The Reactivity of 4-Hydroxy-6-methyl-2-pyrone Towards Aliphatic Saturated and α,β-Unsaturated Aldehydes

P. de March [a], M. Moreno-Mañas* [a], J. Casado, [a], R. Pleixats [b],
J. L. Roca [a] and A. Trius [a]

[a] Departamento de Química Orgánica, Facultad de Ciencias,
[b] Departamento de Química, Facultad de Veterinaria,
Universidad Autónoma de Barcelona, Bellaterra, Barcelona, Spain

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4-Hydroxy-6-methyl-2-pyrone (triacetic acid lactone) reacts at C-3 with 2-butenal and similar aldehydes by Michael addition. The nonisolated intermediates can undergo transformations in at least five different ways. On the contrary, reaction of the title pyrone with cinnamaldehyde occurs at the carbonyl group of the aldehyde.

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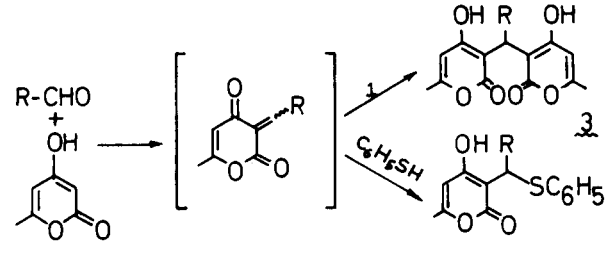
Triacetic acid lactone, **1**, is one of the most simple polyketides [1]. It can be easily prepared by deacetylation of the industrially available 3-acetyl-4-hydroxy-6-methyl-2-pyrone (dehydroacetic acid) [2]. Thus, the lactone **1**, is an appropriate starting material for the synthesis of natural products with 2-pyrone, dihydro- and tetrahydro-2-pyrone structures [3,4,5,6,7].

Triacetic acid lactone reacts, under Knoevenagel conditions, with aromatic aldehydes to afford arylbis(4-hydroxy-6-methyl-2-oxo-2*H*-pyran-3-yl)methanes, **3**, (Scheme 1) formed by Michael addition of a second molecule of **1** to the electrophilic intermediates **2**, which are never isolated [8]. Intermediates **2** can also be trapped by thiophenol to afford aryl(4-hydroxy-6-methyl-2-oxo-2*H*-pyran-3-yl)phenylthiomethanes, **4**.

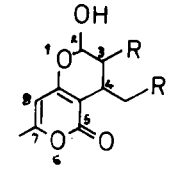
Scheme 1



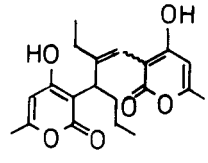
3a CH_3-
3b Et-
3c n-Pr-
3d $C_6H_5CH=CH$-

4a n-Pr-
4b n-C_9H_{19}-

In the course of a synthetic project we had to prepare the lactones **4a** and **4b**. However, from the corresponding reactions we could also isolate and identify two by-products of general constitution **5** (mixtures of stereoisomers),



5a Et-
5b n-C_8H_{17}-



6

as evidenced by the usual spectroscopic techniques and elemental analysis. The pmr spectrum of **5a** presented singlets at δ 5.73 (H at C-8) and 2.18 (methyl group at C-7), two broad singlets for the protons at C-2 of two diastereoisomers at 5.51 and 5.18, and multiplets centered at 1.79 and 2.52 due to the protons at C-3 and C-4. The mass spectrum of **5a** presented the molecular ion at m/e 252 and a peak at 209 arising from the cleavage of the group CH_2-R at C-4. The usual loss of carbon monoxide from the fragment 209 gave a new peak at 181. A similar pattern was observed for **5b**.

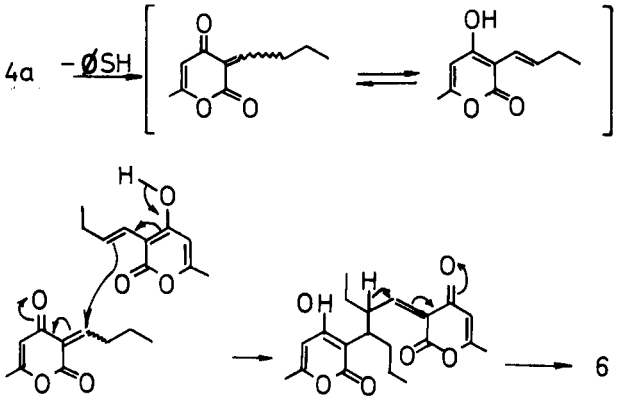
Moreover, in a purification of **4a** by column chromatography on silica gel, a new product could be isolated to which the constitution **6** was assigned on spectroscopic and elemental analysis grounds. Thus, the pmr of **6** showed two pairs of singlets at 5.75 and 5.84 and at 2.23 and 2.25 due, respectively, to the protons and the methyl groups at the pyrone rings. The olefinic proton appeared at 5.38 as a long range coupled singlet. The allylic methinic proton could also be distinguished at 2.66 as a multiplet. The mass spectrum of **6** showed the molecular ion at m/e 360 and also peaks at 317 (loss of the propyl chain) and 180.

Products **5** clearly arose from the α,β-unsaturated aldehydes formed, under the reaction conditions, by aldol condensation of butanal and of decanal. Since **6** was produced by decomposition of **4a** on silica gel, we propose for its formation the mechanism given in Scheme 2.

Table

Run	1:ald	Solvent	(1)	Time (h)	Temp (°C)	Products (%)
1	3:1	EtOH	0.4 *M*	1	Ref	**3a** (24), **7** (47)
2	2:1	EtOH	0.33 *M*	16	rt	**7** (42), **8** (13), **9** (6), **10a** (20)
3	1:1	EtOH	0.4 *M*	16	rt	**7** (27), **8** (44), **9** (6), **10a** (12)
4	1:1	EtOH	0.15 *M*	25	rt	**8** (22), **9** (3), **10a** (41)
5	2:1	MeOH	0.4 *M*	140	rt	**7** (32), **10b** (47)
6	2:1	EtOAc	0.08 *M*	7	60	**7** (66)
7	1:1	EtOAc	0.08 *M*	0.75	60	**7** (21), **8** (28), **9** (13)
8	2:1	EtOH	0.5 *M*	26	rt	**3d** (84)
9	1:1	EtOH	0.5 *M*	26	rt	**3d**, cinnamaldehyde

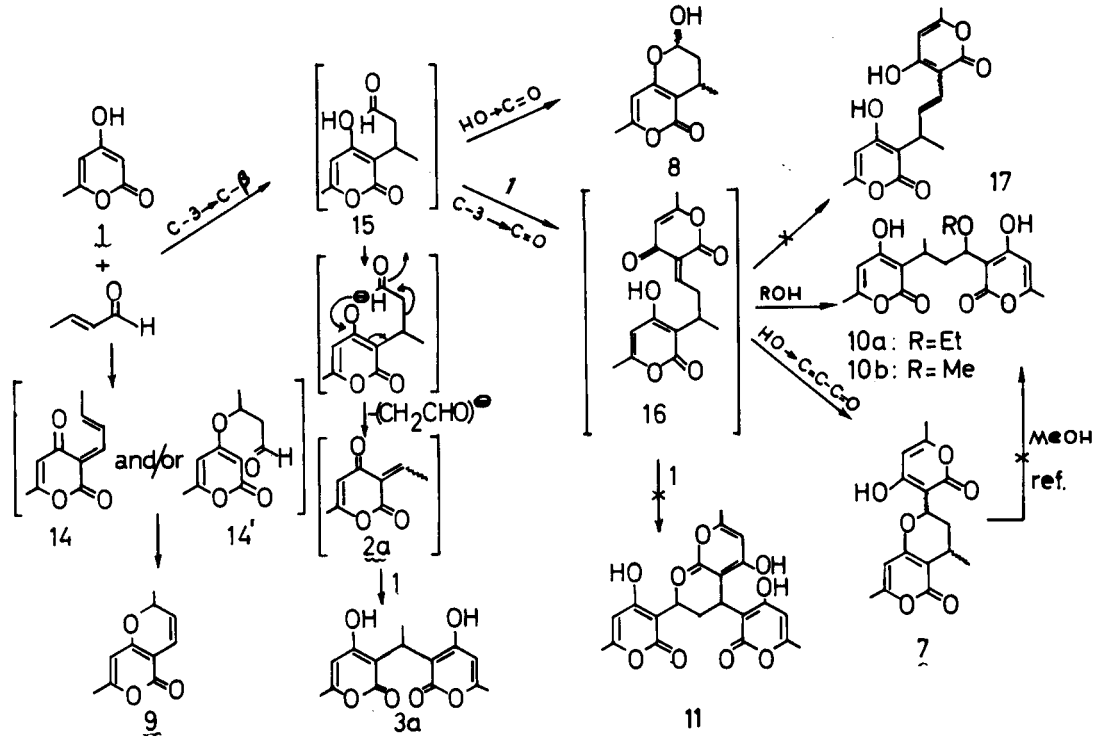
Scheme 2



At this point we decided to study the reactivity of the pyrone **1** towards more simple models, namely *(E)*-2-butenal and cinnamaldehyde. From the pertinent bibliographic search we realized that, although some isolated cases of reactions between 4-hydroxycoumarin and α,β-unsaturated ketones have been reported [9,10,11,12], no systematic studies on the reactivity of **1** towards α,β-unsaturated aldehydes and ketones had been undertaken.

We have performed several reactions of **1** with *(E)*-2-butenal, from which different products were isolated and characterized (see Table). In our first experiment (run 1), carried out with a large excess of the pyrone **1**, two products were isolated: the first one was 1,1-bis(4-hydroxy-6-methyl-2-oxo-2*H*-pyran-3-yl)ethane, **3a** (Scheme 3), as evidenced

Scheme 3

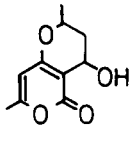


by the usual techniques and independent synthesis (see below). The second product was a mixture of diastereoisomers with the constitution of 2-(4-hydroxy-6-methyl-2-oxo-2*H*-pyran-3-yl)-4,7-dimethyl-3,4-dihydro-2*H*,5*H*-pyrano-[3,2-*c*]pyran-5-one, **7**.

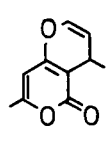
Decreasing the ratio **1**:2-butenal, and lowering the temperature allowed us to isolate other products: 2-hydroxy-4,7-dimethyl-3,4-dihydro-2*H*,5*H*-pyrano[3,2-*c*]pyran-5-one, **8**; 2,7-dimethyl-2*H*,5*H*-pyrano[3,2-*c*]pyran-5-one, **9**; and ethyl [1,3-bis(4-hydroxy-6-methyl-2-oxo-2*H*-pyran-3-yl)]butyl ether, **10a**, or the corresponding methyl ether **10b**, when working in methanol (run 5). The formation of all these proucts can be rationalized as indicated in Scheme 3.

2-Butenal has two electrophilic centers: the carbonyl group and the carbon atom in β position. Attack of the C-3 of the pyrone **1** to the carbonyl group can give the intermediate **14**, which has never been isolated, that can be transformed into **9** by an electrocyclic ring closure. Alternatively, Michael addition of the hydroxyl group at C-4 of **1** to the α,β-unsaturated aldehyde would give raise to **14'** which could also be converted into **9** (runs 2, 3 and 4). In any case, this constitutes a minor reaction pathway and indeed, all the other isolated products can be accounted for through attack of the C-3 position of **1** to the β carbon atom of 2-butenal to yield initially the intermediate saturated aldehyde **15**, which can evolute in several directions. Thus, when the reaction was performed at reflux temperature in ethanol (run 1), a significant pathway was the cleavage of **15** as a 1,5-dicarbonyl compound to give the electrophilic species **2a** (cf. also Scheme 1), which by attack by another molecule of **1** affords the bispyrone **3a**. Alternatively, **15** reacts with a second molecule of **1** in the usual way to afford the Michael acceptor **16**, which by intramolecular reaction gives **7**. Even working with a threefold excess of **1**, product **11** could never be detected.

The adoption of lower temperatures completely eliminated the pathway to **3a**; also, conversion of **16** into **17**, the analogous of **6**, was not observed; instead, the electrophilic **16** was trapped by external nucleophiles, such as ethanol and methanol to yield, respectively **10a** and **10b** (runs 2, 3, 4 and 5). Under an appropriate molar ratio of reagents, product **8**, the analogous of **5** (see above), could be isolated (runs 4 and 7). Finally, upon exclusion of external nucleophiles and proper choice of reagents ratio, product **7** was formed in good yield (run 6).



18



19

Products **8** and **9** had to be distinguished from their isomers **18** and **19**, also reasonable on mechanistic grounds. The cmr spectrum of **8** presents two absorptions at δ 35 and 93 which are assigned to C-4 and C-2. They can not be attributed to any carbon atom of **18**, which should present two absorptions at about 70 ppm due to the carbon atoms linked to oxyen in the saturated part of the compound. Product **9** presents absorptions in its pmr spectrum at 5.07, 5.40 and 6.40 corresponding, respectively, to the protons at C-2, C-3 and C-4, and which are not compatible with structure **19**.

The reaction of **1** with cinnamaldehyde was less complicated, since it gave 1-phenyl-3,3-bis(4-hydroxy-6-methyl-2-oxo-2*H*-pyran-3-yl)-1-propene, **3d**, as the only product when the molar ratio of reagents was 2:1 (run 8). When equimolar amounts of reagents were used, also **3d** was isolated, the excess of aldehyde being recovered. The structure **3d** was determined by the usual spectroscopic methods. The mass spectrum showed the molecular ion at m/e 366, and only thirteen absorptions where shown in the cmr spectrum, thus demonstrating the symmetry of **3d**.

Products **3a** and **3d** are interesting because similar products **3** with an aliphatic chain (Scheme 1) have not been described in the literature but for R = H [13]. Therefore, we prepared **3a**, **3b** and **3c** by condensation of **1** with the corresponding aldehydes, according to Scheme 1, thus demonstrating that the method of preparation of compound **3** is general both for aromatic as well as for aliphatic aldehydes.

EXPERIMENTAL

The ir spectra were recorded on a Perkin-Elmer Infracord spectrophotometer. The pmr and cmr spectra were recorded, respectivley, on a Perkin-Elmer R-12 and Brucker WP8OSY, and on Brucker WP8OSY spectrometers. The ms were run on Hewlett-Packard 5930-A and 5985-B spectrometers.

1,1-Bis(4-hydroxy-6-methyl-2-oxo-2*H*-pyran-3-yl)ethane (**3a**).

The lactone **1** (1.512 g, 0.012 mole), acetaldehyde (0.264 g, 0.06 mole), acetic acid (0.1 ml) and piperidine (0.1 ml) were left in ethanol (30 ml) for 24 hours at room temperature, the reaction being monitored by tlc. The solvent was evaporated and the residue was partitioned between chloroform and dilute aqueous hydrochloric acid. The organic layer was dried over sodium sulphate and evaporated to afford 1.656 g (99%) of crude **3a**, which was crystallized from ether to yield 1.163 g (70%) of pure **3a**, mp 150-152°; ir (potassium bromide): 3500-2800 (broad), 1680, 1600, 1540 cm^{-1}; pmr (deuteriochloroform): δ 1.7 (d, 3H, J = 7 Hz), 2.31 (s, 6H), 4.43 (q, 1H, J = 7 Hz), 6.03 (s, 1H); ms: 278 (M^+, 22), 221 (28), 205 (28), 193 (73), 179 (28), 165 (68), 153 (51), 151 (61), 137 (35), 127 (35), 124 (26), 123 (26), 111 (20), 98 (36), 95 (24), 85 (100), 43 (82).

Anal. Calcd. for $C_{14}H_{14}O_6$: C, 60.43; H, 5.07. Found: C, 60.27; H, 5.18.

The following compounds were prepared in a similar manner.

1,1-Bis(4-hydroxy-6-methyl-2-oxo-2*H*-pyran-3-yl)propane (**3b**).

This compound was obtained in a yield of 93%, mp 180-182° (from ethanol); ir (chloroform): 3500-2700 (broad), 1680, 1610, 1560 cm^{-1}; pmr (deuteriochloroform): δ 0.9 (t, 3H, J = 7 Hz), 2.2 (m, 2H), 2.2 (s, 6H), 4.0

(t, 1H, J = 7 Hz), 5.95 (s, 2H); ms: 292 (M^+, 8), 222 (20), 205 (21), 179 (25), 138 (26), 96 (21), 85 (89), 69 (53), 56 (26), 43 (100).

Anal. Calcd. for $C_{15}H_{16}O_6$: C, 61.64; H, 5.52. Found: C, 61.56; H, 5.77.

1,1-Bis(4-hydroxy-6-methyl-2-oxo-2*H*-pyran-3-yl)butane (**3c**).

This compound was obtained in a yield of 63%, mp 150-151° (from acetone); ir (potassium bromide): 3500-2800 (broad), 1680, 1620, 1570 cm^{-1}; pmr (deuteriochloroform): δ 0.91 (t, 3H, J = 7 Hz), 1.0-1.7 (m, 4H), 2.23 (s, 6H), 4.17 (t, 1H, J = 8 Hz), 5.99 (broad s, 2H); ms: 306 (M^+, 14), 263 (20), 221 (38), 205 (28), 179 (22), 137 (31), 85 (51), 69 (56), 53 (22), 43 (100).

Anal. Calcd. for $C_{16}H_{18}O_6$: C, 62.74; H, 5.92. Found: C, 62.50; H, 5.97.

1-Phenyl-3,3-bis(4-hydroxy-6-methyl-2-oxo-2*H*-pyran-3-yl)-1-propene (**3d**).

This compound was obtained in a yield of 84%, mp 142-145° (from ethyl acetate-hexane); ir (potassium bromide): 3400-2600 (broad), 1680, 1610, 1590 cm^{-1}; pmr (deuteriochloroform): δ 2.25 (s, 6H), 5.15 (d, 1H, J = 3 Hz), 5.95 (s, 2H), 6.45-6.60 (m, 2H), 7.25 (broad s, 5H); cmr (deuteriochloroform): δ 19.3, 33.2, 102.9, 104.2, 125.4, 126.2, 127.3, 128.3, 131.7, 136.8, 161.3, 168.4, 169.0; ms: 366 (M^+, 4), 240 (100), 239 (64), 197 (32), 163 (48), 156 (42), 141 (42), 128 (95), 127 (62), 115 (36), 102 (42), 98 (64), 85 (54), 77 (40), 69 (97), 55 (32).

Anal. Calcd. for $C_{21}H_{18}O_6$: C, 68.85; H, 4.95. Found: C, 68.99; H, 4.68.

1-(4-Hydroxy-6-methyl-2-oxo-2*H*-pyran-3-yl)-1-phenylthiobutane (**4a**), 3-Ethyl-2-hydroxy-7-methyl-4-*n*-propyl-3,4-dihydro-2*H*,5*H*-pyrano[3,2-*c*]-pyran-5-one (**5a**) and 2-Ethyl-1,3-bis(4-hydroxy-6-methyl-2-oxo-2*H*-pyran-3-yl)-1-hexene (**6**).

The lactone **1** (1.00 g, 0.008 mole), butanal (1.717 g, 0.024 mole), thiophenol (2.62 g, 0.024 mole), acetic acid (0.1 ml) and piperidine (0.1 ml) were left in ethanol (30 ml) at 60° for 15 hours, the reaction being monitored by tlc. The solvent was evaporated and the residue was chromatographed through silica gel, the following compounds being eluted: thiophenol (with hexane-ethyl acetate (95/5)), **5a** (with hexane-ethyl acetate (3/1)), 1.259 g (63%), and **4a** (with hexane-ethyl acetate (65/35)), 0.838 g (36%). Both **4a** and **5a** appeared as oils. Samples for elemental analysis were further purified by column chromatography. Product **4a** had ir (film): 3600-2400 (broad), 1670, 1580 cm^{-1}; pmr (deuteriochloroform): δ 0.95 (t, 3H, J = 7 Hz), 1.1-1.7 (m, 2H), 1.7-2.1 (m, 2H), 2.15 (s, 3H), 4.80 (t, 1H, J = 7 Hz), 5.83 (s, 1H), 7.1-7.5 (m, 5H); ms: 290 (M^+, 22), 181 (40), 180 (30), 151 (53), 139 (100), 110 (82), 109 (61), 85 (36), 84 (28), 81 (33), 69 (41), 68 (30), 66 (26), 65 (25), 53 (23), 43 (41).

Anal. Calcd. for $C_{16}H_{18}O_3S$: C, 66.18; H, 6.25. Found: C, 66.08; H, 6.17.

The lactone **5a** had ir (film): 3600-2800 (broad), 1680, 1640, 1570 cm^{-1}; pmr (deuteriochloroform): δ 0.7-1.1 (m, 6H), 1.1-1.4 (m, 4H), 1.65-2.1 (m, 3H), 2.2-2.7 (m, 1H), 2.18 (s, 3H), 5.18 and 5.51 (broad s of two diastereoisomers, 1H), 5.73 (s, 1H); ms: 252 (M^+, 19), 209 (56), 181 (32), 167 (100), 139 (81).

Anal. Calcd. for $C_{14}H_{20}O_4$: C, 66.65; H, 7.99. Found: C, 66.44; H, 8.23.

When the pyrone **4a** was left overnight on a silica gel column, it partially decomposed to **6**. Product **6** was an oil which had ir (film): 3600-2800 (broad), 1690, 1650, 1570 cm^{-1}; pmr (deuteriochloroform): δ 0.8-1.1 (m, 6H), 1.1-2.0 (m, 6H), 2.23 (s, 3H), 2.25 (s, 3H), 2.66 (m, 1H), 5.38 (broad s, 1H), 5.75 (s, 1H), 5.84 (s, 1H); ms: 360 (M^+, 10), 180 (100), 165 (35), 151 (91), 139 (70), 138 (30), 137 (40), 109 (20), 85 (73), 81 (50), 69 (40), 68 (24), 55 (22), 53 (24), 43 (78).

Anal. Calcd. for $C_{20}H_{24}O_6$: C, 66.65; H, 6.71. Found: C, 66.13; H, 6.98.

The small amount available of **6** precluded further purification.

The following products were prepared in a similar manner.

[1-(4-Hydroxy-6-methyl-2-oxo-2*H*-pyran-3-yl)-1-phenylthiodecane (**4b**) and 2-Hydroxy-7-methyl-4-*n*-nonyl-3-*n*-octyl-3,4-dihydro-2*H*,5*H*-pyrano[3,2-*c*]-pyran-5-one (**5b**).

They were obtained from decanal (2.86 g, 0.018 mole), thiophenol (4.03 g, 0.0366 mole), lactone **1** (1.54 g, 0.0122 mole), acetic acid (0.2 ml) and piperidine (0.2 ml) in ethanol (35 ml) at 67° during 16 hours.

Product **4b** (71%) was an oil which had ir (film): 3500-2600 (broad), 1670, 1640 (shoulder), 1580 cm^{-1}; pmr (deuteriochloroform): δ 0.8-1.0 (broad t, 3H), 1.26 (broad s, 14H), 1.6-2.2 (m, 2H), 2.13 (s, 3H), 4.77 (t, 1H, J = 8 Hz), 5.80 (s, 1H), 7.1-7.5 (m, 5H); ms: since **4b** decomposes upon heating no easily reproduceable spectrum could be run, although the following peaks were always observed with variable intensities: 374 (M^+), 264, 179, 165, 152, 139, 110, 85, 69.

Anal. Calcd. for $C_{22}H_{30}O_3S$: C, 70.55; H, 8.07. Found: C, 70.39; H, 8.17.

Product **5b** (22%) was an oil which had ir (film): 3600-3100 (broad), 1685, 1650, 1580 cm^{-1}; pmr (deuteriochloroform): δ 0.7-1.0 (broad t, 6H), 1.25 (broad s, 28H), 1.6-2.0 (m, 3H), 2.17 (s, 3H), 2.2-2.8 (m, 1H), 5.42 (broad s, 1H), 5.70 (s, 1H); ms: 420 (M^+, 20), 293 (86), 265 (82), 251 (77), 139 (100), 57 (24), 43 (57).

Anal. Calcd. for $C_{26}H_{44}O$: C, 74.24; H, 10.54. Found: C, 74.08; H, 10.65.

2-(4-Hydroxy-6-methyl-2-oxo-2*H*-pyran-3-yl)-4,7-dimethyl-3,4-dihydro-2*H*,5*H*-pyrano[3,2-*c*]pyran-5-one (**7**), 2-Hydroxy-4,7-dimethyl-3,4-dihydro-2*H*,5*H*-pyrano[3,2-*c*]pyran-5-one (**8**), 2,7-Dimethyl-2*H*,5*H*-pyrano[3,2-*c*]-pyran-5-one (**9**) and Ethyl [1,3-bis(4-hydroxy-6-methyl-2-oxo-2*H*-pyran-3-yl)]butyl Ether (**10a**), run 2.

Pyrone **1** (1.26 g, 0.010 mole), *(E)*-2-butenal (0.35 g, 0.005 mole) acetic acid (0.1 ml) and piperidine (0.1 ml) in ethanol (30 ml) were left at room temperature for 16 hours, the reaction being monitored by tlc. The solvent was evaporated and the residue was partitioned between chloroform and dilute aqueous hydrochloric acid. The organic layer was dried and evaporated to give 1.494 g of a foam which was dissolved in ethyl acetate. Upon cooling **7** precipitated (42%). Product **7** had mp 176-177° (from chloroform); ir (potassium bromide): 3600-2700 (broad), 1710, 1680, 1630, 1580 cm^{-1}; pmr (hexadeuteriodimethyl sulfoxide): δ 1.07 (d, 3H, J = 6.5 Hz), 1.3-1.6 (m, 1H), 2.03 (s, 3H), 2.07 (s, 3H), 2.6-3.0 (m, 2H), 5.25 (dd, 1H, J = 12 and 2 Hz), 5.86 (s, 1H), 5.97 (s, 1H); ms: 304 (M^+, 2), 163 (48), 126 (25), 98 (78), 85 (52), 69 (100), 55 (54).

Anal. Calcd. for $C_{16}H_{16}O_6 \cdot \frac{1}{2}H_2O$: C, 61.34; H, 5.47. Found: C, 61.16 and 61.43; H, 5.32 and 5.28.

The mother liquor from the recrystallization was evaporated and the residue was chromatographed through a silica gel column, the following products being eluted: **9** (with ethyl acetate-hexane (1/9)), 49 mg (6%), as an oil which had ir (chloroform): 1705, 1660, 1590 cm^{-1}; pmr (deuteriochloroform): δ 1.40 (d, 3H, J = 6 Hz), 2.18 (s, 3H), 5.0-5.25 (m, 1H), 5.40 (dd, 1H, J = 10 and 3 Hz), 5.77 (s, 1H), 6.40 (d, 1H, J = 10 Hz); ms: 178 (M^+, 21), 163 (100), 121 (25), 69 (31), 66 (31), 43 (66); **10a** (with ethyl acetate-hexane (15/85)), 335 mg (20%), as an oil which had ir (deuteriochloroform): 3600-2700 (broad), 1675, 1610, 1570 cm^{-1}; pmr (deuteriochloroform) at 200 MHz: δ 1.13 (t, 3H, J = 7 Hz), 1.14 (d, 3H, J = 6 Hz), 1.9-2.1 (m, 1H), 2.24 (s, 3H), 2.25 (s, 3H), 2.5-2.7 (m, 1H), 3.1-3.3 (m, 2H), 3.55 (dq, 1H, J = 9 and 7 Hz), 4.54 (dd, 1H, J = 10 and 5 Hz), 5.99 (broad s, 2H); ms: 351 (35), 350 (M^+, 10), 179 (29), 85 (33), 45 (52), 43 (100).

Anal. Calcd. for $C_{18}H_{22}O_7$: C, 61.71; H, 6.33. Found: C, 61.84; H, 6.49.

Compound **8** (with ethyl acetate-hexane (1/4)), 130 mg (13%), was obtained as an oily mixture of diastereoisomers (ratio 7/3) which had ir (chloroform): 3600, 3600-3100 (broad), 1690, 1650, 1575 cm^{-1}; pmr (deuteriochloroform) at 200 MHz: δ 1.27 (d, 3H, J = 7 Hz, major isomer) and 1.40 (d, 3H, J = 7 Hz, minor isomer), 1.9-2.0 (m, 2H), 2.19 (s, 3H), 2.90-2.96 (m, 1H), 5.50 (dd, 1H, J = 10 and 4 Hz, major isomer), 5.62 (dd, 1H, J = 4 and 4 Hz, minor isomer), 5.75 (s, 1H); cmr (deuteriochloroform): δ (major isomer given first) 19.4 and 19.0, 19.8 and 19.6, 23.8 and 23.3, 35.3 and 34.8, 93.2 and 94.4, 100.5 and 100.6, 102.6 and 103.0, 160.4 and 160.1, 163.4 and 162.7, 164.8 and 164.8; ms: 196 (M^+, 11), 153 (20), 139 (38), 99 (21), 98 (23), 97 (20), 85 (100), 83 (66), 69 (81), 68 (24), 55 (27), 53 (20), 43 (81).

Anal. Calcd. for $C_{10}H_{12}O_4$: C, 61.22; H, 6.16. Found: C, 61.17; H, 6.38.

All other experiments were performed in a similar manner under the conditions given in the Table. In run 5, when methanol was used as solvent, [1,3-bis(4-hydroxy-6-methyl-2-oxo-2*H*-pyran-3-yl)]butyl methyl ether, **10b**, was obtained. Compound **10b** was an oil which had ir (deuteriochloroform): 3400-2600 (broad), 1680, 1610, 1570 cm^{-1}; pmr (deuterio-

chloroform): δ 1.12 (d, 3H, J = 6 Hz), 1.8-2.1 (m, 1H), 2.25 (s, 6H), 2.4-2.8 (m, 1H), 3.0-3.2 (m,1 H), 3.22 (s, 3H), 4.48 (dd, 1H, J = 10 and 6 Hz), 5.97 (broad s, 2H); ms: 336 (M^+, 2), 179 (27), 149 (29), 111 (20), 98 (34), 85 (69), 69 (78), 59 (30), 55 (30), 43 (100).

Anal. Calcd. for $C_{17}H_{20}O_7$: C, 60.71; H, 5.99. Found: C, 60.34; H, 5.97.

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REFERENCES AND NOTES

[1] R. Bentley and P. M. Zwitkowits, *J. Am. Chem. Soc.*, **89**, 676 and 681 (1967).

[2] J. N. Collie, *J. Chem. Soc.*, **59**, 607 (1891).

[3] G. A. Poulton and T. D. Cyr, *Can. J. Chem.*, **60**, 2821 (1982).

[4] R. Bacardit and M. Moreno-Mañas, *Tetrahedron Letters*, **21**, 551 (1980).

[5] R. Bacardit and M. Moreno-Mañas, *J. Chem. Ecol.*, **9**, 703 (1983).

[6] R. Bacardit and M. Moreno-Mañas, *Chem. Letters*, 5 (1982).

[7] R. Bacardit, M. Moreno-Mañas and R. Pleixats, *J. Heterocyclic Chem.*, **19**, 157 (1982).

[8] P. de March, M. Moreno-Mañas, R. Pi and A. Trius, *ibid.*, **19**, 335 (1982).

[9] M. Ikawa, M. A. Stahmann and K. P. Link, *J. Am. Chem. Soc.*, **66**, 902 (1944).

[10] M. Seidman, D. N. Robertson and K. P. Link, *ibid.*, **72**, 5193 (1950).

[11] M. Seidman and K .P. Link, *ibid.*, **74**, 1885 (1952).

[12] D. W. Hutchinson and J. A. Tomlinson, *Tetrahedron Letters*, 5027 (1968).

[13] W. Dieckmann and F. Breest, *Ber.*, **37**, 3387 (1904).