173. β-Cleavage of Bis(homoallylic) Potassium Alkoxides. Preparation of 3-Hydroxypropyl and 4-Hydroxybutyl Propenyl Ketones from γ- and δ-Lactones. Synthesis of (±)-Rose Oxide

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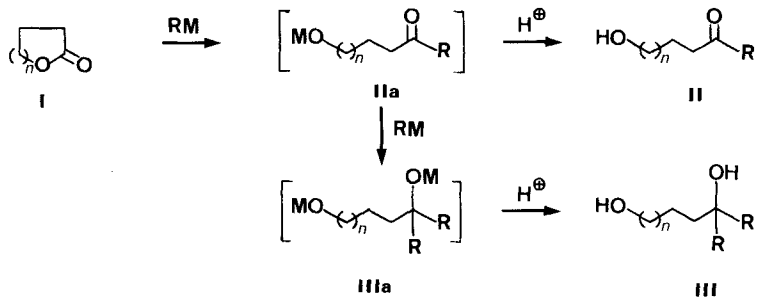
Starting from γ- and δ-lactones **1**–**3**, a two-step preparation of 3-hydroxypropyl and 4-hydroxybutyl propenyl ketones **10**–**18** is described, involving as the key step the β-cleavage of the bis(homoallylic) potassium alkoxides **4a**–**9a**. This novel methodology is illustrated by a short synthesis of (±)-rose oxide (**20**).

Introduction. – The direct preparation of a γ-hydroxy ketone **II** (n = 1) or a δ-hydroxy ketone **II** (n = 2) by the mono-addition of an organometallic reagent RM (M = Li, MgX) to a lactone **I** (n = 1, 2) is generally inefficient due to further rapid addition to the intermediate metaloxy ketone **IIa**, which leads to diol **III** after protonation of the dialkoxide **IIIa** *(cf. Scheme 1)* [1]). We now present an indirect solution to this synthetic problem for allylic organometallic reagents by describing a two-step procedure for the preparation of 3-hydroxypropyl and 4-hydroxybutyl propenyl ketones from γ- and δ-lactones, respectively. To illustrate this novel homologation methodology, we also report a synthesis of racemic rose oxide (**20**)[2]), a naturally occurring compound [3] which has incited much synthetic work because of its extensive use in perfumery [4].

Scheme 1



Results and Discussion. – *β-Cleavage of Bis(homoallylic) Potassium Alkoxides* **4a**–**9a**. In the preceding paper [5], we described an efficient two-step preparation of propenyl ketones from carboxylic esters which took advantage of the facile β-cleavage of bis(ho-

[1]) For various solutions to this general synthetic problem, see [1] and ref. cit. therein.

[2]) For a preliminary communication of this strategy for the synthesis of **20**, see [2].

Scheme 2

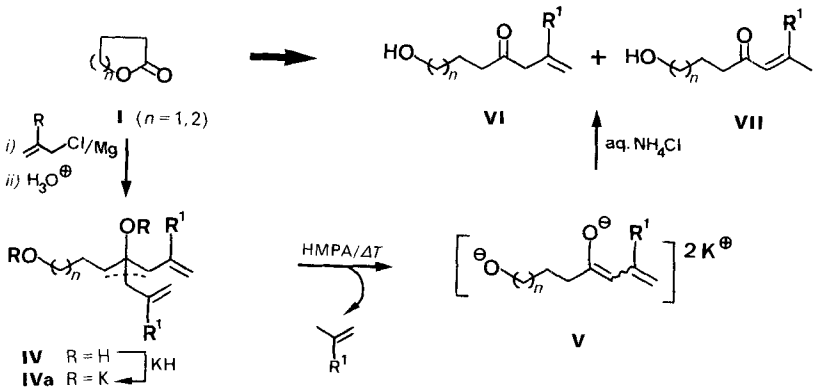
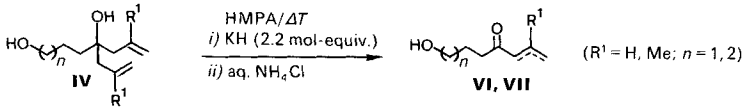
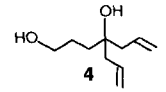
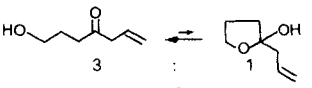
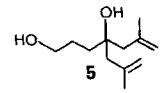
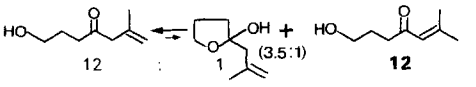
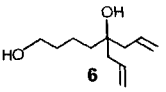
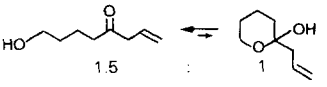
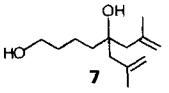
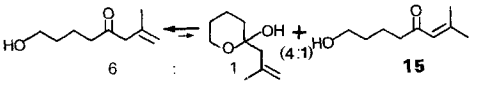
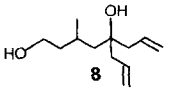
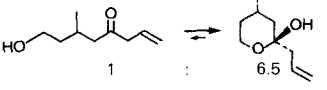
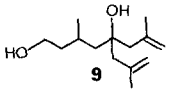
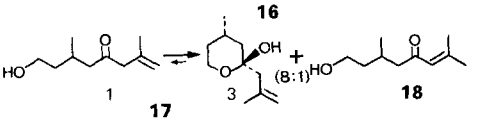


Table 1. *β-Cleavage of Bis(homoallylic) Potassium Alkoxides* **4a–9a**



Entry	Diol	Yield [%]	Reaction cond.	Products[a])	Yield [%]
1	 **4**	85[b])	100°/2 h	 3 : 1 **10**	31
2	 **5**	69[b])	100°/2 h	 12 : 1 (3.5:1) **11** **12**	67
3	 **6**	68[c])	90°/3 h	 1.5 : 1 **13**	62
4	 **7**	87[c])	75°/3 h	 6 : 1 (4:1) **14** **15**	68
5	 **8**	65[d])	95°/2 h	 1 : 6.5 **16**	67
6	 **9**	82[d])	65°/3 h	 1 : 3 (8:1) **17** **18**	76

[a]) Products isolated by column chromatography on silica gel *(cf. Exper. Part)*; compositions of tautomeric mixtures measured at 25°; in $CDCl_3$ solution, by ^{1}H-NMR (360 MHz) spectroscopy. [b]) Yield from γ-butyrolactone (**1**). [c]) Yield from δ-valerolactone (**2**). [d]) Yield from 3-methyl-δ-valerolactone (**3**).

moallylic) potassium alkoxides in dipolar aprotic solvents. It was thus envisaged that the same strategy could be employed for an analogous transformation of lactones **I** (n = 1, 2) *via* diols **IV** to hydroxyalkyl 2- and 1-propenyl ketones **VI** and **VII**, respectively *(cf. Scheme 2)*.

Accordingly, the six diols **4–9** were prepared in 65–87% yield *(cf. Table 1)* by reaction of commercially available γ-butylrolactone (**1**), δ-valerolactone (**2**) and 3-methyl-δ-valerolactone (**3**) with an excess of either allylmagnesium chloride or methallylmagnesium chloride, formed *in situ* in THF, using *Barbier* conditions[3]). Each of these diols was then treated with KH (2.2 mol-equiv.) in hexamethylphosphoric triamide (HMPA) at 25°, and the resulting HMPA solutions of the dipotassium dialkoxides **4a–9a** were then heated under the reaction conditions indicated *(cf. Table 1)*. Aqueous workup (aq. NH_4Cl solution), extraction with Et_2O, and column chromatography on silica gel resulted in the isolation of the products **10–18** in 31–81% yield. Compounds **10**, **11**, **13**, **14**, **16**, and **17** are tautomeric mixtures of β,γ-unsaturated hydroxy ketones and lactols whose equilibrium composition at 25° in $CDCl_3$ solution was conveniently measured by ^{1}H-NMR (360 MHz) spectroscopy. For **10**, **11**, **13**, and **14**, the hydroxy-ketone tautomer is energetically favoured, whereas the introduction of a Me group in **16** and **17** results in a reversal of this situation, and it is the lactol tautomer which is relatively more stable. As previously observed in analogous systems [5], the formation of β,γ-unsaturated ketones **VI** is preferred with respect to their α,β-unsaturated isomers **VII**. This result is kinetically controlled and reflects a site-selective α-protonation of the intermediate potassium dienolate **V** formed from the β-cleavage of the bis(homoallylic) alkoxide **IVa** *(cf. Scheme 2)*. It is interesting to note the absence of the α,β-unsaturated isomers of **10**, **13**, and **16** amongst the isolated products *(cf. Entries 1, 3,* and *5, Table 1)*. This result may be the consequence of an exclusive α-protonation of **V**, but is more likely due to the relative instability of these putative products[4]). The only moderate yields of isolated products in these cases, especially for **10** *(cf. Entry 1)*, lend support to this latter hypothesis.

Because the transformation of **9** to afford **17** and **18** was of special interest in the context of a projected synthesis of rose oxide (**20**; *vide infra*), it was decided to investigate

Table 2. *β-Cleavage of* **9a**

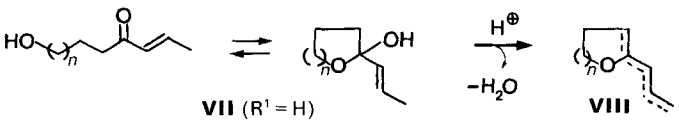
Entry	Reaction cond.[a])	**17**	**18**	Yield [%]
1[b])	KH, HMPA, 65°	89	11	76
2[b])	*t*-BuOK, DMF, 80°	86	14	81
3[c])	NMP, 210°	6	94	72
4[c])	400° (gas phase)	95	5	67

[a]) For details, see *Exper. Part.*

[b]) Products isolated after aqueous workup.

[c]) Products isolated by distillation *i.v.*

[3]) Recent studies [6] indicate that the *Barbier* reaction does not necessarily involve the *in-situ* formation of an organometallic compound but may occur *via* a radical-anion intermediate.



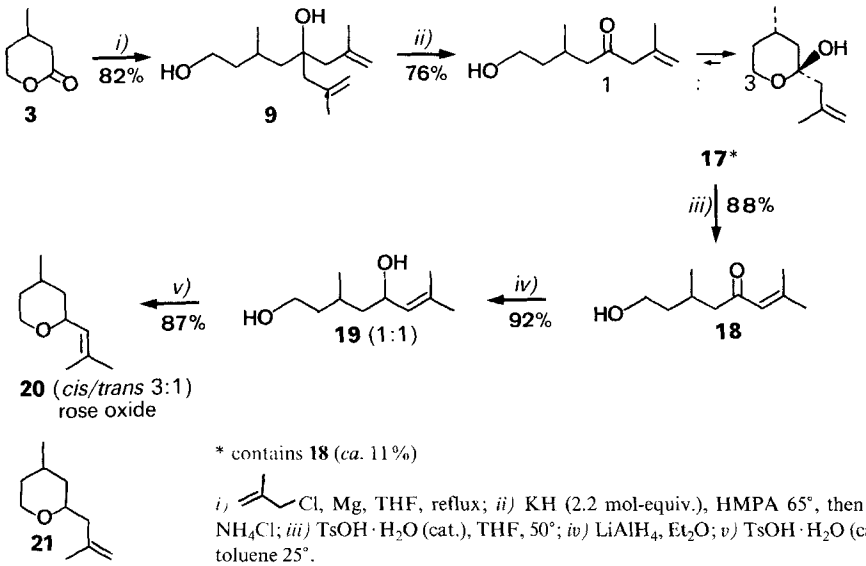
VII (R^1 = H) **VIII**

[4]) A possible decomposition pathway for **VII** (R′ = H) may involve acid-catalysed dehydration to dienol ethers **VIII**.

alternative conditions for the β-cleavage of its dipotassium dialkoxide **9a**. The results of four experiments are summarised in *Table 2*. Treatment of **9** with *t*-BuOK (2.2 mol-equiv.) in dimethylformamide (DMF) at 80° [2] *(cf. Entry 2)* gave essentially the same result as the use of KH in HMPA *(cf. Entry 1)* as did the replacement of DMF by other dipolar aprotic solvents such as HMPA or *N*-methylpyrrolidone (NMP). In addition, the thermal *retro*-ene reaction [7] of **9** was studied, either in the liquid phase at 210° with NMP as solvent[5]) *(cf. Entry 3)* or in the gas phase at 400° *(cf. Entry 4)*. In the former experiment, the *retro*-ene reaction was followed by essentially complete equilibration of **17** to **18**, whereas the latter pyrolysis experiment afforded **17** as expected, with almost no observed equilibration.

Synthesis of (±)-Rose Oxide (**20**). *Scheme 3* outlines a short synthesis of (±)-rose oxide (**20**) starting from 3-methyl-δ-valerolactone (**3**)[6]). The two-step transformation of **3** to a 8:1 mixture **17**/**18** (overall yield 61%) has already been described *(cf. Table 1)*. Equilibration of this mixture with a catalytic amount of TsOH in THF at 50° led smoothly to **18** in 88% yield. Reduction with $LiAlH_4$ in Et_2O afforded the diol **19** (1:1 diastereoisomeric mixture) which underwent acid-catalysed ring closure (TsOH/toluene, 25°)[7]) to furnish **20** (*cis*/*trans* 3:1) in 87% yield, identical in all respects with an authentic sample.

Scheme 3



* contains **18** (*ca.* 11%)

i) Cl, Mg, THF, reflux; *ii)* KH (2.2 mol-equiv.), HMPA 65°, then aq. NH_4Cl; *iii)* $TsOH \cdot H_2O$ (cat.), THF, 50°; *iv)* $LiAlH_4$, Et_2O; *v)* $TsOH \cdot H_2O$ (cat.), toluene 25°.

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[5]) For the use of NMP as solvent in the oxy-*Cope* rearrangement, see [8].

[6]) For a stereoselective synthesis of *trans*-**20** from **3**, see [9].

[7]) Acid-catalysed ring closure of **19** to **20** (*cis*/*trans* 4:1) may also be effected using $KHSO_4$ at 50–60°/12 Torr (76% yield) [2]. In contrast, treatment of **19** with a catalytic amount of $TsOH \cdot H_2O$ in refluxing toluene afforded substantial amounts of *3,4,5,6-tetrahydro-4-methyl-2-(2'-methyl-2'-propenyl)-2H-pyran* (**21**; *cis*/*trans ca.* 10:1). *cis*-**21**: ^{1}H-NMR: 0.93 (*d*, *J* = 7, 3 H); 1.75 (*s*, 3 H); 0.80–1.80 (5 H); 2.09 (*dd*, *J* = 14, 6, 1 H); 2.27 (*dd*, *J* = 14, 8, 1 H); 3.42 (*ddd*, *J* = 11, 9, 2, 1 H); 3.93–4.03 (2 H); 4.75 (*s*, 1 H); 4.80 (*s*, 1 H). MS: 154 (0, $M^{+\cdot}$), 99 (100), 81 (25), 69 (15), 55 (25), 43 (49). *trans*-**21**: ^{1}H-NMR: 1.05 (*d*, *J* = 7, 3 H); 1.75 (*s*, 3 H); 0.80–2.40 (7 H); 3.60–3.85 (3 H); 4.75 (*s*, 1 H); 4.80 (*s*, 1 H). MS: 154 (0, $M^{+\cdot}$), 99 (100), 81 (25), 55 (26), 43 (58).

Experimental Part

General. See [5]. ^{1}H-NMR spectra: recorded at 360 MHz unless otherwise indicated.

General Procedure for the Preparation of Diols 4–9. – A soln. of either allyl chloride or methallyl chloride (0.25 mol) and γ-butyrolactone (**1**), δ-valerolactone (**2**), or 3-methyl-δ-valerolactone[8]) (**3**; 0.1 mol) in THF (120 ml) was added dropwise to a stirred slurry of Mg turnings (0.24 mol) in THF (20 ml) under N_2 at such a rate as to maintain a gentle reflux. After the addition (*ca.* 1 h), the mixture was refluxed until TLC indicated completion of the reaction (1–3 h). The mixture was then poured into cold sat. aq. NH_4Cl soln., the aq. phase extracted with Et_2O (4 × 50 ml), and the combined org. phase washed once with H_2O, 4 times with sat. aq. NaCl soln., dried (Na_2SO_4), and evaporated. Fractional distillation *i.v.* afforded diols **4**, **6**, **8**, and **9** as colourless oils and **5** and **7** as white crystals.

4-(2'-Propenyl)-6-hepten-1,4-diol (**4**) (85% yield from **1**). B.p. 96–97°/0.04 Torr ([10]: 118°/2 Torr; [11]: 75–78°/0.001 Torr). R_f (AcOEt) 0.49. IR: 3320 (br.), 3060, 2910, 1638, 1438, 990, 905. ^{1}H-NMR (60 MHz, +D_2O): 1.67 (4 H); 2.23 (*d*, *J* = 7, 4 H); 3.58 (*m*, 2 H); 5.04 (br. *d*, *J* = 18, 2 H); 5.08 (*dd*, *J* = 11, 2, 2 H); 5.83 (*m*, 2 H). MS: 170 (0, $M^{+\cdot}$), 111 (62), 91 (21), 87 (40), 79 (18), 69 (100), 55 (18), 41 (79).

6-Methyl-4-(2'-methyl-2'-propenyl)-6-hepten-1,4-diol (**5**) (69% yield from **1**). B.p. 97–98°/0.03 Torr. M.p. 59–60°. R_f (AcOEt) 0.61. IR ($CDCl_3$): 3350 (br.), 3060, 2900, 1638, 1436, 1360, 1040. ^{1}H-NMR (60 MHz, +D_2O): 1.60 (4 H); 1.82 (*s*, 6 H); 2.23 (*s*, 4 H); 3.57 (*m*, 2 H); 4.76 (2 H); 4.90 (2 H). MS: 198 (0, $M^{+\cdot}$), 125 (18), 87 (100), 83 (22), 69 (26), 55 (57), 41 (27).

5-(2'-Propenyl)-7-octen-1,5-diol (**6**) (68% yield from **2**). B.p. 98–99°/0.03 Torr. R_f (AcOEt) 0.49. IR: 3320 (br.), 3060, 2900, 1638, 1430, 990, 904. ^{1}H-NMR (60 MHz, +D_2O): 1.46 (6 H); 2.23 (*d*, *J* = 7, 4 H); 3.58 (*m*, 2 H); 5.05 (br. *d*, *J* = 18, 2 H); 5.10 (*dd*, *J* = 11, 2, 2 H); 5.82 (*m*, 2 H). MS: 184 (0, $M^{+\cdot}$), 143 (9), 125 (55), 101 (27), 83 (35), 69 (100), 55 (78), 41 (81).

7-Methyl-5-(2'-methyl-2'-propenyl)-7-octen-1,5-diol (**7**) (87% yield from **2**). B.p. 99–100°/0.04 Torr. M.p. 35–36°. R_f (AcOEt) 0.65. IR: 3350 (br.), 3060, 2900, 1638, 1440, 1372, 900. ^{1}H-NMR (60 MHz, +D_2O): 1.50 (6 H); 1.84 (6 H); 2.22 (*s*, 4 H); 3.63 (*m*, 2 H); 4.78 (2 H); 4.94 (2 H). MS: 212 (0, $M^{+\cdot}$), 139 (29), 109 (100), 98 (17), 83 (30), 67 (42).

3-Methyl-5-(2'-propenyl)-7-octen-1,5-diol (**8**) (65% yield from **3**). B.p. 96–97°/0.03 Torr. R_f (AcOEt) 0.61. IR: 3320 (br.), 3060, 2900, 1636, 1430, 1050, 988, 906. ^{1}H-NMR (60 MHz, +D_2O): 0.98 (*d*, *J* = 7, 3 H); 1.00–2.20 (5 H); 2.26 (*dd*, *J* = 7, 2, 4 H); 3.64 (*t*, *J* = 7, 2 H); 5.06 (br. *d*, *J* = 18, 2 H); 5.10 (br. *d*, *J* = 11, 2, 2 H); 5.83 (*m*, 2 H). MS: 198 (0, $M^{+\cdot}$), 139 (38), 91 (21), 79 (23), 69 (100), 55 (32), 41 (69).

3,7-Dimethyl-5-(2'-methyl-2'-propenyl)-7-octen-1,5-diol (**9**) (82% yield from **3**). B.p. 103–104°/0.05 Torr. R_f (AcOEt) 0.73. IR: 3350 (br.), 3060, 2910, 1638, 1440, 1368, 1052, 882. ^{1}H-NMR (60 MHz, +D_2O): 1.01 (*d*, *J* = 7, 3 H); 1.84 (*s*, 6 H); 2.23 (*s*, 4 H); 1.00–2.40 (5 H); 3.66 (*t*, *J* = 7, 2 H); 4.74 (2 H); 4.92 (2 H). MS: 226 (0, $M^{+\cdot}$), 115 (100), 97 (23), 83 (26), 73 (55), 69 (89), 55 (85).

General Procedure for the β-Cleavage of the Dipotassium Dialkoxides 4a–9a. – A soln. of the corresponding diol (8 mmol) in HMPA (10 ml) was added dropwise within 20 min to a stirred slurry of KH (20 mmol) in HMPA (25 ml) at r.t. under N_2. The mixture was stirred at r.t. for further 20 min and then heated[9]), until TLC (after quenching of an aliquot with sat. aq. NH_4Cl soln. followed by extraction with Et_2O) indicated completion of the reaction. The cooled mixture was then poured cautiously into cold sat. aq. NH_4Cl soln. (150 ml) and extracted with Et_2O (4 × 50 ml). The combined org. phase was washed with H_2O, sat. aq. $NaHCO_3$ and sat. aq. NaCl soln., dried (Na_2SO_4), concentrated at atmospheric pressure, and the residual oil purified by column chromatography (silica gel (50 g), cyclohexane/AcOEt 1:1). Distillation *i.v.* afforded the products described below.

7-Hydroxy-1-hepten-4-one and 2,3,4,5-Tetrahydro-2-(2'-propenyl)furan-2-ol (3:1 tautomeric mixture; **10**) (31% yield from **4**). B.p. (bulb-to-bulb distillation) 50–60°/0.04 Torr. R_f (cyclohexane/AcOEt 3:2) 0.22. IR: 3400 (br.), 3060, 2920, 2870, 1700, 1638, 1400, 1040, 920. ^{1}H-NMR (+D_2O): hydroxy ketone: 1.84 (*tt*, *J* = 7, 7, 2 H); 2.60 (*t*, *J* = 7, 2 H); 3.21 (*d*, *J* = 7, 2 H); 3.64 (*t*, *J* = 6.5, 2 H); 5.15 (br. *d*, *J* = 18, 1 H); 5.19 (br. *d*, *J* = 11, 1 H); 5.92 (*m*, 1 H); lactol: 1.75–2.15 (4 H); 2.51 (*m*, 2 H); 3.89 (*m*, 1 H); 4.04 (*m*, 1 H); 5.10–5.25 (*m*, 2 H); 5.85–6.00 (*m*, 1 H). MS: 128 (0, $M^{+\cdot}$), 111 (53), 84 (30), 69 (100), 41 (28).

7-Hydroxy-2-methyl-1-hepten-4-one and 2,3,4,5-Tetrahydro-2-(2'-methyl-2'-propenyl)furan-2-ol (12:1 tautomeric mixture; **11**) (52% yield from **5**). B.p. (bulb-to-bulb distillation) 90–120°/0.03 Torr. R_f (cyclohexane/AcOEt 3:2) 0.14. IR: 3400 (br.), 1700, 1612, 1440, 1370, 1040, 890. ^{1}H-NMR (+D_2O): hydroxy ketone: 1.75 (*s*, 3 H); 1.84

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[8]) Obtained from *BASF AG*, Ludwigshafen.

[9]) For the individual reaction conditions, *cf. Table 1.*

(*tt*, J = 7, 7, 2 H); 2.61 (*t*, J = 7, 2 H); 3.14 (*s*, 2 H); 3.63 (*t*, J = 6, 2 H); 4.83 (*s*, 1 H); 4.95 (*s*, 1 H); lactol: 1.70–2.00 (7 H); 2.44 (*d*, J = 14, 1 H); 2.52 (*d*, J = 14, 1 H); 3.89 (*m*, 1 H); 4.02 (*m*, 1 H); 4.74 (br. *s*, 1 H); 4.84 (br. *s*, 1 H). MS: 142 (0, $M^{+\cdot}$), 83 (100).

Also isolated was *7-hydroxy-2-methyl-2-hepten-4-one* (**12**) (15% yield from **5**). B.p. (bulb-to-bulb distillation) 90–120°/0.03 Torr. R_f (cyclohexane/AcOEt 3:2) 0.12. IR: 3400 (br.), 1680. ^{1}H-NMR (+D_2O): 1.82 (*tt*, J = 7, 7, 2 H); 1.89 (*s*, 3 H); 2.15 (*s*, 3 H); 2.58 (*t*, J = 7, 2 H); 3.64 (*t*, J = 6, 2 H); 6.10 (br. *s*, 1 H). MS: 142 (0, $M^{+\cdot}$), 83 (100).

*8-Hydroxy-1-octen-4-one and 3,4,5,6-Tetrahydro-2-(2'-propenyl)-2*H*-pyran-2-ol* (1.5:1 tautomeric mixture; **13**) (62% yield from **6**). B.p. (bulb-to-bulb distillation) 100–125°/0.03 Torr. R_f (cyclohexane/AcOEt 3:2) 0.22. IR: 3400 (br.), 3070, 2850, 1700, 1638, 1400, 1036, 986, 912. ^{1}H-NMR (+D_2O): hydroxy ketone: 1.55 (*m*, 2 H); 1.67 (*m*, 2 H); 2.50 (*t*, J = 7, 2 H); 3.18 (*d*, J = 6.5, 2 H); 3.62 (*t*, J = 7, 2 H); 5.10–5.24 (2 H); 5.93 (1 H); lactol: 1.45–1.95 (6 H); 2.26 (*dd*, J = 14, 8, 1 H); 2.44 (*dd*, J = 14, 6, 1 H); 3.63 (*m*, 1 H); 3.93 (*m*, 1 H); 5.10–5.24 (2 H); 5.91 (*m*, 1 H). MS: 142 (0, $M^{+\cdot}$), 125 (40), 83 (15), 69 (100), 55 (36), 41 (26).

*8-Hydroxy-2-methyl-1-octen-4-one and 3,4,5,6-Tetrahydro-2-(2'-methyl-2'-propenyl)-2*H*-pyran-2-ol* (6:1 tautomeric mixture; **14**) (54% yield from **7**). B.p. 110–120°/0.03 Torr. R_f (cyclohexane/AcOEt 3:2) 0.18. IR: 3400 (br.), 3060, 2900, 1700, 1640, 1440, 1400, 1370, 1050, 890. ^{1}H-NMR (+D_2O): hydroxy ketone: 1.56 (*m*, 2 H); 1.67 (*m*, 2 H); 1.74 (*s*, 3 H); 2.52 (*t*, J = 7, 2 H); 3.11 (*s*, 2 H); 3.61 (*t*, J = 7, 2 H); 4.82 (br. *s*, 1 H); 4.94 (br. *s*, 1 H); lactol: 1.50–1.90 (6 H); 1.85 (*s*, 3 H); 2.26 (*d*, J = 14, 1 H); 2.36 (*d*, J = 14, 1 H); 3.62 (*m*, 1 H); 3.92 (*m*, 1 H); 4.81 (br. *s*, 1 H); 4.98 (br. *s*, 1 H). MS: 156 (0, $M^{+\cdot}$), 138 (11), 123 (29), 101 (78), 83 (88), 55 (100).

Also isolated was *8-hydroxy-2-methyl-2-octen-4-one* (**15**) (14% yield from **7**). B.p. (bulb-to-bulb distillation 120–130°/0.02 Torr. R_f (cyclohexane/AcOEt 3:2) 0.14. IR: 3400 (br.), 2900, 1675, 1610, 1440, 1374, 1220, 1110, 1025, 840. ^{1}H-NMR (+D_2O): 1.56 (*m*, 2 H); 1.68 (*m*, 2 H); 1.89 (*s*, 3 H); 2.14 (*s*, 3 H); 2.46 (*t*, J = 7, 2 H); 3.61 (*t*, J = 7, 2 H); 6.08 (br. *s*, 1 H). MS: 156 (0, $M^{+\cdot}$), 138 (5), 109 (8), 83 (100), 69 (10), 55 (38).

*(2*RS*,4*RS*)-3,4,5,6-Tetrahydro-4-methyl-2-(2'-propenyl)-2*H*-pyran-2-ol and 8-Hydroxy-6-methyl-1-octen-4-one* (6.5:1 tautomeric mixture; **16**) (67% yield from **8**). B.p. (bulb-to-bulb distillation) 50–60°/0.04 Torr. R_f (cyclohexane/AcOEt 3:2) 0.42. IR: 3400 (br.), 3065, 2925, 1704*w*, 1640, 1170, 1118, 980, 910, 870. ^{1}H-NMR (+D_2O): lactol: 0.91 (*d*, J = 7, 3 H); 1.12 (*dd*, J = 12.5, 12.5, 1 H); 1.18 (*dddd*, J = 12.5, 12.5, 12.5, 4.5, 1 H); 1.56 (br. *d*, J = 12.5, 1 H); 1.71 (br. *d*, J = 12.5, 1 H); 1.97 (*m*, 1 H); 2.27 (*dd*, J = 14, 8, 1 H); 2.43 (*dd*, J = 14, 6.5, 1 H); 3.65 (*m*, 1 H); 3.92 (*m*, 1 H); 5.17 (br. *d*, J = 18, 1 H); 5.20 (br. *d*, J = 11, 1 H); 5.90 (*m*, 1 H); hydroxy ketone: 0.95 (*d*, J = 7, 3 H); 1.10–1.25 (1 H); 1.49 (*dt*, J = 7, 7, 2 H); 2.20–2.50 (2 H); 3.17 (*d*, J = 7, 2 H); 3.60–3.70 (2 H); 5.10–5.25 (2 H); 5.92 (*m*, 1 H). MS: 156 (0, $M^{+\cdot}$), 138 (4), 123 (11), 115 (92), 97 (30), 87 (20), 73 (85), 69 (100), 55 (47), 41 (39).

*(2*RS*,4*SR*)-3,4,5,6-Tetrahydro-4-methyl-2-(2'-methyl-2'-propenyl)-2*H*-pyran-2-ol and 8-Hydroxy-2,6-dimethyl-1-octen-4-one* (3:1 tautomeric mixture; **17**) (68% yield from **9**). B.p. (bulb-to-bulb distillation) 70–90°/0.03 Torr. R_f (cyclohexane/AcOEt 3:2) 0.42. IR: 3400 (br.), 3060, 2850, 1700*w*, 1640, 1440, 1220, 1180, 1030, 980, 886, 856. ^{1}H-NMR (+D_2O): lactol: 0.90 (*d*, J = 7, 3 H); 1.13 (*dd*, J = 12.5, 12.5, 1 H); 1.17 (*dddd*, J = 12.5, 12.5, 12.5, 4.5, 1 H); 1.55 (br. *d*, J = 14, 1 H); 1.70 (br. *d*, J = 14, 1 H); 1.86 (*s*, 3 H); 1.99 (*m*, 1 H); 2.28 (*d*, J = 12.5, 1 H); 2.35 (*d*, J = 12.5, 1 H); 3.63 (*m*, 1 H); 3.90 (*m*, 1 H); 4.80 (br. *s*, 1 H); 4.98 (br. *s*, 1 H); hydroxy ketone: 0.94 (*d*, J = 7, 3 H); 1.10–1.25 (1 H); 1.49 (*dt*, J = 7, 7, 2 H); 1.75 (*s*, 3 H); 2.37 (*dd*, J = 17, 7, 1 H); 2.49 (*dd*, J = 17, 7, 1 H); 3.10 (*s*, 2 H); 3.63 (*t*, J = 6, 2 H); 4.82 (br. *s*, 1 H); 4.95 (br. *s*, 1 H). MS: 170 (0, $M^{+\cdot}$), 137 (18), 115 (100), 97 (24), 83 (18), 69 (72), 55 (36), 40 (50).

Also isolated was *8-hydroxy-2,6-dimethyl-2-octen-4-one* (**18**) (8% yield from **9**). B.p. (bulb-to-bulb distillation) 90–120°/0.01 Torr. R_f (cyclohexane/AcOEt 3:2) 0.26. R_f (AcOEt) 0.60. IR: 3400 (br.), 2900, 1670, 1610, 1440, 1370, 1040. ^{1}H-NMR (+D_2O): 0.95 (*d*, J = 7, 3 H); 1.50 (*m*, 2 H); 1.89 (*s*, 3 H); 2.15 (*s*, 3 H); 2.22 (*m*, 1 H); 2.31 (*dd*, J = 16, 6.5, 1 H); 2.43 (*dd*, J = 16, 7, 1 H); 3.62 (*m*, 2 H); 6.08 (*s*, 1 H). MS: 170 (0, $M^{+\cdot}$), 152 (2), 137 (5), 98 (8), 83 (100), 55 (41).

Alternative Procedures for the Conversion of 9 to 17 and 18. – *t-BuOK/DMF, 80°.* A mixture of **9** (2.26 g, 0.01 mol) and *t*-BuOK (2.5 g, 0.022 mol) in DMF (20 ml) was heated at 80° for 3 h under N_2. The cooled mixture was poured into cold aq. NH_4Cl soln. and extracted with Et_2O (4 × 50 ml). The combined org. phase was washed with sat. aq. $NaHCO_3$ and sat. aq. NaCl soln., dried (Na_2SO_4), concentrated, and distilled *i.v.* (bulb-to-bulb distillation: 90–120°/0.01 Torr) to afford a pale-yellow oil (1.5 g) which consisted of a 6:1 mixture (purity 92%) **17**/**18** (81% yield).

N-Methylpyrrolidone (NMP)/210°. A soln. of **9** (10 g, 0.044 mol) in NMP (20 ml) was heated in a sealed *Pyrex* tube at 210° for 1.5 h. Fractional distillation *i.v.* afforded a pale-yellow oil (6.1 g) which consisted of a 15:1 mixture (purity 88%) **18**/**17** (72% yield).

400° (Gas Phase). Alcohol **9** (10 g, 0.044 mmol) containing pyridine (0.5 g) was pumped at 1 ml/min through a 5 m *Pyrex* pyrolysis column (diameter 5 mm) under a N_2 stream. Distillation *i.v.* of the pyrolysate afforded a pale-yellow oil (5.6 g) which consisted of a 19:1 mixture (purity 90%) **17/18** (67% yield).

Acid-Catalysed Equilibration of 17 to 18. – A crude 8:1 mixture **17/18** (1.7 g, 10 mmol) in THF (70 ml) containing $TsOH \cdot H_2O$ (200 mg) was stirred at r.t. for 18 h and then heated at 50° for 2 h. The cooled mixture was diluted with Et_2O (50 ml) and washed with sat. aq. $NaHCO_3$ and sat. aq. NaCl soln. The org. phase was then dried (Na_2SO_4), concentrated *i.v.*, and the residual oil purified by column chromatography (silica gel (100 g), cyclohexane/AcOEt 7:3) to afford **18** as a colourless oil (1.5 g, 88%). *Vide supra* for physical and spectral properties.

Conversion of 18 to Rose Oxide (20). – *3,7-Dimethyl-6-octen-1,5-diol* (**19**; 1:1 diastereoisomeric mixture). A soln. of **18** (850 mg, 5 mmol) in Et_2O (10 ml) was added dropwise, within 15 min to a stirred slurry of $LiAlH_4$ (190 mg, 5 mmol) in Et_2O (10 ml) at 25° under N_2. After further 45 min at 30°, the mixture was cooled and H_2O (0.2 ml) added cautiously. Subsequent addition of 15% aq. NaOH soln. (0.2 ml) and H_2O (0.6 ml) followed by filtration *(Hyflo)* of the white slurry afforded an ethereal solution which was evaporated. The residual oil was purified by column chromatography (silica gel (100 g), AcOEt) to afford **19** as a viscous, colourless oil (700 mg, 92%). B.p. (bulb-to-bulb distillation) 160–180°/0.04 Torr ([12]: 132–133°/3 Torr). R_f (AcOEt) 0.38, 0.41. IR: 3300 (br.), 2800, 1440, 1366, 1000, 838. ^{1}H-NMR (+D_2O): 0.92, 0.96 (2*d*, *J* = 7, 3 H); 0.85–2.00 (5 H); 1.69–1.72 (2 br. *s*, 6 H); 3.68 (*m*, 2 H); 4.45 (*m*, 1 H); 5.15, 5.18 (2*d*, *J* = 7, 1 H). MS: 172 (0, $M^{+\cdot}$), 154 (10), 139 (100), 83 (32), 69 (72), 55 (30), 41 (22).

*3,4,5,6-Tetrahydro-4-methyl-2-(2'-methyl-1'-propenyl)-2*H*-pyran* (= *Rose Oxide*; **20**; *cis*/*trans* 3:1). A soln. of **19** (1:1 diastereoisomeric mixture; 516 mg, 3 mmol) in toluene (8 ml) containing $TsOH \cdot H_2O$ (100 mg) was stirred at 25° for 2 h under N_2. The org. solution was washed with sat. aq. $NaHCO_3$ and sat. aq. NaCl soln. and dried (Na_2SO_4). Concentration and distillation *i.v.* of the residual oil afforded **20** (*cis*/*trans* 3:1) as a colourless oil (400 mg, 87%). B.p. (bulb-to-bulb distillation) 100–120°/15 Torr ([4]: 70°/11 Torr).

Data of cis-**20**: R_f (CH_2Cl_2) 0.46. ^{1}H-NMR: 0.93 (*d*, *J* = 7, 3 H); 0.95–1.80 (5 H); 1.68 (*s*, 3 H); 1.72 (*s*, 3 H); 3.46 (*ddd*, *J* = 11, 9, 2, 1 H); 3.93–4.03 (2 H); 5.16 (*d*, *J* = 9, 1 H). MS: 154 (10, $M^{+\cdot}$), 139 (100), 84 (24), 69 (56), 55 (23), 41 (19).

Data of trans-**20**: R_f (CH_2Cl_2) 0.41. ^{1}H-NMR: 1.06 (*d*, *J* = 7, 3 H); 0.95–1.80 (4 H); 1.68 (*s*, 3 H); 1.72 (*s*, 3 H); 2.01 (*m*, 1 H); 3.71 (*m*, 2 H); 4.36 (*ddd*, *J* = 11, 9, 4, 1 H); 5.28 (*d*, *J* = 9, 1 H). MS: 154 (7, $M^{+\cdot}$), 139 (100), 83 (37), 69 (51), 55 (27), 41 (28).

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