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LETTERS

A facile three-component reaction of dicarbomethoxycarbene, aldehydes and *o*-quinones: synthesis of novel spiro-dioxolanes

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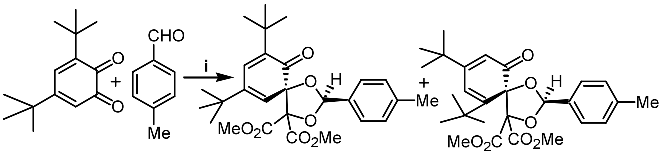
Abstract—Successful trapping of the carbonyl ylides generated from dicarbomethoxycarbene and aldehydes with 1,2-diones is described.

The reaction of carboalkoxycarbenes with carbonyl compounds[1] dates back to the first report in 1885 by Buchner and Curtius.[2] The products of the reaction were characterized as dioxolanes by Dieckmann[3] in 1910. These reactions evoked very little interest until two decades ago, when Huisgen and de March investigated the chemistry in detail and demonstrated the intermediacy of carbonyl ylides by trapping with DMAD.[4] Very recently Jiang et al. have utilized this reaction in a highly diastereoselective synthesis of dioxolanes.[5] A stereospecific synthesis of epoxides involving the collapse of the ylide reported by Doyle is also noteworthy.[6]

In spite of the above investigations, there has been no report on the addition of carbonyl ylides derived from carboalkoxycarbenes to dicarbonyl compounds. In view of this and in the context of our continued interest in the chemistry of *o*-quinones,[7] we have explored the reaction of the latter with carbonyl ylides generated from aldehydes and dicarbomethoxycarbene and our results are presented in this Letter.

Our studies commenced with the Rh(II) catalyzed decomposition of dimethyl diazomalonate in the presence of *p*-tolualdehyde and 3,5-di-*tert*-butyl-1,2-benzoquinone. A facile reaction occured affording a regioisomeric mixture of dioxolanes **3a** and **4a** (Scheme 1).



1a **2a** **3a (44%)** **4a (15%)**

Scheme 1. *Reagents and conditions*: (i) $N_2C(CO_2Me)_2$, $Rh_2(OAc)_4$, dry benzene, argon, 80°C, 14 h.

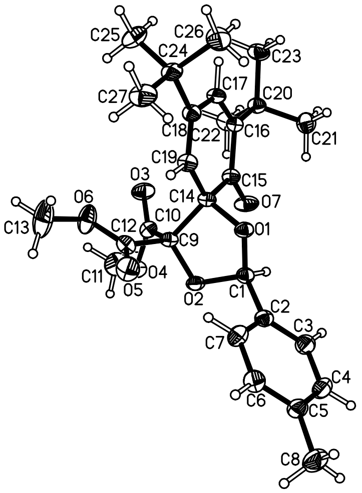


Figure 1.

Keywords: carbonyl ylides; dicarbomethoxycarbene.

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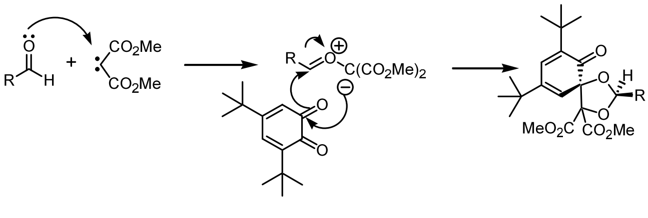


Scheme 2.

The products were separated by chromatography on a silica gel column and characterized by spectroscopic analysis. The relative stereochemistry of **3a** was defined by single crystal X-ray analysis (Fig. 1),[8] and that of **4a** was assigned on the basis of the comparable chemical shift of the acetal proton (δ 6.59) to that of **3a** (δ 6.78).

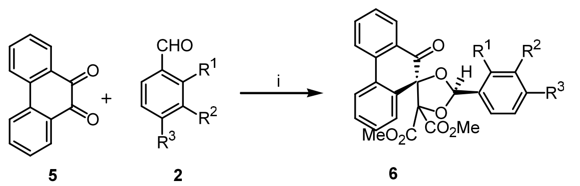
Mechanistically the reaction may be considered to involve the formation of a carbonyl ylide by the reaction of the carbene and the aldehyde and its trapping by the quinone carbonyl (Scheme 2). The diastereoselectivity of the reaction may be rationalised by the concerted nature of the carbonyl ylide cycloaddition and, the observed relative stereochemistry of the products may be attributed to the preferred *trans* geometry of the ylide.

The reaction was found to be general with respect to a variety of aromatic aldehydes and 1,2-benzoquinones (Table 1).

The stereochemistry of compounds **3b–h** and **4b–h** is assigned by analogy to **3a–4a**.

A similar reactivity pattern was observed with phenanthrenequinone and the results are presented in Table 2. The relative stereochemistry of **6c** was established by single crystal X-ray analysis (Fig. 2).

Table 2.



i. $N_2C(CO_2Me)_2$, $Rh_2(OAc)_4$, dry benzene, argon, 80 °C, 14 h

Aldehyde	Substituents	Product	Yield (%)
2a	$R^1=R^2=H$, $R^3=CH_3$	**6a**	85
2b	$R^1=R^2=R^3=H$	**6b**	68
2c	$R^1=R^2=H$, $R^3=OCH_3$	**6c**	73
2d	$R^1=R^3=H$, $R^2=OCH_3$	**6d**	49
2e	$R^1=R^3=OCH_3$, $R^2=H$	**6e**	78

In conclusion, we have demonstrated that carbonyl ylides generated from dicarbomethoxycarbene and aldehydes react efficiently with 1,2-quinones leading to novel spiro dioxolanes.

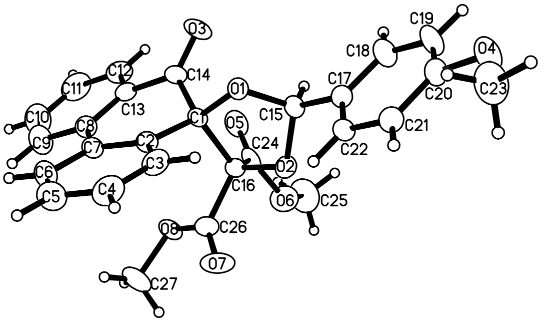
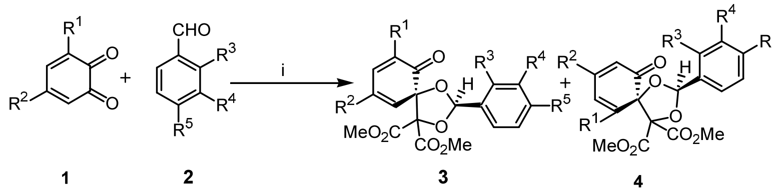


Figure 2.

Table 1.



i. $N_2C(CO_2Me)_2$, $Rh_2(OAc)_4$, dry benzene, argon, 80 °C, 14 h.

o-Benzoquinone	Aldehyde	Substituents	Product	Yield (%)/(ratio)
1a	**2b**	$R^1=R^2=C(CH_3)_3$, $R^3=R^4=R^5=H$	**3b**, **4b**	62 (3:1)
1a	**2c**	$R^1=R^2=C(CH_3)_3$, $R^3=R^4=H$, $R^5=OCH_3$	**3c**, **4c**	51 (3:1)
1a	**2d**	$R^1=R^2=C(CH_3)_3$, $R^3=R^5=H$, $R^4=OCH_3$	**3d**, **4d**	40 (3:1)
1b	**2a**	$R^1=CHPh_2$, $R^2=C(CH_3)_3$, $R^3=R^4=H$, $R^5=CH_3$	**3e**, **4e**	74 (2:1)
1b	**2c**	$R^1=CHPh_2$, $R^2=C(CH_3)_3$, $R^3=R^4=H$, $R^5=OCH_3$	**3f**, **4f**	55 (7:1)
1c	**2a**	$R^1=H$, $R^2=C(CH_3)_3$, $R^3=R^4=H$, $R^5=CH_3$	**3g**, **4g**	41 (1:1)
1c	**2c**	$R^1=H$, $R^2=C(CH_3)_3$, $R^3=R^4=H$, $R^5=OCH_3$	**3h**, **4h**	33 (1:1)

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8. All new compounds were fully characterized.
   Typical experimental procedure and data for compounds **3a** and **4a**: A mixture of 3,5-di-*tert*-butyl-1,2-benzoquinone **1a** (0.1 g, 0.45 mmol), *p*-tolualdehyde **2a** (0.054 g, 0.45 mmol), dimethyl diazomalonate (0.074 g, 0.5 mmol) and 2 mol% of $Rh_2(OAc)_4$ was refluxed in 5 ml of dry benzene under an argon atmosphere for 14 h. The solvent was then removed under vacuum and the residue after chromatographic separation on silica gel using hexane–ethyl acetate (95:5) gave the spiro dioxolanes **3a** (0.094 g, 44%) and **4a** (0.032 g, 15%) as yellow crystalline solids.
   Compound **3a**: Yellow crystalline solid, recrystallised from ethyl acetate–hexane mixture, mp 160°C; IR (KBr) ν_{max}: 2965, 2866, 1745, 1646, 1427, 1374, 1288, 1228, 1122, 1069, 1003, 963, 937, 817, 791, 738, 645 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$–CCl_4, v/v, 3:1): 1.14 (s, 9H, $C(CH_3)_3$), 1.25 (s, 9H, $C(CH_3)_3$), 2.37 (s, 3H, $ArCH_3$), 3.73 (s, 3H, OCH_3), 3.80 (s, 3H, OCH_3), 5.72 (d, 1H, $J=2.2$ Hz), 6.78 (s, 1H), 6.87 (d, 1H, $J=2.2$ Hz), 7.19 (d, 2H, ArH, $J=7.9$ Hz), 7.60 (d, 2H, ArH, $J=8.0$ Hz), ^{13}C NMR (75 MHz, $CDCl_3$–CCl_4, v/v, 3:1): 21.47, 28.48; 29.28, 34.62, 34.89, 52.99, 84.03, 107.05, 123.29, 123.37, 127.84, 128.93, 132.76, 134.44, 139.64, 143.52, 147.08, 167.01, 198.24. Elemental analysis calcd. for $C_{27}H_{34}O_7$: C, 68.92, H, 7.28, Found: C, 69.00, H, 7.41, Compound **4a**: Yellow crystalline solid, recrystallised from ethyl acetate–hexane mixture, mp 102°C; IR (KBr) ν_{max}: 2959, 2919, 2866, 1752, 1659, 1639, 1580, 1440, 1387, 1295, 1222, 1129, 1016, 963, 824, 658, 492 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$–CCl_4, v/v, 3:1): 1.12 (s, 9H, $C(CH_3)_3$), 1.21 (s, 9H, $C(CH_3)_3$), 2.39 (s, 3H, $ArCH_3$), 3.71 (s, 3H, OMe), 3.75 (s, 3H, OCH_3), 5.74 (d, 1H, $J=1.4$ Hz), 6.37 (d, 1H, $J=1.4$ Hz), 6.59 (s, 1H) 7.20 (d, 2H, ArH, $J=8.0$ Hz), 7.56 (d, 2H, ArH, $J=8.0$ Hz); ^{13}C NMR (75 MHz, $CDCl_3$–CCl_4, v/v, 3:1): 21.42, 28.06, 30.67, 35.52, 37.66, 52.80, 53.53, 107.12, 117.17, 123.36, 126.82, 128.93, 131.90, 139.09, 153.14, 167.55, 204.56; Elemental analysis calcd. for $C_{27}H_{34}O_7$: C, 68.92, H, 7.28, Found: C, 68.80 H, 7.52