Oxidation of Furans with Dimethyldioxirane. Interception of Malealdehyde and Related Aldehydes *via* Wittig Reactions

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Unsaturated aldehydes including malealdehyde, generated in acetone by oxidation of furans with dimethyldioxirane, can be trapped efficiently by phosphoranes in Wittig reactions.

The preparation of aqueous solutions of malealdehyde **1**, where it exists as the cyclic hydrate, has been mentioned several times in the older literature.[1] These solutions have been used to prepare nitrogen heterocycles, *e.g.* pyridazines, by condensation with amines, but the dialdehyde itself has been isolated only in a very impure state.[1] Recently, Cram and coworkers[2] demonstrated that attack by oxygen on cyclobutadiene lodged in the inner cavity of a rigid hemispherand leads to the formation of malealdehyde, also incarcarated and thereby prevented from engaging in bimolecular reactions.

We have recently found[3] that oxidation of furan with distilled dimethyldioxirane (DMD) in acetone produces malealdehyde free of nucleophiles in a high state of purity and we now report that in this medium malealdehyde and similar furan oxidation products can be intercepted efficiently in Wittig reactions. This preliminary account describes the use of carbonyl-stabilised phosphoranes **2–5**, fluoren-9-ylidenephosphorane **6** and the dithiolyl ylide **7**.

The experimental procedure consisted of adding a distilled solution of DMD in acetone[4,5] (*ca.* 0.09 mol dm^{-3} solution; 1 equiv.) to a 10% solution of furan in acetone at 0 °C. After *ca.* 30 min a solution of (triphenylphosphoranylidene)acetaldehyde **2** (1 equiv.) in dichloromethane was added and the mixture was allowed to come to room temperature over *ca.* 3 h. Work-up and purification by flash chromatography over silica gel yielded a 1:2 mixture (62%) of (*E*,*Z*)- and (*E*,*E*)-mucondialdehyde, **8** and **9** [eqn. (1)], the presence of the (*E*,*E*)-isomer showing that partial isomerisation had occurred during either the reaction or the chromatographic purification. Brief treatment of the isomer mixture with iodine in dichloromethane or thermally in the same solvent caused quantitative isomerisation to yield the known (*E*,*E*)-isomer **9**.[6] Repetition of the above procedure employing two equivalents of the Wittig reagent **2** led to reaction at both carbonyl groups of malealdehyde to furnish, after double bond isomerisation, the all-*trans*-octatrienedialdehyde **10**, m.p. 105–107 °C, in 70% yield.

The one-pot procedure is applicable to a range of furans and phosphoranes, some combinations of which are shown in Table 1. In most cases crude products were mixtures of double bond isomers which were converted into all-*trans*-isomers by thermal or iodine treatment prior to purification. Yields refer to analytically pure products whose structures are supported by ^1H NMR spectra data.†

Malealdehyde combined efficiently with phosphoranes **3**—**7** in either 1:1 or 1:2 molar proportions. The former are illustrated by products **11–14** (entries 1–4) and the latter by products **15–18** (entries 5–8). Entries 4 and 8 show the

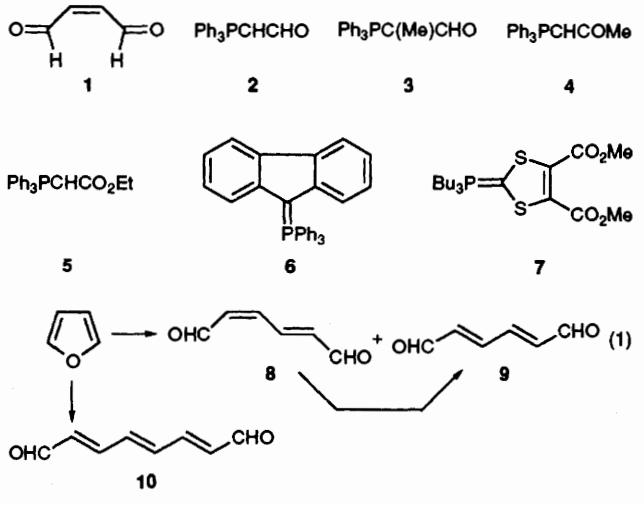
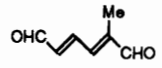
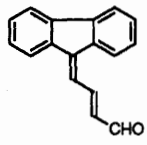
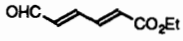
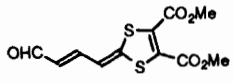
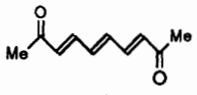
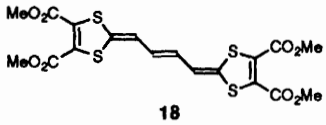
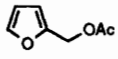
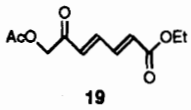
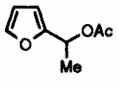
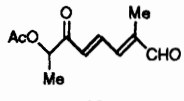
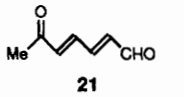
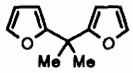
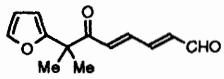
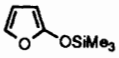
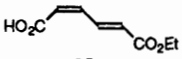


Table 1 Oxidation of furans with DMD and trapping with Wittig reagents

Entry	Furan precursor	Wittig reagent (equiv.)	Product	Yield (%)
1	Furan	3 (1)	 **11**	84
2	Furan	6 (1)	 **12**	78
3	Furan	5 (1)	 **13**	94
4	Furan	7 (1)	 **14**	40
5	Furan	4 (2)	 **15**	30
6	Furan	5 (2)	 **16**	91
7	Furan	5 (2)	 **17**	92
8	Furan	7 (2)	 **18**	45
9		5 (1)	 **19**	85
10		3(1)	 **20**	85
11		2(1)	 **21**	73
12		2(1)	 **22**	78
13		5(1)	 **23**	61

† *Selected data* (*J* values in Hz): **14** ^1H NMR (500 MHz, $CDCl_3$) δ 3.88 (6H, s, CH_3), 5.97 (1H, dd, J_1 7.8, J_2 14.7, =CH–), 6.29 (1H, d, *J* 11.7), 6.94 (1H, dd, J_1 14.7, J_2 11.4, =CH–), 9.53 (1H, d, *J* 8.0, CHO); **20** ^1H NMR (300 MHz, $CDCl_3$) δ 1.45 (3H, d, *J* 6.9, CH_3), 1.98 (3H, s, $COCH_3$), 2.16 (3H, d, *J* 6.3, CH_3), 5.27 (1H, q, *J* 6.9, $CHCH_3$), 6.66 (1H, d, *J* 15.2, =CH–), 6.95 (1H, d, *J* 11.5, =CH–), 7.75 (1H, dd, J_1 15.2, J_2 11.6, =CH–), 9.57 (1H, d, *J* 6.3, CHO); **23** ^1H NMR (300 MHz, $CDCl_3$) δ 1.32 (3H, t, CH_2CH_3), 4.25 (2H, q, CH_2CH_3), 5.99 (1H, d, *J* 11.0, =CH–), 6.15 (1H, d, *J* 15.5, =CH–), 6.74 (1H, dd, J_1 11.0, J_2 15.5, =CH–), 7.80 (1H, brs, OH), 8.35 (1H, dd, J_1 11.0, J_2 11.0, =CH–); **16** ^1H NMR (300 MHz, $CDCl_3$) δ 1.33 (6H, t, CH_3), 4.22 (4H, q, CH_2), 6.02 (2H, d, *J* 15.1, =CH–), 6.40 (2H, d, *J* 9.7, =CH–), 7.81 (2H, dd, J_1 9.7, J_2 15.1, =CH–).

application of this methodology to the synthesis of novel dithiafulvene derivatives **14** and **18**. Whereas the aldehydic Wittig reagents furnished isomer mixtures, the ethoxycarbonylphosphorane **5** combined cleanly with malealdehyde to afford the (*E*,*Z*,*E*)-octatriene diester **16** in 91% yield. Isomerisation of **16** furnished the all-*trans*-isomer **17**,[7] m.p. 88–89 °C, in 92% yield. The final five entries in Table 1 show some of the options that are available with substituted furans as precursors, furfuryl acetate and its α-methyl derivative affording polyfunctional products **19** and **20** with Wittig reagents **5** and **3**, respectively. 2-Methylfuran (entry 11) afforded ketoaldehyde **21** with ylide **2**. In entry 12 where 2,2-difurylpropane is the substrate, use of one equivalent of DMD in the oxidation stage ensures that only one of the furan rings is opened prior to formation of **22**. In the final entry oxidation leads to a hydroxybutenolide which undergoes ring opening with Wittig reagent **5** to form exclusively the (*Z*,*E*)-monoacid **23**.

We thank Great Lakes Chemical (Europe) Ltd for a postgraduate studentship to C.B. and the N. Ireland Department of Education for a CAST award to P.Mc.G.

Received, 7th May 1993; Com. 3/02629I

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