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Carbenoid induced irreversible ring opening of naphthopyrans

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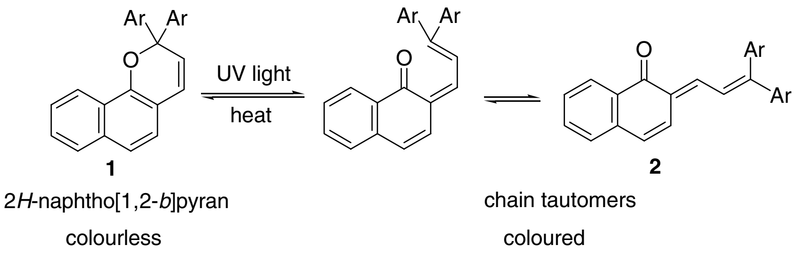
Abstract—Contrary to expectation rhodium carbenoids do not undergo cycloaddition to the 2*H*-pyran unit of the isomeric naphthopyrans **3** and **5**. With **3**, a naphtho[2,1-*b*]pyran-8-ylacetate, **4** is formed and a novel merocyanine dye **6** results from a cycloaddition across the C-5–C-6 double bond of the naphtho[1,2-*b*]pyran **5**. Tethering the carbenoid to the naphtho[1,2-*b*]pyran system **5**, as in **10**, results in a similar mode of addition and affords the intensely coloured tetracycle **11**.

The facile reversible electrocyclic ring-opening of the 2*H*-pyran system is well documented[1] and has generated significant commercial interest when the 2*H*-pyran moiety is fused to a naphthalene unit.[2] The ring-opening of these naphthopyrans, for example, **1** (Scheme 1) is accompanied by a dramatic change in their absorption spectrum resulting in a reversible colourless to coloured transformation; a phenomenon known as photochromism.[3]

We have investigated the photochromism of naphthopyrans[4] and in this work focused on their reactions with a view to trapping irreversibly a coloured ring-opened isomer, for example, **2**. Carbenoids[5] offer considerable potential in this work.

Thus the dropwise addition of a solution of ethyl diazoacetate over 5 h to a solution of 3,3-bis(4-methoxyphenyl)-3*H*-naphtho[2,1-*b*]pyran **3** containing $Rh_2(OAc)_4$ in anhydrous CH_2Cl_2 at rt gave a disappointingly low yield (6%) of an unexpected new naphthopyran **4**[6] together with recovered staring material (Scheme 2). The formation of this compound may be rationalised by either attack of the carbenoid at the electron rich C-8 atom, an overall S_EAr process or by insertion into the C-8–H-8 bond. The isomeric 2,2-bis(4-methoxyphenyl)-2*H*-naphtho[1,2-*b*]pyran **5** was subjected to the same protocol. In this instance an intense yellow dye **6** (only relative stereochemistry shown) was obtained (8% yield, λ_{max} (EtOH) 421 nm, $\varepsilon_{max} = 2.3 \times 10^4\ mol^{-1}\ dm^3\ cm^{-1}$, *m*/*e* 481.2017 for $[M+H]^+$) with a significant quantity of



Scheme 1.

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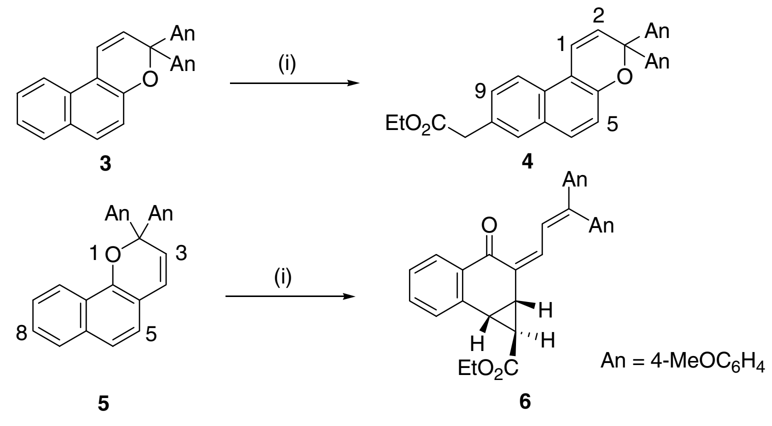


Scheme 2. Reagents and conditions: (i) $Rh_2(OAc)_4$, N_2CHCO_2Et, CH_2Cl_2, rt.

5 recovered. The ^1H NMR spectrum of **6** displayed a dd (J 4.2, 3.9 Hz) at δ 1.53 mutually coupled to a dd at δ 2.84 (J 8.5, 4.2 Hz) and at δ 3.03 (J 8.5, 3.9 Hz), which confirmed the formation of a *cis*-fused cyclopropane unit.[7] Furthermore, the presence of a doublet at δ 6.78 (J 11.8 Hz) and at δ 8.07 affirmed the *s-trans* diene unit.[4a,8] The structure of **6** was confirmed by X-ray crystallography (Fig. 1).[9] There are two probable pathways for the formation of **6**. Thus, the carbenoid undergoes a cycloaddition to the C-5–C-6 double bond of the naphthopyran; loss of aromatic character of the naphthalene unit favours the formation of the coloured ring-opened isomer.[8,10] Alternatively, the carbenoid adds to the isolated double bond of the small amount of ring-opened isomer that is present under the reaction conditions, the equilibrium then adjusts to generate more of this dienone, which suffers the same fate.

We were keen to explore this unique reactivity[11] of the naphthopyrans towards carbenoids further and improve the trapping protocol using a carbene precursor tethered to a naphthopyran thereby making use of a favourable intramolecular process. Thus reduction of the ester function of naphthopyran **7**[10] with $LiAlH_4$ in THF at rt effected the clean conversion to the hydroxymethyl compound **8** in 63% yield (mp 153–154 °C, found $[M+H]^+$ 455.1855, $C_{29}H_{26}O_5$ requires $[M+H]^+$ 455.1858) (Scheme 3). Attempts to improve this conversion using elevated temperatures resulted in a complex mixture from which 2-[3′,3′-bis(4-methoxyphe-

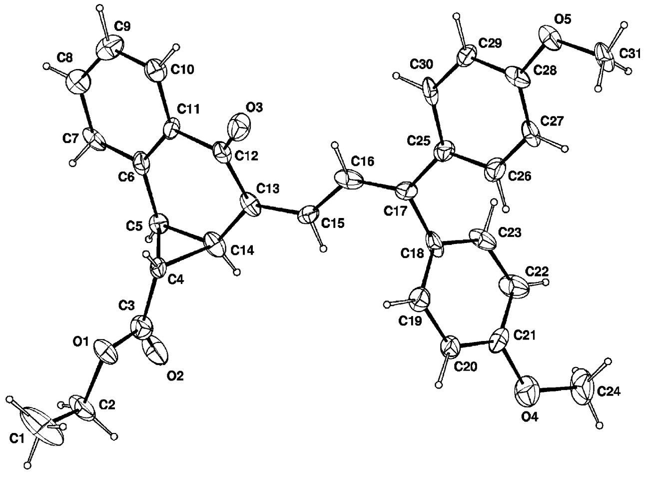
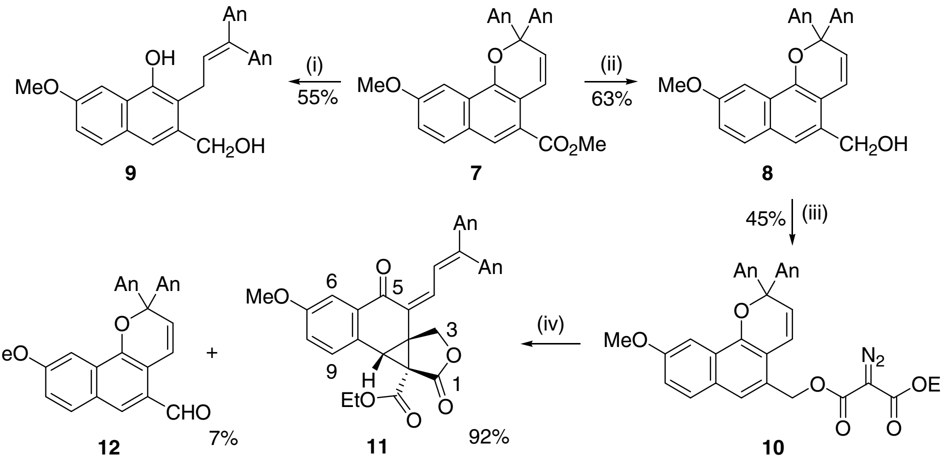


Figure 1. X-ray crystal structure of **6**.



Scheme 3. Reagents and conditions: (i) $LiAlH_4$, THF, reflux; (ii) $LiAlH_4$, THF, rt; (iii) ethyl 2-diazomalonly chloride, 2,6-lutidine, DMAP, CH_2Cl_2, 0 °C to rt; (iv) Rh_2 $(OAc)_4$, CH_2Cl_2, rt.

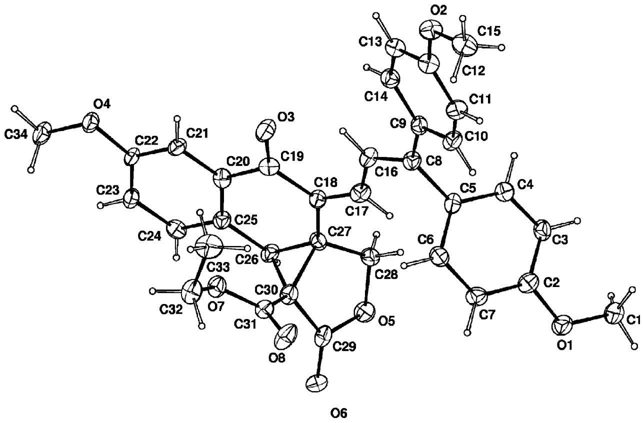


Figure 2. X-ray crystal structure of **11**.

nyl)prop-2′-enyl]-3-hydroxymethyl-7-methoxy-1-naphthol **9** was obtained by column chromatography in 55% yield. Evidently under the more forceful reaction conditions ring opening of the pyran unit ensues and reduction of the quinone methide unit is effected.

Diazoacetylation of the hydroxymethyl function of **8** was readily accomplished to afford **10** in 45% yield using ethyl 2-diazomalonyl chloride according to the procedure reported by Padwa and co-workers.[12] Treatment of a solution of this tethered carbenoid precursor with $Rh_2(OAc)_4$ in CH_2Cl_2 at rt resulted in the formation of the tetracycle **11**[13] in 92% yield together with a small amount of the oxidation product, the aldehyde **12** (δ 10.08, CHO; $[M+H]^+$, 453.1706). The structure of **12** was confirmed by unambiguous synthesis from **8** using Swern methodology.[14] An X-ray crystal structure of **11** is presented in Figure 2.[15] The intramolecular cycloaddition of the tethered Rh-carbenoid derived from (1-naphthylmethyl) diazoacetate to the 1,2-bond of the naphthalene moiety gives a tetracyclic unit structurally related to **11**.[16]

Further reactions of carbenes and carbenoids with photochromic naphthopyrans will be reported in due course.

Acknowledgements

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