-5 [21]. The same procedure applied to t-butanol gave the same salt in 76% yield. With a reaction time of 12h 2-methyl-1-pentene gave a 80% yield whereas t-butanol gave no sulfonium salt.

For comparison, DMVC, 2-methyl-1-pentene, isopentenyl acetate 8b, isopentenol 8a and 3-methyl-1,3-butanediol 6a (10mmol) were treated with Me_2S (20mmol) and TFA (40mmol) in CH_2Cl_2 (10ml) 14h at 20°C. After evaporation of the solvent, ^{1}H NMR analysis was carried out with tetrachloroethane as internal standard. The yield % of the corresponding sulfonium salts were 93 prenyldimethylsulfonium, 82 (2-methyl-2-pentyl)dimethylsulfonium, 42 (of which 65% was 15b and 35% the hydroxysulfonium salt 15a), 25 (trifluoroacetate ester of 15a) and 0% respectively.

Dimethyl(3-methyl-2-buten-1-yl)sulfonium tetrafluoroborate

To a solution of isoprene (10mmol) and Me_2S(1.5ml, 20mmol) in CH_2Cl_2 (10ml) trifluoroacetic acid (1.5ml, 20mmol) was added at -5°C. After standing 16h at 20°C the solution was evaporated i.v. The yield of salt (53%) was determined by comparison with an authentic sample [21] by NMR. A similar experiment with tetrafluoroboric acid gave an 85% yield of the corresponding salt (the same ref.).

3-Methyl-1,3-bis(dimethylsulfonio)butane bis tetrafluoroborate

To a solution of Me_2S (3ml,40mmol) in methanesulfonic acid (7ml) was added isoprene (1ml) at -10°C and the mixture was stirred 45h at 25°C. After the usual workup the salt was converted into the bis tetrafluoroborate (2.72g, 74%). mp : 148-50°C (MeOH). Combustion analysis in agreement with $C_9H_{22}S_2B_2F_8$.

^{1}H NMR (D_2O) (DSS) : 1.57(6H,s) ; 2.32(2H,m) ; 2.83(6H,s) ; 2.94(6H,s) ; 3.45 (2H,m).

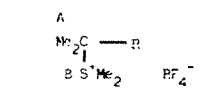
When treated under these conditions dimethylprenylsulfonium tetrafluoroborate was converted into the same bis salt.

Basic elimination of sulfonium salts

Conditions A : To a suspension of a given sulfonium salt (1mmol) in DMSO (9ml) was added a solution of t-BuOK in DMSO 1M (1ml). After standing 24h the solution was poured into water, and extracted (3x) with ether. The ethereal solution was washed and dried, an internal standard was added and analysed by glc. After evaporation of the solvent 1,1,2,2-tetrachloroethane was added as internal standard for the NMR analysis.

Conditions B : To a suspension of the sulfonium salt (1mmol) in MeOH (2.5ml) and CH_2Cl_2 (7.5ml) sodium hydroxide was added (10%)(0.1mmol). The analyses were carried out as above.

Table 6 : ^{1}H NMR spectra.



	mp	yield	A*	B*	R						Calc.			Found		
											C	H	S	C	H	S
15a		73 d	1.58	2.81	2.09	3.85										
					2H,t,J=6.5Hz	2H,t,J=6.5Hz										
15b		81 a	1.50	2.80	2.12	4.15	2.02			$C_9H_{19}O_2SBF_4$	38.87	6.89	11.53	39.01	7.03	11.11
					2H,t,J=6Hz	2H,t,J=6Hz	3H,s									
15c	68	80 c	1.60	2.85	2.10	3.65	3.48	1.60-1.12	0.92	$C_{11}H_{25}OSBF_4$	45.22	8.62	10.97	45.08	8.63	10.62
					2H,t,J=6Hz	2H,t,J=6Hz	2H,t,J=6Hz	4H,m	3H,m							
15d	41	84 a	1.50	2.80	2.18	4.18	6.83			$C_9H_{17}OSBClF_3$	30.66	4.86		30.30	5.01	
					2H,t,J=5.5Hz	2H,t,J=5.5Hz	1H,dt,J_{HF}^{2}=48Hz									
							J_{HF}^{3}=3.7Hz									
15e	124	90 b	1.58	2.95	1.5-1.07	0.87				$C_{11}H_{25}SBF_4$	47.84	9.12		47.97	9.32	
					10H,m	3H,m										
15f		78 b	1.58	2.93	2.1-1.6	3.63										
					4H,m	2H,t,J=5.2Hz										
15g		82 b	1.58	2.93	2.1-1.75	4.10	2.02			$C_{10}H_{21}O_2SBF_4$	41.11	7.25	10.97	41.04	7.11	11.40
					4H,m	2H,t,J=6Hz	3H,s									
15h		74 b	1.58	2.92	2.07-1.40	3.75	1.13									
					6H,m	1H,m	3H,d,J=6Hz									
15i		82 a	1.44	2.78	1.85-1.40	4.75	2.02			$C_{12}H_{25}O_2SBF_4$	45.01	7.87	10.01	44.71	8.14	9.61
					6H,m	1H,m	3H,s									
15j	99	81 a	1.60	2.93	2.35	4.26	7.57-6.97			$C_{13}H_{21}OSBF_4$	50.02	6.78	10.27	50.10	6.70	10.40
					2H,t,J=6Hz	2H,t,J=6Hz	5H,m									
15k	130	87 a	1.48	2.85	1.90	4.02	7.60-7.00			$C_{14}H_{23}OSBF_4$	51.55	7.11	9.83	51.37	7.00	9.43
					4H,m	2H,t,J=6Hz	5H,m									
15l	68	83 b	1.57	2.92	2.10-1.50	4.53	1.25	7.30-6.8		$C_{16}H_{27}OSBF_4$	54.25	7.68	9.05	54.36	7.65	9.23
					6H,m	1H,m	3H,d,J=6Hz	5H,m								
15m		76 c	1.56	2.89	1.84	2.46	3.73									
					4H,m	2H,m	3H,s									

* (6H,s)

a) DMSO-d6 DSS. b) CD_3COCD_3 TMS. c) $CDCl_3$ TMS. d) D_2O/DSS.

Table 7 : ^{13}C NMR spectra. DMSO-d6/TMS.

15a	56.4(CH_2O) ; 56.2(C-S^+) ; 39.5(CH_2) ; 22.1(2xCH_2) ; 19.9(2xCH_2)
15b	169.8(C=O) ; 59.3(CH_2O) ; 55.7(C-S^+) ; 35.5(CH_2) ; 21.7(2xCH_3) ; 20.7(CH_3) ; 19.4(2xCH_3)
15c	70.4(CH_2O) ; 65.6(CH_2O) ; 56.3(C-S^+) ; 37.6 ; 31.5(2xCH_2) ; 22.1(2xCH_3) ; 19.9(2xCH_3) ; 19.3(CH_2) ; 14.1(CH_3)
15d	118.6(OCF_2td) ; 95.2(CFClH dt) ; 60.7(CH_2O) ; 55.5(C-S^+) ; 35.61(CH_2) ; 21.8(2xCH_3) ; 19.5(2xCH_3)
15e	51.7(C -S^+) ; 37.7 ; 31.0 ; 28.8 ; 23.1 ; 22.1(5xCH_2) ; 21.5(2xCH_3) ; 19.2(2xCH_3) ; 14.0(CH_3)
15f	60.7(CH_2O) ; 57.6(C-S^+) ; 34.1 ; 26.9(2xCH_2) ; 21.9(2xCH_3) ; 19.5(2xCH_3)
15g	170.1(C=O) ; 63.3(CH_2) ; 56.8(C-S^+) ; 33.3 ; 22.7(2xCH_2) ; 21.4(2xCH_3) ; 20.7(CH_3) ; 19.1(2xCH_3)
15h	65.6(CHOH) ; 57.3(C-S^+) ; 39.5 ; 37.0(2xCH_2) ; 23.9(CH_3) ; 21.6(2xCH_3) ; 19.8(CH_2) ; 19.2(2xCH_3)
15i	169.7(C=O) ; 69.8(CHO) ; 57.0(C-S^+) ; 36.5 ; 35.2(2xCH_2) ; 21.4(2xCH_3) ; 21.1(CH_3) ; 19.9(CH_3) ; 19.1(2xCH_3).
15j	157.3 ; 129.2 ; 120.7 ; 114.2(arom) ; 63.0(CH_2O) ; 55.7(C-S^+) ; 36.5(CH_2) 21.9(2xCH_3) ; 19.7(2xCH_3)
15k	158.0 ; 129.2 ; 120.3 ; 114.2(arom) ; 66.7(CH_2O) ; 56.9(C-S^+) ; 33.5 ; 23.2(2xCH_2) ; 21.4(2xCH_3) ; 19.2(2xCH_3)
15l	157.3 ; 129.2 ; 120.1 ; 115.5(arom) ; 72.5(CH_2O) ; 57.0(C-S^+) ; 36.6 ; 35.7(2xCH_2) ; 21.4(2xCH_3) ; 19.6(CH_3) ; 19.3(CH_2) ; 19.1(2xCH_3)
15m	172.9(C=O) ; 57.2(C-S^+) ; 51.6(OCH_3) ; 36.4 ; 32.9(2xCH_2) ; 21.6(2xCH_3) ; 19.3(2xCH_3) ; 18.9(CH_2).

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