84. A Novel Access to Ionone-Type Compounds: (*E*)-4-Oxo-β-ionone and (*E*)-4-Oxo-β-irone *via* Metal-Catalyzed, Intramolecular Reactions of α-Diazo Ketones with Furans

by **Ernest Wenkert**

Department of Chemistry (D-006), University of California-San Diego, La Jolla, California 92093, U.S.A.

and **René Decorzant** and **Ferdinand Näf***

Firmenich SA, Research Laboratories, CH–1211 Geneva 8

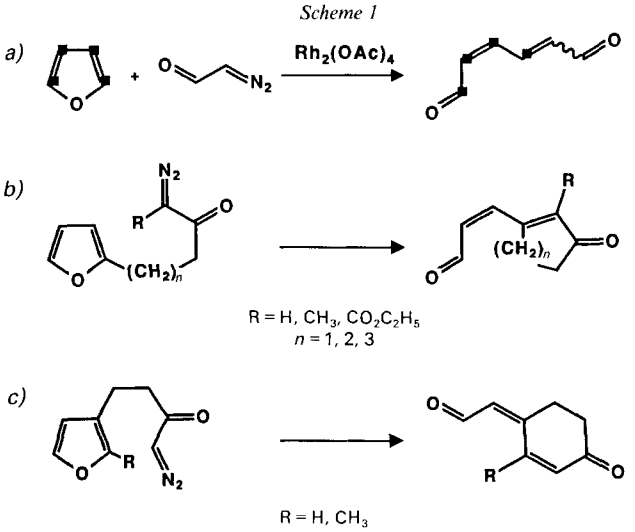
Dedicated to Dr. *G. Ohloff* on the occasion of his 65th birthday

(5.IV.89)

(*E*)-5-Demethyl-4-oxo-β-ionone (**2**), (*E*)-4-oxo-β-ionone (**3**), (*E*)-4-oxo-β-irone (**4**), and the five-membered ring analogs **36**–**41** were synthesized by a novel, convergent route starting from 2-methylfuran (**1**). A recently discovered, intramolecular reaction of 2-(diazoacyl)furans, catalyzed by dirhodium tetraacetate, leading to dienediones served as key step, thereby testing its utility in natural-product synthesis for the first time.

Introduction. – As part of a broad study of reactions of α-diazocarbonyl compounds with enol derivatives by one of the authors [1], there was recently developed a route for a general access to dienediones by the interaction of furans with metal carbenoids, generated by $Rh_2(OAc)_4$-catalyzed decomposition of α-diazoacyl derivatives *(Scheme 1a)* [2].

Scheme 1



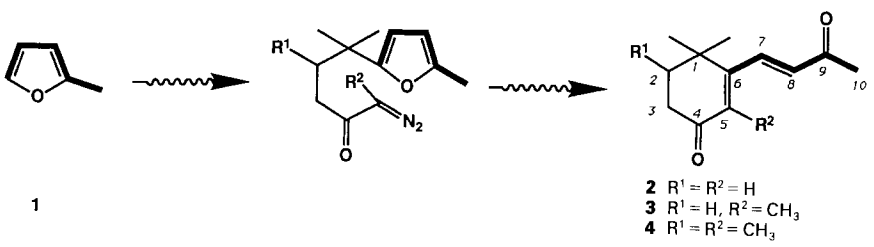
Variation of this theme, by utilization of an intramolecular version of the reaction, has more recently led to a general synthesis of highly functionalized ring systems. Thus, $Rh_2(OAc)_4$-induced decomposition of α-diazo (2-furyl)alkyl ketones yielded 3-(2-acylvinyl)cycloalk-2-enones *(Scheme 1b)* [3][1]). The decomposition of α-diazo (3-furyl)alkyl ketones produced cycloalkenones of a different structure pattern *(Scheme 1c)* [3] [4].

Since an ultimate test of the efficiency and reliability of a new reaction is its successful application to structurally demanding natural products, such an investigation was undertaken. The present communication reports the syntheses of the terpenes (*E*)-4-oxo-β-ionone (**3**) [5], a constituent of *Osmanthus* absolute oil [6] and burley tobacco [7] and used as a flavor ingredient [8], and (*E*)-4-oxo-β-irone (**4**) [9], a component of *Orris* root oil [10], as well as related compounds, *e.g.* (*E*)-5-demethyl-4-oxo-β-ionone (**2**).

Results and Discussion. – The syntheses, based on *Scheme 1b,* were intended to emanate from 2-methylfuran (**1**) and follow the path outlined in abbreviated form in *Scheme 2.* This route of synthesis constitutes a completely new approach to the important class of ionone-like substances. Without prior knowledge of the new diazo-ketone reaction, the possibility of this approach would not have been recognized at all. In general, the potential of complex molecular rearrangements is rarely acknowledged in synthesis planning and also poses a real problem in computer-assisted synthesis programs.

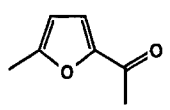
Our synthetic approach *(Scheme 2)* was expected to allow for maximum structure flexibility and yield ultimately not only the two desired natural products **3** and **4**, but also an entire series of homologous substances. The construction of nor-compounds of the five-membered-ring type seemed especially attractive for testing the new approach, since classical carotenoid chemistry [11] does not offer an easy access to them.

Scheme 2

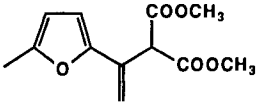


Diazo Ketones. Acetylation of 2-methylfuran (**1**) gave the 2-furyl ketone **5** [12] which underwent readily a $TiCl_4$-catalyzed *Knoevenagel* condensation [13] with dimethyl malonate yielding a 2:1 mixture of esters **7** and **6**. Since the deconjugated malonate **6** was useless for the next step, the whole reaction mixture was subjected to isomerization (CH_3ONa/CH_3OH) giving, after distillation, **7**/**6** in a *ca.* 13:1 ratio. Exposure of **7**/**6** to MeMgI afforded diester **8** along with an equal amount of **6**. Evidently, part of **7** had been deprotonated by the *Grignard* reagent and reprotonated during workup accounting for the high content of **6**. The use of more nucleophilic reagents, favoring conjugate addition,

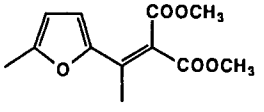
[1]) *Padwa et al.* recently reported a related study [4].



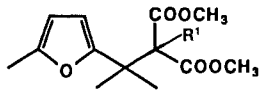
5



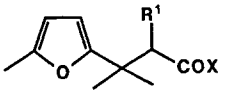
6



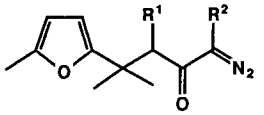
7



8 $R^1 = H$
9 $R^1 = CH_3$



10 $R^1 = H$, $X = OCH_3$
11 $R^1 = H$, $X = OH$
12 $R^1 = H$, $X = Cl$
13 $R^1 = CH_3$, $X = OCH_3$
14 $R^1 = CH_3$, $X = OH$
15 $R^1 = CH_3$, $X = Cl$

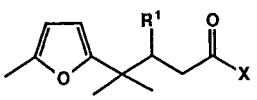


16 $R^1 = R^2 = H$
17 $R^1 = CH_3$, $R^2 = H$
18 $R^1 = H$, $R^2 = CH_3$

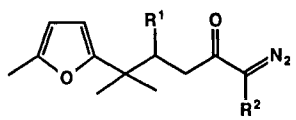
e.g. $(CH_3)_2CuLi$, did not improve the situation. Steric crowding in the transition state on the way to ester **8** may account for this behavior of conjugate ester 7[2]).

Base-induced methylation of diester **8** furnished **9**. The malonates **8** and **9** were converted into diazo ketones **16** and **17**, respectively, by a sequence of demethoxycarbonylation (LiI/DMF [15]; →**10**, **13**), saponification ($KOH/H_2O/CH_3OH$; →**11**, **14**), acyl-halide formation (oxalyl chloride; →**12**, **15**), and diazomethane treatment. Diazo ketone **18** was obtained from chloride **12** and diazoethane.

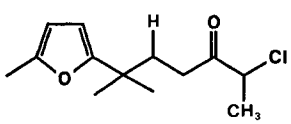
The homologous diazo ketones **25–27** (needed for the construction of the oxo-*β*-ionones) were synthesized from diazo compounds **16** and **17** by a sequence (involving intermediates **19–24**) of *Wolff* rearrangement (Ag_2O [16]), saponification, acyl-halide



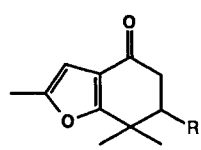
19 $R^1 = H$, $X = OCH_3$
20 $R^1 = H$, $X = OH$
21 $R^1 = H$, $X = Cl$
22 $R^1 = CH_3$, $X = OCH_3$
23 $R^1 = CH_3$, $X = OH$
24 $R^1 = CH_3$, $X = Cl$



25 $R^1 = R^2 = H$
26 $R^1 = H$, $R^2 = CH_3$
27 $R^1 = R^2 = CH_3$



28

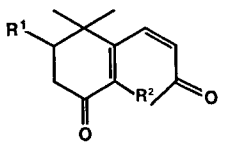


29 $R = H$
30 $R = CH_3$

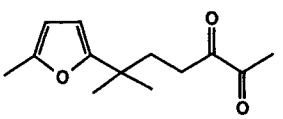
[2]) A different, more direct approach toward a structure of type **8**, *i.e.* the acid-catalyzed addition of 2-methylfuran (**1**) to *β*,*β*-dimethylacrolein, gave (in agreement with the literature) only a trace of adduct, in contrast to the addition to acrolein leading to product in *ca.* 30% yield [14]. This result also seems to reflect problems of steric bulk.

formation, and diazomethane or diazoethane treatments [17] [18]. The reactions of acyl chlorides **21** and **24** with diazoethane were fraught with difficulties. The yields of diazo ketones **26** and **27**, respectively, never higher than 50%, were hard to reproduce. Chloro ketone **28** was a by-product of the first reaction, and side-products of competitive, intramolecular *Friedel-Crafts* acylation, *i.e.* the bicyclic ketones **29** and **30**[3]), respectively, were formed in both reactions.

Ionones. Exposure of diazo ketone **25** to $Rh_2(OAc)_4$ [20] in CH_2Cl_2 at room temperature for 15 min gave (*Z*)-5-demethyl-4-oxo-β-ionone (**31**; 62% yield). The same reaction caused the conversion of diazo ketone **26** into (*Z*)-4-oxo-β-ionone (**32**; 66% yield) and a small amount of diketone **34**. Finally, diazo ketone **27** was transformed into (*Z*)-4-oxo-β-irone (**33**; 45% yield) in the same fashion[4]). Iodine-catalyzed isomerization (I_2/THF, 65°, 18 h) of the (*Z*)-isomers **31**, **32**, and **33** produced the target compounds **2**, **3**, and **4**, respectively.

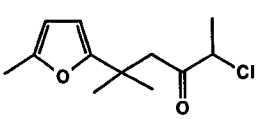


31 $R^1 = R^2 = H$
32 $R^1 = H$, $R^2 = CH_3$
33 $R^1 = R^2 = CH_2$

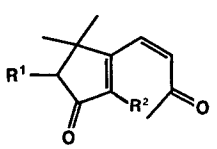


34

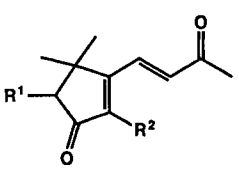
Five-Membered-Ring Analogs of the Ionones. In view of the earlier preparation of diazo ketones **16** and **17** and the formation of diazo ketone **18** on exposure of acyl chloride **12** to diazoethane (chloro ketone **35** being a by-product), diazo compounds were on hand for the construction of the cyclopentene equivalents of the ionone derivatives **2**–**4**. Indeed $Rh_2(OAc)_4$-promoted decomposition of the diazo ketones **16**–**18** provided cyclopentenones **36**–**38** (43–48% yield), respectively, and I_2-assisted side-chain isomerization of the latter produced the 3-nor-ionones **39**–**41**, respectively.



35



36 $R^1 = R^2 = H$
37 $R^1 = CH_3$, $R^2 = H$
38 $R^1 = H$, $R^2 = CH_3$



39 $R^1 = R^2 = H$
40 $R^1 = CH_3$, $R^2 = H$
41 $R^1 = H$, $R^2 = CH_3$

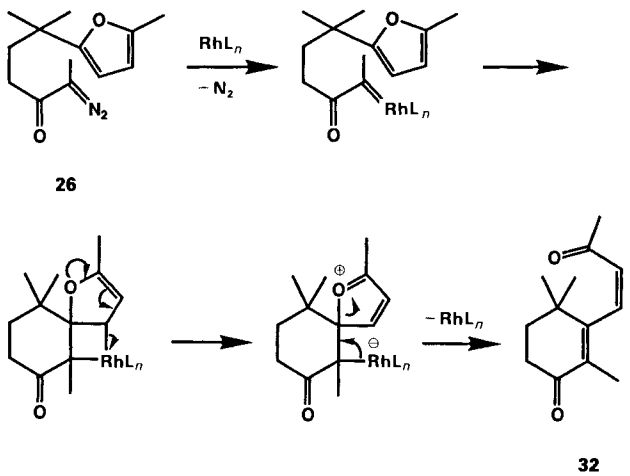
The mechanistic rationale of the key transformation, as exemplified by the $Rh_2(OAc)_4$-catalyzed formation of (*Z*)-4-oxo-β-ionone (**32**) from the diazo ketone **26** *(Scheme 3)*, is based on an earlier suggestion [3].

---

[3]) The structures of ketones **29** and **30** were supported by UV, NMR, and MS data. But especially the UV maximum at 270 nm (ε = 3200) was instructive in light of the UV absorptions at 274 (ε = 4100) and 283 nm (15200) for 2,5-dimethyl-3-furyl methyl ketone [19] and methyl 5-methyl-2-furyl ketone (**5**), respectively.

[4]) Ketone **30** accompanied irone **33**, indicative of its presence in the unstable, impure diazo ketone **27**. Unfortunately, the latter resisted all attempts of purification.

Scheme 3



26 **32**

Conclusion. – The present approach to the ionones and their five-membered-ring analogs using a recently reported, general synthesis of dienediones (starting from furans and diazo ketones or diazo esters), exemplifies the usefulness and versatility of this reaction scheme for the synthesis of complex natural products.

We are indebted to Drs. *Y. Bessière-Thomas, A.F. Thomas, B. Maurer,* and *A. Zaslona* for many interesting discussions and useful suggestions. *E.W.* expresses his heartfelt thanks to Dr. *G. Ohloff* and his colleagues at *Firmenich SA* for their generous hospitality during his sabbatical quarter in Geneva in the fall 1986.

Experimental Part

General. Diazoethane was prepared fresh according to [17]. Solvents were removed with a *Büchi Rotavapor-R.* Bulb-to-bulb distillation: *Büchi GKR-50* apparatus with external temp. reading. Gas chromatography (GLC): *Hewlett-Packard-5890A* instrument, glass capillary 5 m × 530 mμ coated with methyl silicone. Column chromatography: silica gel *Merck* (regular: particle size 0.063–0.2 mm and normal pressure; fine: particle size 0.04–0.063 mm with 1 atm pressure), and *Florisil* 100–200 mesh. UV spectra: *Kontron Uvikon 820;* solvent EtOH; λ_{max} (ε) in nm. IR spectra: *Perkin-Elmer-1310* spectrometer; absorption bands in cm^{-1}. ^{1}H-NMR spectra (360 MHz): *Bruker-WH-360* instrument; $CDCl_3$ with TMS (= 0.00 ppm) as internal standard; *J* in Hz. MS: *Finnigan MAT* quadrupole intrument; *m/z* (% relative abundance).

1. *1-(5-Methylfuran-2-yl)ethanone* (**5**). A mixture of Ac_2O (153 g, 1.5 mol) and $BF_3 \cdot Et_2O$ (7.1 g, 50 mmol) at reflux temp. (115–120°) was treated with 2-methylfuran (**1**; 82 g, 1 mol) during 15 min (→ black, exothermic reaction). Stirring was continued at 115° for another 15 min. The mixture was cooled to 20° within 2 h and then hydrolyzed by addition of H_2O (50 ml). Stirring at 20° was continued for 30 min, the soln. neutralized (pH 6.5–7) by addition of 30% aq. NaOH soln. (*ca.* 200 ml) and extracted with Et_2O. The extract was washed (sat. aq. NaCl soln.), dried ($MgSO_4$), and evaporated to yield 122 g of crude material. Distillation (b.p. 88–92°/14 Torr, bath temp. 122–126°) using a *Vigreux* column (2 × 20 cm) gave pure **5** (76.9 g, 62%[5]), leaving a black residue (44 g). UV: 283 (15000). ^{1}H-NMR: 2.39, 2.44 (2 *s*, 2 CH_3); 6.16 (*d*, *J* = 3.5, H–C(3)); 7.10 (*d*, *J* = 3.5, H–C(4)). MS: 124 (44), 109 (100), 81 (5), 53 (20), 43 (9).

[5]) Using a slightly different procedure, *Farrar* and *Levine* [12] obtained a 42% yield of **5**.

2. *Dimethyl 2-[1-(5-Methylfuran-2-yl)ethenyl]propane-1,3-dioate* (**6**) *and Dimethyl 2-[1-(5-Methylfuran-2-yl)ethylidene]propane-1,3-dioate* (**7**). A soln. of $TiCl_4$ (180 ml, 0.72 mol) in CCl_4 (150 ml) was added dropwise under efficient stirring at 0–10° (dry-ice cooling) within 30 min to THF (500 ml), causing a vigorous reaction and the formation of a yellow precipitate. After stirring for another 10 min at −10°, a soln. of **5** (44.6 g, 0.36 mol), dimethyl malonate (47.5 g, 0.36 mol), and dry THF (100 ml) was added at −10° within 15 min, and stirring was continued at −10° for another 15 min. Pyridine (118.5 g, 1.5 mol) in dry THF (200 ml) was added dropwise at 0–10° within 90 min, and the resulting mixture was stirred at 20° for 18 h. The mixture was filtered through a *G-3* sintered-glass funnel and the filtrate concentrated. Both concentrate and solid material were then poured onto ice, extracted (2 × Et_2O), washed (2N aq. HCl, sat. aq. $NaHCO_3$ soln., H_2O), dried ($MgSO_4$), and evaporated to yield 91 g of a crude oil containing **6**/**7** (1:2 by GLC). The crude oil was added to a soln. of NaOMe (0.8 g Na in 200 ml MeOH) and stirred at 20° for 3 days. The mixture was evaporated and taken up in Et_2O. The Et_2O soln. was washed (1N aq. HCl, sat. aq. $NaHCO_3$ soln., H_2O), dried ($MgSO_4$), and evaporated to give 75 g of crude material which was distilled (b.p. 116–119°/0.2 Torr, bath temp. 162–174°) using a *Vigreux* column (2 × 10 cm): **7** (48.9 g, 57%; 93% pure) and black residue (18 g). For spectral data, small samples of **6** and **7** were collected by GLC.

Data of **6**: ^{1}H-NMR: 2.29 (*s*, CH_3–C(5″)); 3.77 (*s*, 2 CH_3O); 4.51 (*s*, H–C(2)); 5.20 (*s*, 1 H–C(2′)); 5.80 (*s*, 1 H–C(2′)); 5.97, 6.23 (2 *d*, *J* = 3.5, 3.5, H–C(3″), H–C(4″)). MS: 238 (33), 223 (1), 207 (4), 179 (100), 163 (12), 147 (7), 119 (26), 105 (13), 91 (15), 77 (10), 59 (33), 43 (9).

Data of **7**: ^{1}H-NMR: 2.31 (*s*, CH_3); 2.46 (*s*, CH_3); 3.77, 3.85 (2 *s*, 2 CH_3O); 6.10, 6.70 (2 *d*, *J* = 3.5, 3.5, H–C(3″), H–C(4″)). MS: 238 (0), 223 (17), 206 (100), 191 (11), 178 (17), 164 (35), 149 (45), 135 (13), 120 (37), 107 (58), 91 (28), 77 (18), 67 (12), 59 (56), 51 (12), 43 (27).

3. *Dimethyl 2-[1-Methyl-1-(5-methylfuran-2-yl)ethyl]propane-1,3-dioate* (**8**). A *Grignard* soln. was prepared from Mg turnings (7.2 g, 0.3 mol) and MeI (42.6 g, 0.3 mol) in Et_2O (300 ml). A soln. of **7** (46.7 g, 0.2 mol) in dry Et_2O (100 ml) was added dropwise at 15°. The mixture was stirred at 20° for 2 h, then poured onto aq. NH_4Cl soln./ice, and acidified (10% aq. HCl soln.) to dissolve the precipitate. After extraction (2 × Et_2O), washing (2 × H_2O), and drying ($MgSO_4$), 46.5 g of a crude oil was obtained (GLC: 2:1 mixture **8**/**6**).

In order to allow a separation of **8**/**6** by distillation, it was necessary to isomerize **6** into **7** by an additional step as follows. The crude **8**/**6** was stirred in a soln. of NaOMe (from 1 g Na and 200 ml MeOH) at 30° for 18 h. After evaporation, extraction (Et_2O), washing (2 × H_2O), drying ($MgSO_4$), and reevaporation, 43 g of **8**/**7** (2:1 by GLC) were obtained. *Vigreux* distillation gave pure **8** (22.4 g; b.p. 91–97°/0.3 Torr), pure **7** (11.9 g; b.p. 112–124°/0.3 Torr), and 5.2 g of residue. **8**: ^{1}H-NMR: 1.48 (*s*, 2 CH_3–C(1′)); 2.24 (*s*, CH_3–C(5″)); 3.64 (*s*, 2 CH_3O); 3.85 (*s*, H–C(2)); 5.83, 5.91 (2 *d*, *J* = 3.5, 3.5, H–C(3″), H–C(4″)). MS: 254 (3), 239 (1), 207 (1), 175 (2), 149 (6), 123 (100), 107 (5), 91 (4), 77 (5), 69 (7), 59 (15), 43 (7).

4. *Dimethyl 2-Methyl-2-[1-methyl-1-(5-methylfuran-2-yl)ethyl]propane-1,3-dioate* (**9**). To a slurry of 50–55% NaH dispersion (*Fluka;* 3.3 g, 70 mmol) in dry THF (50 ml), a soln. of **8** (15.7 g, 61 mmol) in DMF (20 ml) was added (slightly exothermic reaction, H_2 evolution). After the soln. had been stirred at 20° for 7 h, a soln. of MeI (14.2 g, 100 mmol) in dry DMF (20 ml) was added dropwise at 15–20° (slightly exothermic reaction), and stirring was continued at 30–35° for 30 min and then at 20° for 18 h during which period a greyish precipitate was formed. The mixture was poured on ice, extracted (2 × Et_2O), washed (1N aq. HCl, sat. aq. $NaHCO_3$ soln., H_2O), dried ($MgSO_4$), and concentrated to give 16.2 g of crude methylation product. *Vigreux* distillation yielded 12.95 g (79%) of **9**, b.p. 73–80°/0.3 Torr (1 g of forerun, and 1.3 g of residue). ^{1}H-NMR: 1.49 (*s*, CH_3); 1.54 (*s*, 2 CH_3); 2.22 (*s*, CH_3–C(5″)); 3.66 (*s*, 2 CH_3O); 5.84, 5.96 (2 *d*, *J* = 3.5, 3.5, H–C(3″), H–C(4″)). MS: 268 (1), 179 (1), 163 (1), 149 (1), 135 (1), 123 (100), 107 (4), 95 (4), 83 (4), 59 (12), 43 (7).

5. *Methyl 3-Methyl-3-(5-methylfuran-2-yl)butanoate* (**10**). For 5 h, **8** (2.54 g, 10 mmol), dry LiI (5 g), and dry DMF (50 ml) were stirred at reflux. The cold mixture was diluted with H_2O, acidified (1N aq. HCl), and extracted (2 × Et_2O). The Et_2O extract was washed (H_2O), dried ($MgSO_4$), and evaporated to give 1.95 g of product. Chromatography (73 g of fine silica gel, cyclohexane/Et_2O 9:1) gave 1.01 g of pure **10**. ^{1}H-NMR: 1.37 (*s*, 2 CH_3–C(3)); 2.25 (*s*, CH_3–C(5′)); 2.58 (*s*, 2 H–C(2)); 3.60 (*s*, CH_3O); 5.82, 5.87 (2 *d*, *J* = 3.5, 3.5, H–C(3′), H–C(4′)). MS: 196 (6), 181 (2), 149 (2), 139 (4), 123 (100), 107 (6), 95 (6), 77 (7), 59 (9), 43 (13), 42 (14).

6. *3-Methyl-3-(5-methylfuran-2-yl)butanoic Acid* (**11**). At 20°, **10** (8.07 g, 40 mmol) and 40 ml of *Claisen*'s alkali (35 g of KOH dissolved in 25 ml of H_2O and diluted with 100 ml of MeOH) were stirred for 18 h. The mixture was taken up in Et_2O, extracted with H_2O, dried ($MgSO_4$), and evaporated to give 5.9 g of pure liquid **11**. ^{1}H-NMR: 1.39 (*s*, 2 CH_3–C(3)); 2.24 (*s*, CH_3–C(5′)); 2.61 (*s*, 2 H–C(2)); 5.83, 5.88 (2 *d*, *J* = 3.5, 3.5, H–C(3′), H–C(4′)). MS: 182 (15), 167 (7), 149 (3), 139 (1), 123 (100), 107 (10), 91 (7), 79 (6), 60 (6), 45 (30).

7. *3-Methyl-3-(5-methylfuran-2-yl)butanoyl Chloride* (**12**). At 0–5°, **11** (5.9 g, 32 mmol) in toluene (30 ml) was treated dropwise with oxalyl chloride (4.45 g, 35 mmol). The mixture was stirred at 20° for 18 h and then evaporated: 6.6 g of crude **12** which was used as such in *Exper. 11* and *28*.

8. *Methyl 2,3-Dimethyl-3-(5-methylfuran-2-yl)butanoate* (**13**). According to *Exper. 5*, 14 g (50 mmol) of **9** were transformed into 6.94 g of **13**; b.p. 47–49°/0.3 Torr. ^{1}H-NMR: 1.01 (*d*, J = 7, CH_3–C(2)); 1.28 (*s*, 2 CH_3–C(3)); 2.24 (*s*, CH_3–C(5′)); 2.83 (*q*, J = 7, H–C(2)); 3.60 (*s*, CH_3O); 5.82, 5.87 (2 *d*, J = 3.5, 3.5, H–C(3′), H–C(4′)). MS: 210 (2), 149 (1), 135 (1), 123 (100), 107 (3), 95 (4), 77 (3), 67 (2), 55 (3), 43 (12).

9. *2,3-Dimethyl-3-(5-methylfuran-2-yl)butanoic Acid* (**14**). Saponification of **13** according to *Exper. 6* gave 4.6 g of **14**. ^{1}H-NMR: 1.03 (*d*, J = 7, CH_3–C(2)); 1.32, 1.35 (2 *s*, 2 CH_3–C(3)); 2.25 (*s*, CH_3–C(5′)); 2.86 (*q*, J = 7, H–C(2)); 5.82, 5.90 (2 *d*, J = 3.5, 3.5, H–C(3′), H–C(4′)). MS: 196 (3), 135 (1), 123 (100), 107 (3), 95 (5), 79 (4), 67 (4), 55 (4), 43 (30).

10. *2,3-Dimethyl-3-(5-methylfuran-2-yl)butanoyl Chloride* (**15**). Chlorination of **14** according to *Exper. 7* yielded 5.1 g of crude **15**.

11. *1-Diazo-4-methyl-4-(5-methylfuran-2-yl)pentan-2-one* (**16**). At 0–5°, **12** (4.4 g, *ca.* 10 mmol) in Et_2O (50 ml) was added dropwise within 20 min to an Et_2O soln. of CH_2N_2 (215 ml, 60 mmol) (evolution of gas). After stirring at 20° for 3 h, MeOH (50 ml) was added and the Et_2O evaporated. The crude uncharacterized diazo-ketone soln. was used directly for the next step. A small aliquot of this soln. was evaporated for measurement of spectra. IR (neat): 2095*s* (C=N_2). ^{1}H-NMR: 1.35 (*s*, 2 CH_3–C(4)); 2.28 (*s*, CH_3–C(5′)); 2.58 (*s*, 2 H–C(3)); 4.76 (*s*, H–C(1)); 5.85, 5.88 (2 *d*, J = 3.5, 3.5, H–C(3′), H–C(4′)).

12. *1-Diazo-3,4-dimethyl-4-(5-methylfuran-2-yl)pentan-2-one* (**17**). At 10–15°, **15** (*ca.* 5 g, *ca.* 23 mmol) in dry Et_2O (50 ml) was added dropwise to an Et_2O soln. of CH_2N_2 (160 ml, 50 mmol) (evolution of gas). After stirring at 20° for 3 h, the soln. was evaporated and the crude material (4.9 g) filtered through a silica-gel (20 g) column with cyclohexane/Et_2O 4:1: 4.4 g of **17**. IR (neat): 2095*s* (C=N_2). ^{1}H-NMR: 1.03 (*d*, J = 7, CH_3–C(3)); 1.28, 1.29 (2 *s*, 2 CH_3–C(4)); 2.27 (*s*, CH_3–C(5′)); 2.75 (br. *q*, J = 7, H–C(3)); 4.93 (*s*, H–C(1)); 5.83, 5.87 (2 *d*, J = 3.5, 3.5, H–C(3′), H–C(4′)).

13. *Methyl 4-Methyl-4-(5-methylfuran-2-yl)pentanoate* (**19**). The crude soln. of **16** *(Exper. 12)* was diluted with MeOH (150 ml) and treated portionwise with a suspension of Ag_2O (0.23 g, 1 mmol) in MeOH (20 ml) and H_2O (4 ml) at 60° during 30 min (yellow → brown, gas evolution). The mixture was stirred at 60° for another 30 min, evaporated, and taken up in Et_2O. The Et_2O soln. was washed (2 × H_2O), dried ($MgSO_4$), evaporated, and chromatographed on fine silica gel (73 g, cyclohexane/Et_2O 9:1). After evaporation of the 1st fraction, 2.81 g (67%) of pure **19** was obtained. ^{1}H-NMR: 1.24 (*s*, 2 CH_3–C(4)); 1.90 (*m*, 2 H–C(3)); 2.17 (*m*, 2 H–C(2)); 2.24 (*s*, CH_3–C(5′)); 3.63 (*s*, CH_3O); 5.81, 5.84 (2 *d*, J = 3.5, 3.5, H–C(3′), H–C(4′)). MS: 210 (3), 195 (1), 179 (2), 135 (6), 123 (100), 109 (5), 95 (4), 43 (14).

14. *4-Methyl-4-(5-methylfuran-2-yl)pentanoic Acid* (**20**). Saponification of **19** (2.52 g, 12 mmol) according to *Exper. 6* gave 2.1 g (90%) of **20**. ^{1}H-NMR: 1.24 (*s*, 2 CH_3–C(4)); 1.9 (*m*, 2 H–C(3)); 2.21 (*m*, 2 H–C(2)); 2.24 (*s*, CH_3–C(5′)); 5.81, 5.84 (2 *d*, J = 3.5, 3.5, H–C(3′), H–C(4′)). MS: 196 (4), 181 (1), 163 (2), 135 (3), 123 (100), 107 (3), 95 (5), 77 (5), 67 (3), 55 (3), 43 (19).

15. *4-Methyl-4-(5-methylfuran-2-yl)pentanoyl Chloride* (**21**). Chlorination of **20** (1.96 g, 10 mmol) according to *Exper. 7* yielded 2.2 g of **21**.

16. *Methyl 3,4-Dimethyl-4-(5-methylfuran-2-yl)pentanoate* (**22**). Crude **17** (4.4 g; see *Exper. 12*) was transformed into **22** (2.07 g, after chromatography) according to *Exper. 13*. ^{1}H-NMR: 0.84 (*d*, J = 7, CH_3–C(3)); 1.09, 1.22 (2 *s*, 2 CH_3–C(4)); 1.94 (*'dd'*, J = 14, 11, *A* of *ABX*, 1 H–C(2)); 2.23 (*'ddq'*, J = 11, 7, 3.5, *X* of *ABX*, H–C(3)); 2.25 (*s*, CH_3–C(5′)); 2.39 (*'dd'*, J = 14, 3.5, *B* of *ABX*, 1 H–C(2)); 3.63 (*s*, CH_3O); 5.82, 5.85 (2 *d*, J = 3.5, 3.5, H–C(3′), H–C(4′)). MS: 224 (4), 209 (< 1), 193 (2), 123 (100), 109 (5), 43 (13).

17. *3,4-Dimethyl-4-(5-methylfuran-2-yl)pentanoic Acid* (**23**). Saponification of **22** (1.85 g, 8 mmol) according to *Exper. 6* gave 1.5 g of **23**. ^{1}H-NMR: 0.91 (*d*, J = 7, CH_3–C(3)); 1.19, 1.22 (2 *s*, 2 CH_3–C(4)); 1.97 (*'dd'*, J = 14, 11, *A* of *ABX*, 1 H–C(2)); 2.24 (*s*, CH_3–C(5′)); 2.29 (*'ddq'*, J = 11, 7, 4, *X* of *ABX*, H–C(3)); 2.43 (*'dd'*, J = 14, 4, *B* of *ABX*, 1 H–C(2)); 5.81, 5.85 (2 *d*, J = 3.5, 3.5, H–C(3′), H–C(4′)). MS: 210 (6), 177 (1), 149 (1), 123 (100), 107 (4), 95 (6), 79 (3), 67 (3), 55 (3), 43 (30).

18. *3,4-Dimethyl-4-(5-methylfuran-2-yl)pentanoyl Chloride* (**24**). Chlorination of **23** (0.84 g, 4 mmol) according to *Exper. 7* gave 0.91 g of **24**.

19. *1-Diazo-5-methyl-5-(5-methylfuran-2-yl)hexan-2-one* (**25**). At 0–5°, **21** (0.53 g, 2.5 mmol) in Et_2O (10 ml) was added dropwise to an Et_2O soln. of CH_2N_2 (12 ml, 0.31M, 3.5 mmol) and Et_3N. The mixture was stirred at 0° for 4 h, filtered, and evaporated. The crude product (0.52 g) was purified by column chromatography (10 g of regular silica gel, cyclohexane/Et_2O 4:1) giving 0.46 g (84%) of pure (NMR, IR) **25**. IR (neat): 2090*s* (C=N_2). ^{1}H-NMR: 1.23 (*s*, 2 CH_3–C(5)); 1.9 (*m*, 2 H–C(4)); 2.15 (*m*, 2 H–C(3)); 2.24 (*s*, CH_3–C(5′)); 5.13 (*s*, H–C(1)); 5.82, 5.84 (2 *d*, *J* = 3.5, 3.5, H–C(3′), H–C(4′)).

20. *2-Diazo-6-methyl-6-(5-methylfuran-2-yl)heptan-3-one* (**26**). At 0–5°, **21** (2.8 g, *ca.* 13 mmol) in Et_2O (20 ml) was added dropwise to an Et_2O soln. of freshly prepared diazoethane (32 ml, 17 mmol) and Et_3N (1.71 g, 17 mmol). The mixture was stirred at 0° for 4 h, filtered over cotton wool, evaporated, and chromatographed (30 g of *Florisil*, cyclohexane/Et_2O 1:1): 2.71 g of crude material (absence of **21** by IR and NMR). After a 2nd chromatography (1.2 g) on *Florisil* (30 g, cyclohexane/Et_2O 95:5 to 4:1), 2 fractions were obtained. The 1st fraction gave 0.38 g of *2-chloro-6-methyl-6-(5-methylfuran-2-yl)heptan-3-one* (**28**). ^{1}H-NMR: 1.24 (*s*, 2 CH_3–C(6)); 1.55 (*d*, *J* = 7, CH_3(1)); 1.88 (*m*, 2 H–C(5)); 2.25 (*s*, CH_3–C(5′)); 2.45 (*'ddd'*, *J* = 18, 10, 7, *A* of *ABXY*, 1 H–C(4)); 2.57 (*'ddd'*, *J* = 18, 10, 7, *B* of *ABXY*, 1 H–C(4)); 4.28 (*q*, *J* = 7, H–C(2)); 5.82, 5.85 (2 *d*, *J* = 3.5, 3.5, H–C(3′), H–C(4′)). The 2nd fraction contained 0.65 g (48%) of pure **26**. ^{1}H-NMR: 1.23 (*s*, 2 CH_3–C(6)); 1.90 (*s*, CH_3(1), and *m*, 2 H–C(5)); 2.25 (*s*, CH_3–C(5′)); 2.29 (*m*, 2 H–C(4)); 5.82, 5.84 (2 *d*, *J* = 3.5, 3.5, H–C(3′), H–C(4′)).

In other experiments, *6,7-dihydro-2,7,7-trimethylbenzo[b]furan-4(5H)-one* (**29**) was obtained as a 3rd fraction. ^{1}H-NMR: 1.35 (*s*, 2 CH_3–C(7)); 1.97 (*t*, *J* = 7, 2 H–C(6)); 2.29 (*s*, CH_3–C(2)); 2.54 (*t*, *J* = 7, 2 H–C(5)); 6.19 (*s*, H–C(3)). MS: 178 (35), 163 (100), 150 (3), 135 (43), 122 (18), 107 (15), 91 (13), 79 (12), 65 (6), 55 (9), 43 (36).

21. *2-Diazo-5,6-dimethyl-6-(5-methylfuran-2-yl)heptan-3-one* (**27**). At 0–5°, **24** (from 2.5 mmol of **23**) in Et_2O (5 ml) was added dropwise to an Et_2O soln. of diazoethane (15 ml, 3 mmol), Et_3N (0.3 g, 3 mmol), and Et_2O (30 ml) (→white precipitate). The mixture was stirred at 0–5° for 4 h, then filtered, and the filtrate was concentrated to yield 0.64 g of crude **27** which was chromatographed on regular silica gel (20 g) with cyclohexane/Et_2O 9:1 to 8:1. The 1st fraction (0.08 g) was discarded. The 2nd fraction contained 0.31 g of the desired **27** (50% yield based on **23**). IR (neat): 2070*s* (C=N_2). ^{1}H-NMR: 0.87 (*d*, *J* = 7, CH_3–C(5)); 1.17, 1.23 (2 *s*, 2 CH_3–C(6)); 1.92 (*s*, CH_3(1)); 2.11 (*'dd'*, *J* = 14, 11, *A* of *ABX*, 1 H–C(4)); 2.25 (*s*, CH_3–C(5′)); 2.30 (*'ddq'*, *J* = 14, 7, 3.5, *X* of *ABX*, H–C(5)); 2.46 (*'dd'*, *J* = 14, 3.5, *B* of *ABX*, 1 H–C(4)); 5.82, 5.85 (2 *d*, *J* = 3.5, 3.5, H–C(3′), H–C(4′)).

The 3rd fraction contained 0.11 g of *6,7-dihydro-2,6,7,7-tetramethylbenzo[b]furan-4(5H)-one* (**30**). UV: 270 (3200). ^{1}H-NMR: 1.03 (*d*, *J* = 7, CH_3–C(6)); 1.17, 1.37 (2 *s*, 2 CH_3–C(7)); 2.19 (*ddq*, *J* = 10, 7, 6, H–C(6)); 2.29 (*'s'*, CH_3–C(2)); 2.39 (*d*, *J* = 10, 1 H–C(5)); 2.41 (*d*, *J* = 6, 1 H–C(5)); 6.18 (*s*, H–C(3)). MS: 192 (48), 177 (100), 162 (4), 150 (41), 122 (49), 107 (15), 91 (8), 79 (10), 65 (4), 53 (6), 43 (46).

22. *(Z)-5-Demethyl-4-oxo-β-ionone* (= *(Z)-4-(6,6-Dimethyl-3-oxocyclohex-1-enyl)but-3-en-2-one*; **31**). A soln. of **25** (0.22 g, 1 mmol) in dry CH_2Cl_2 (10 ml) was added dropwise to a stirred soln. of $Rh_2(OAc)_4$ (10 mg, 0.025 mmol) in CH_2Cl_2 (5 ml) at 20–25° within 10 min (evolution of N_2, slightly exothermic) and stirred at 20° for another 30 min. Then, the soln. was evaporated and chromatographed (20 g of *Florisil*, cyclohexane/Et_2O 1:1): 0.12 g (62% yield) of pure **31**. UV: 258 (8000). ^{1}H-NMR[6]): 1.26 (*s*, 2 CH_3–C(6′)); 1.97 (*t*, *J* = 7, 2 H–C(5′)); 2.24 (*s*, CH_3(1)); 2.50 (*t*, *J* = 7, 2 H–C(4′)); 5.75 (*s*, H–C(2′)); 6.23 (*d*, *J* = 12, H–C(3)); 6.57 (*d*, *J* = 12, H–C(4)). MS: 192 (26), 177 (12), 163 (5), 159 (2), 149 (40), 136 (63), 122 (65), 108 (100), 91 (33), 77 (28), 65 (13), 55 (15), 51 (17), 43 (48).

23. *(Z)-4-Oxo-β-ionone* (= *(Z)-4-(2,6,6-Trimethyl-3-oxocyclohex-1-enyl)but-3-en-2-one*; **32**). A soln. of **26** (0.23 g, 1 mmol) in dry CH_2Cl_2 (10 ml) was added dropwise to a stirred soln. of $Rh_2(OAc)_4$ (10 mg, 0.02 mmol) in CH_2Cl_2 (5 ml) at 20° within 5 min (evolution of N_2). After stirring at 20° for another 30 min, additional 5 mg of $Rh_2(OAc)_4$ were added to check whether all **26** had reacted (no further N_2 evolution). Evaporation and column chromatography (10 g of *Florisil*, cyclohexane/Et_2O 4:1 to 1:1) gave 0.19 g of a mixture of *6-methyl-6-(5-methylfuran-2-yl)heptane-2,3-dione* (**34**; 8%) and **32** (72%). Yield of **32**: 66%. Pure samples were obtained by chromatography on fine silica gel (cyclohexane/Et_2O 9:1).

Data of **34** (fr. 1): ^{1}H-NMR: 1.24 (*s*, 2 CH_3–C(6)); 1.86 (*t*, *J* = 7, 2 H–C(5)); 2.24, 2.27 (2 *s*, CH_3(1), CH_3–C(5′)); 2.61 (*t*, *J* = 7, 2 H–C(4)); 5.79, 5.82 (2 *d*, *J* = 3.5, 3.5, H–C(3′), H–C(4′)). MS: 222 (12), 179 (28), 161 (3), 137 (12), 123 (100), 109 (51), 95 (12), 83 (5), 69 (5), 55 (7), 43 (55).

Data of **32** (fr. 2): UV: 234 (8836), 252 (sh, 8330). ^{1}H-NMR[6]): 1.18 (*s*, 2 CH_3–C(6′)); 1.64 (*s* with fine splitting, CH_3–C(2′)); 1.94 (*t*, *J* = 7, 2 H–C(5′)); 2.21 (*s*, CH_3(1)); 2.53 (*t*, *J* = 7, 2 H–C(5′)); 6.33, 6.48 (2 *d*, *J* = 13, 13, H–C(3), H–C(4)). MS: 206 (8), 191 (4), 177 (16), 163 (80), 150 (30), 135 (51), 122 (100), 107 (15), 91 (20), 77 (13), 65 (13), 55 (12), 43 (55).

---

[6]) Systematic numbering.

24. *(Z)-4-Oxo-β-irone* (= *(Z)-4-(2,5,6,6-Tetramethyl-3-oxocyclohex-1-enyl)but-3-en-2-one*; **33**). According to *Exper. 23*, **27** (0.75 g, 3 mmol) was allowed to rearrange and gave, after chromatography (fine silica gel, cyclohexane/Et_2O 4:1), 0.27 g of **30** (b.p. 80–90°/0.3 Torr by bulb-to-bulb dist.), and 0.3 g (45%) of pure **33** (b.p. 80–90°/0.3 Torr by bulb-to-bulb dist.). UV: 235 (9081), 253 (sh, 7732). ^{1}H-NMR[6]): 1.01 (*d*, *J* = 7, CH_3–C(5′)); 1.06, 1.17 (2 *s*, 2 CH_3–C(6′)); 1.65 (*s* with fine splitting, *J* = 2, CH_3–C(2′)); *ca.* 2.14 (*m*, H–C(5′)); 2.21 (*s*, CH_3(1)); 2.33 (*'dd'*, *J* = 17, 11, *A* of *ABX*, 1 H–C(4)); 2.49 (*'dd'*, *J* = 17, 4, *B* of *ABX*, 1 H–C(4′)); 6.34 (*d*, *J* = 12, H–C(3)); 6.51 (*d* with fine splitting, *J* = 12, 2, H–C(4)). MS: 220 (17), 205 (5), 191 (15), 177 (54), 159 (9), 150 (42), 135 (51), 122 (100), 107 (26), 91 (25), 79 (17), 65 (17), 55 (15), 43 (90).

25. *(E)-4-Oxo-5-demethyl-β-ionone* (= *(E)-4-(6,6-Dimethyl-3-oxocyclohex-1-enyl)but-3-en-2-one*; **2**). At 0°, **31** (50 mg, 0.26 mmol), dry THF (3 ml), and 1 crystal of I_2 were stirred for 24 h. The mixture was taken up in Et_2O, washed (10%, aq. $Na_2S_2O_3$ soln., H_2O), dried ($MgSO_4$), and evaporated: *ca.* 50 mg of crude **2** (pure by NMR). UV: 280 (10500). ^{1}H-NMR[6]): 1.25 (*s*, 2 CH_3–C(6′)); 1.93 (*t*, *J* = 7, 2 H–C(5′)); 2.34 (*s*, CH_3(1)); 2.51 (*t*, *J* = 7, 2 H–C(4)); 6.13 (*s*, H–C(2′)); 6.54 (*d*, *J* = 16, H–C(3)); 7.28 (*d*, *J* = 16, H–C(4)). MS: 192 (43), 177 (12), 163 (2), 159 (2), 149 (43), 135 (17), 122 (100), 107 (37), 91 (29), 79 (28), 65 (13), 55 (18), 51 (18), 43 (76).

26. *(E)-4-Oxo-β-ionone* (= *(E)-4-(2,6,6-Trimethyl-3-oxocyclohex-1-enyl)but-3-en-2-one*; **3**). For 18 h, **32** (*ca.* 206 mg, 1 mmol), dry THF (5 ml), and 1 crystal of I_2 were heated at reflux temp. (65°). The mixture was taken up in Et_2O, washed (10% aq. $Na_2S_2O_3$ soln., H_2O), dried, and concentrated to yield 0.2 g of crude **3**. Chromatography (10 g of regular silica gel, cyclohexane/Et_2O 4:1 to 3:2) gave 0.17 g of pure **3**. UV: 275 (9842). ^{1}H-NMR[6]): 1.19 (*s*, 2 CH_3–C(6′)); 1.80 (*s*, CH_3–C(2′)); 1.90 (*t*, *J* = 7, 2 H–C(5′)); 2.36 (*s*, CH_3(1)); 2.54 (*t*, *J* = 7, 2 H–C(4′)); 6.18 (*d*, *J* = 16, H–C(3)); 7.24 (*d* with fine splitting, *J* = 16, 2, H–C(4)). MS: 206 (54), 191 (11), 163 (82), 149 (17), 135 (19), 121 (37), 107 (15), 91 (20), 79 (12), 65 (13), 55 (21), 43 (10).

27. *(E)-4-Oxo-β-irone* (= *(E)-4-(2,5,6,6-Tetramethyl-3-oxocyclohex-1-enyl)but-3-en-2-one*; **4**). For 10 h, **33** (0.04 g), dry THF (3 ml), and 1 crystal of I_2 were heated at reflux temp. Dilution with Et_2O, washing (10% aq. $Na_2S_2O_3$, H_2O), drying, and evaporation gave 0.04 g of crude **4**. Chromatography (10 g of regular silica gel, cyclohexane/Et_2O 4:1 to 3:2) yielded 0.02 g of pure **4**. UV: 270 (8352). ^{1}H-NMR[6]): 1.00 (*d*, *J* = 7, CH_3–C(5′)); 1.07, 1.17 (2 *s*, 2 CH_3–C(6′)); 1.79 (*s*, CH_3–C(2′)); 2.11 (*ddq*, *J* = 11, 7, 4, H–C(5′)); 2.33 (*'dd'*, *J* = 17, 11, *A* of *ABX*, 1 H–C(4′)); 2.36 (*s*, CH_3(1)); 2.50 (*'dd'*, *J* = 17, 4, *B* of *ABX*, 1 H–C(4′)); 6.15 (*d*, *J* = 17, H–C(3)); 7.26 (*d*, *J* = 17, H–C(4)). MS: 220 (39), 205 (11), 191 (2), 177 (50), 163 (11), 150 (10), 135 (34), 121 (26), 107 (13), 91 (17), 79 (10), 69 (11), 53 (9), 43 (100).

28. *2-Diazo-5-methyl-5-(5-methylfuran-2-yl)hexan-3-one* (**18**). At 20°, **12** (*ca.* 2.2 g, 10 mmol) in Et_2O (10 ml) was added dropwise to a stirred Et_2O soln. of diazoethane (125 ml, *ca.* 14 mmol). Stirring at 20° was continued for 24 h. After evaporation, the residue (2.2 g) was chromatographed (66 g of regular silica gel, cyclohexane/Et_2O 4:1 to Et_2O). The 1st fraction gave *ca.* 0.13 g of *2-chloro-5-methyl-5-(5-methylfuran-2-yl)hexan-3-one* (**35**). ^{1}H-NMR: 1.35, 1.37 (2 *s*, 2 CH_3–C(5)); 1.44 (*d*, *J* = 7, CH_3(1)); 2.25 (*s*, CH_3–C(5′)); 2.77 (*'d'*, *J* = 15, *A* of *AB*, 1 H–C(4)); 3.02 (*'d'*, *J* = 15, *B* of *AB*, 1 H–C(4)); 3.91 (*q*, *J* = 7, H–C(2)); 5.83, 5.85 (2 *d*, *J* = 3.5, 3.5, H–C(3′), H–C(4′)). MS: 228 (2), 213 (1), 123 (100), 107 (4), 91 (5), 77 (4), 63 (6), 55 (3), 43 (10).

The 2nd fraction contained 1.18 g of pure **18**. ^{1}H-NMR: 1.37 (*s*, 2 CH_3C(5)); 1.84 (*s*, CH_3(1)); 2.25 (*s*, CH_3–C(5′)); 2.69 (*s*, 2 H–C(4)); 5.83 (*s*, H–C(3′), H–C(4′)).

29. *(Z)- and (E)-4,4-Dimethyl-3-(3-oxobut-1-enyl)cyclopent-2-en-1-one* (**36** and **39**, resp.). A soln. of **16** (*ca.* 2 mmol) in dry Et_2O (*ca.* 19 ml) was added dropwise to a stirred soln. of $Rh_2(OAc)_4$ (32 mg, 0.07 mmol) in CH_2Cl_2 (20 ml) at 20° (color change: green → brown). After 30 min at 20°, the reaction was finished. The mixture was poured onto ice, extracted (2 × Et_2O), washed (sat. aq. $NaHCO_3$ soln., H_2O), dried ($MgSO_4$), and concentrated to give 0.32 g of crude **36**. Chromatography (15 g of regular silica gel, cyclohexane/Et_2O 7:1 to 1:1) gave 0.17 g (48%) of **36** containing a trace of **39**.

Data of **36**: UV: 270 (8320). IR ($CHCl_3$): 1680, 1708 (CO). ^{1}H-NMR: 1.29 (*s*, 2 CH_3–C(4)); 2.28 (*s*, CH_3(4′)); 2.38 (*s*, 2 H–C(5)); 6.15 (*s*, H–C(2)); 6.40 (*d*, *J* = 12, H–C(2′)); 6.47 (*d*, *J* = 12, H–C(1′)). MS: 178 (13), 163 (13), 150 (24), 135 (100), 121 (18), 107 (14), 91 (31), 79 (36), 65 (8), 51 (11), 43 (42).

Data of **39**: UV: 284 (17310). ^{1}H-NMR: 1.34 (*s*, 2 CH_3–C(4)); 2.39 (*s*, CH_3(4′)); 2.43 (*s*, 2 H–C(5)); 6.27 (*s*, H–C(2)); 6.70 (*d*, *J* = 16, H–C(2′)); 7.24 (*d*, *J* = 16, H–C(1′)). MS: 178 (37), 163 (25), 149 (4), 135 (100), 122 (30), 107 (22), 91 (32), 79 (51), 65 (14), 51 (16), 43 (59).

30. *(Z)- and (E)-4,4,5-Trimethyl-3-(3-oxobut-1-enyl)cyclopent-2-en-1-one* (**37** and **40**, resp.). As described in *Exper. 29*, 0.78 g of crude material was obtained from **17** (*ca.* 2 mmol). Chromatography (20 g of regular silica gel, cyclohexane/Et_2O 4:1) gave 2 fractions. The 1st (0.24 g) was discarded and the 2nd (0.33 g) was bulb-to-bulb distilled (100–110°/0.1 Torr) to give 0.19 g (48%) of **37** and **40** (2:1 ratio).

Data of **37**: UV: 272 (6780). ^{1}H-NMR: 1.09 (*s*, 1 CH_3–C(4)); 1.11 (*d*, *J* = 7, CH_3–C(5)); 1.25 (*s*, 1 CH_3–C(4)); 2.25 (*q*, *J* = 7, H–C(5)); 2.26 (*s*, CH_3(4′)); 6.16 (*s*, H–C(2)); 6.39 (*d*, *J* = 12, H–C(2′)); 6.50 (*d*, *J* = 12, H–C(1′)). MS: 192 (2), 177 (4), 164 (24), 149 (100), 135 (18), 122 (38), 105 (12), 94 (46), 79 (53), 65 (14), 55 (17), 43 (54).

Data of **40**: UV: 283 (14640). ^{1}H-NMR: 1.12 (*s*, 1 CH_3–C(4)); 1.13 (*d*, *J* = 7, CH_3–C(5)); 1.31 (*s*, 1 CH_3–C(4)); 2.29 (*q*, *J* = 7, H–C(5)); 2.38 (*s*, CH_3(4′)); 6.29 (*s*, H–C(2)); 6.71 (*d*, *J* = 16, H–C(2′)); 7.26 (*d*, *J* = 16, H–C(1′)). MS: 192 (22), 177 (35), 159 (1), 149 (85), 135 (81), 122 (62), 105 (33), 91 (48), 79 (88), 65 (18), 55 (30), 43 (100).

31. *(Z)- and (E)-2,4,4-Dimethyl-3-(3-oxobut-1-enyl)cyclopent-2-en-1-one* (**38** and **41**, resp.). As described in *Exper. 29*, 0.73 g of crude product was obtained from **18** (1.18 g, 5.3 mmol). Chromatography (20 g of regular silica gel, cyclohexane/Et_2O 4:1) yielded 0.44 g (43%) of **38** containing a trace of **41**.

Data of **38**: UV: 267 (6668). ^{1}H-NMR: 1.24 (*s*, 2 CH_3–C(4)); 1.56 (*s* with fine splitting, CH_3–C(2)); 2.23 (*s*, CH_3(4′)); 2.36 (*s*, 2 H–C(5)); 6.43 (*d*, *J* = 12, H–C(2′)); 6.51 (*d*, *J* = 12, H–C(1′)). MS: 192 (5), 177 (5), 164 (36), 149 (100), 135 (21), 122 (95), 108 (84), 93 (42), 79 (25), 65 (29), 55 (13), 43 (57).

Data of **41**: UV: 294 (19550). ^{1}H-NMR: 1.32 (*s*, 2 CH_3–C(4)); 1.88 (*s*, CH_3–C(2)); 2.39 (*s*, CH_3(4′), 2 H–C(5)); 6.59 (*d*, *J* = 16, H–C(2′)); 7.25 (*d*, *J* = 16, H–C(1′)). MS: 192 (46), 177 (14), 164 (9), 149 (87), 135 (62), 122 (48), 108 (45), 93 (47), 79 (21), 65 (20), 53 (11), 43 (100).

32. *(E)-Dienedione* **39** *by Isomerization of (Z)-Dienedione* **36**. For 18 h, **36** (*ca.* 50 mg), dry THF (3 ml), and 1 crystal of I_2 were stirred at 20°. The mixture was taken up in Et_2O, washed (10% aq. $Na_2S_2O_3$ soln., H_2O), dried ($MgSO_4$), and evaporated to give 50 mg of pure (GLC) **39**.

33. *(E)-Dienedione* **40** *by Isomerization of (Z)-Dienedione* **37**. Isomerization of a 1:1 mixture **37**/**40**, treated as described in *Exper. 32*, gave **40** with only a trace of **37**.

34. *(E)-Dienedione* **41** *by Isomerization of (Z)-Dienedione* **38**. For 7 days **38** (192 mg, 1 mmol), dry THF (5 ml), and 1 crystal of I_2 were stirred, with addition of another crystal of I_2 after the 2nd and 4th day. Workup as described in *Exper. 32* yielded 0.2 g of crude material (87% of **41** and 7% of **38** by GLC) which, after crystallization from Et_2O/cyclohexane, gave 0.09 g of pure **41**. M.p. 93–95°.

REFERENCES

[1] E. Wenkert, R.A. Mueller, E.J. Reardon, Jr., S.S. Sathe, D.J. Scharf, G. Tosi, *J. Am. Chem. Soc.* **1970,** *92,* 7428; E. Wenkert, C.A. McPherson, E.L. Sanchez, R.L. Webb, *Synth. Commun.* **1973,** *3,* 255; E. Wenkert, B.L. Buckwalter, S.S. Sathe, *ibid.* **1973,** *3,* 261; E. Wenkert, T.E. Goodwin, B.C. Ranu, *J. Org. Chem.* **1977,** *42,* 2137; E. Wenkert, M.E. Alonso, B.L. Buckwalter, K.J. Chou, *J. Am. Chem. Soc.* **1977,** *99,* 4778; E. Wenkert, K.J. Chou, R.P. Hatch, *Synth. Commun.* **1977,** *7,* 375; E. Wenkert, J.R. de Souza, *ibid.* **1977,** *7,* 457; E. Wenkert, M.E. Alonso, H.E. Gottlieb, E.L. Sanchez, R. Pellicciari, P. Cogoli, *J. Org. Chem.* **1977,** *42,* 3945; E. Wenkert, B.L. Buckwalter, A.A. Craveiro, E.L. Sanchez, S.S. Sathe, *J. Am. Chem. Soc.* **1978,** *100,* 1267; E. Wenkert, *Acc. Chem. Res.* **1980,** *13,* 27; E. Wenkert, *Heterocycles* **1980,** *14,* 1703; E. Wenkert, M.L.F. Bakuzis, B.L. Buckwalter, P.D. Woodgate, *Synth. Commun.* **1981,** *11,* 533; E. Wenkert, T.D.J. Halls, L.D. Kwart, G. Magnusson, H.D.H. Showalter, *Tetrahedron* **1981,** *37,* 4017; E. Wenkert, M.E. Alonso, B.L. Buckwalter, E.L. Sanchez, *J. Am. Chem. Soc.* **1983,** *105,* 2021; M.E. Alonso, P. Jano, M.I. Hernandez, R.S. Greensberg, E. Wenkert, *J. Org. Chem.* **1983,** *48,* 3047; E. Wenkert, R.S. Greensberg, M.S. Raju, *ibid.* **1985,** *50,* 4681.

[2] E. Wenkert, 'Polyene Synthesis', in 'New Trends in Natural Products Chemistry 1986, Studies in Organic Chemistry', Eds. Atta-ur-Rahman and P.W. Le Quesne, Elsevier Science Publishers B.V., Amsterdam, 1986, Vol. 26, p. 557.

[3] E. Wenkert, M. Guo, F. Pizzo, K. Ramachandran, *Helv. Chim. Acta* **1987,** *70,* 1429.

[4] A. Padwa, Th.J. Wisnieff, E.J. Walsh, *J. Org. Chem.* **1986,** *51,* 5036; *ibid.* **1989,** *54,* 299.

[5] V. Prelog, H.L. Meier, *Helv. Chim. Acta* **1950,** *33,* 1276; E. Becher, R. Albrecht, K. Bernhard, H.G.W. Leuenberger, H. Meyer, R.K. Müller, W. Schüep, H.P. Wagner, *Helv. Chim. Acta* **1981,** *64,* 2419.

[6] R. Kaiser, D. Lamparsky, *Helv. Chim. Acta* **1978,** *61,* 373.

[7] T. Fujimori, R. Kasuga, H. Matsushita, H. Kaneko, M. Noguchi, *Agric. Biol. Chem.* **1976,** *40,* 303.

[8] G. Ohloff, 'Recent Developments in the Field of Naturally Occurring Aroma Components', in 'Progress in the Chemistry of Natural Products', Eds. W. Herz, H. Griesbach, and G.W. Kirby, Springer-Verlag, Wien–New York, 1978, p. 431.

[9] R. Kaiser, D. Lamparsky, *Helv. Chim. Acta* **1978,** *61,* 2328.
[10] B. Maurer, A. Hauser, unpublished results (*Firmenich S.A.*, CH–1211 Geneva 8).
[11] G. Britton, *Nat. Prod. Rep.* **1986,** *3,* 591, and ref. cit. therein; H. Mayer, O. Isler, in 'Carotenoids', Ed. O. Isler, Birkhäuser Verlag, Basel and Stuttgart, 1971, p. 325.
[12] M. W. Farrar, R. Levine, *J. Am. Chem. Soc.* **1950,** *72,* 3695.
[13] W. Lehnert, *Tetrahedron Lett.* **1970,** 4723.
[14] G. Jenner, J. Rimmelin, *Bull. Soc. Chim. Fr., Part II* **1981,** 65; B. Winter, unpublished results (*Firmenich S.A.*, CH–1211 Geneva 8).
[15] P. D. G. Dean, *J. Chem. Soc.* **1965,** 6655.
[16] H. Meier, K.-P. Zeller, *Angew. Chem. Int. Ed.* **1975,** *14,* 32.
[17] A. L. Wilds, A. L. Maeder, Jr., *J. Org. Chem.* **1948,** *13,* 763.
[18] V. Lee, M. S. Newman, *Org. Synth.* **1970,** *50,* 77.
[19] H. Gilman, R. R. Burtner, *J. Am. Chem. Soc.* **1935,** *57,* 909.
[20] A. Hubert, A. F. Nods, A. J. Anciaux, Ph. Teyssié, *Synthesis* **1976,** 600; M. P. Doyle, *Acc. Chem. Res.* **1986,** *19,* 348.