

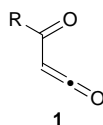
# New thermal rearrangements of vinylogous ketoketenes and related intermediates

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2-Oxopyran-5-carbaldehydes (e.g. **3**) containing a trapping group in the 5-position rearrange thermally by a sequence involving electrocyclic ring opening, *E/Z* isomerisation and ring closure; a similar strategy has enabled the first cases of thermal interconversion of pyran-2-ones and 2-pyridones, and of automerisation of 2-pyridones to be identified.

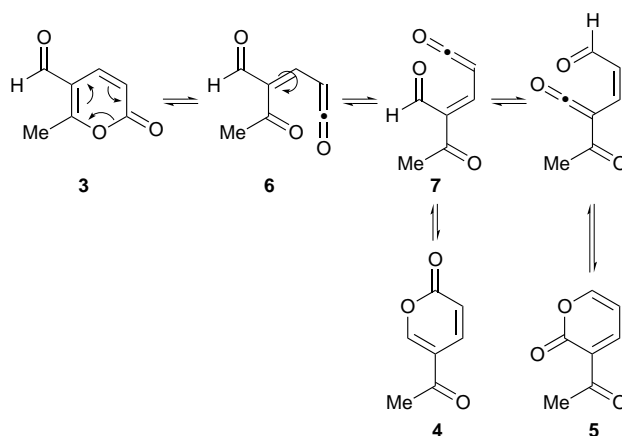
Studies of the thermal chemistry of unsaturated ketenes have provided in recent years many examples of unusual molecular rearrangements.<sup>1</sup> The ketoketene system **1** (R = Ph) undergoes 1,3-aryl shifts,<sup>2</sup> and its vinylogue **2**, which can be generated by ring opening of pyran-2-ones under flash vacuum pyrolysis (FVP) conditions,<sup>3</sup> shows 1,5-hydrogen shifts which serve to equilibrate 3- and 5-substituted pyran-2-one isomers (Scheme 1). Pyran-2-thione similarly rearranges quantitatively to thia-pyran-2-one.<sup>3</sup> Here we demonstrate that in the presence of an appropriate trapping group the potential for thermal rearrangement in vinylogous ketoketenes is more extensive than has been previously recognised, due to the possibility of thermal *E-Z* isomerisation.<sup>4</sup> In addition, this strategy has provided the first examples of equilibration of pyran-2-ones and 2-pyridones, and of automerisation in the 2-pyridone system.



Thus 6-methyl-2-oxopyran-5-carboxaldehyde **3**<sup>†</sup> was synthesised in 79% yield by the reaction of diazomethane with 2-oxopyran-5-carbaldehyde<sup>5</sup> (cf. ref. 6). This compound lacks a good migrating substituent at the 6-position and therefore cannot give rearrangement products by the standard Pirkle mechanism (Scheme 1). Nevertheless, FVP of **3** at 550–750 °C gave rise to a quantitative mixture of the isomers **3**, **4** and **5** which were not separated but could be readily identified by characteristic<sup>7</sup> coupling constants in the <sup>1</sup>H NMR spectra of the mixtures. Thus the 5-acetyl compound **4** showed <sup>3</sup>J<sub>3,4</sub> (10.0 Hz), and the 3-acetyl derivative **5** showed typical values of <sup>3</sup>J<sub>4,5</sub> (6.8 Hz) and <sup>3</sup>J<sub>5,6</sub> (5.0 Hz) which compare well with data for α-pyrone itself (<sup>3</sup>J<sub>3,4</sub> 9.4, <sup>3</sup>J<sub>4,5</sub> 6.3 and <sup>3</sup>J<sub>5,6</sub> 5.0 Hz).<sup>7</sup> Methyl signals of **4** and **5** occurred at δ<sub>H</sub> 2.42 and 2.61 respectively, positions typical of acetyl groups. The formation of **4** is readily explained by *Z* to *E* isomerisation<sup>4</sup> of the alkene function of the ring-opened intermediate **6**, followed by collapse *via* electrocyclic ring closure involving the initial aldehyde substituent (Scheme 2). An extension of the mechanism by 1,5-H-shift in the newly generated intermediate **7** gives the third isomer **5** after similar electrocyclic ring closure. The ratio of **3**:**4**:**5** at equilibrium (> 700 °C; Fig. 1) presumably reflects the relative stereoelec-

tronic effects of the ring substituents; pyrones with certain other 5-carbonyl-containing substituents apparently do not rearrange significantly to the 3-isomers at high temperatures.<sup>3</sup>

In order to apply this methodology to pyran-2-one–2-pyridone equilibria, a 5-imino-substituted pyrone was required. The substrate **8** was therefore synthesised by condensation of the appropriate aldehyde (prepared in 60% yield by Rosenmund



Scheme 2

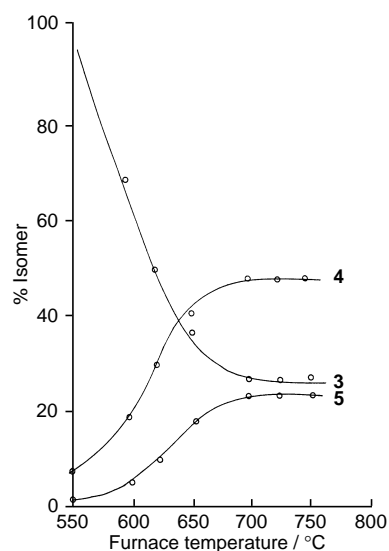
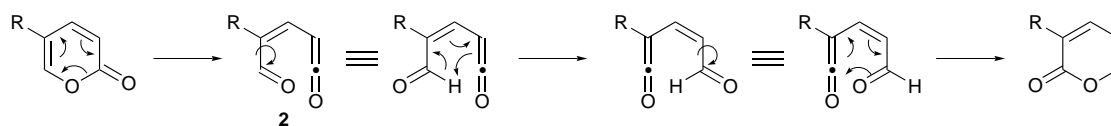


Fig. 1 Equilibration of **3**, **4** and **5** by FVP of **3** at different furnace temperatures



Scheme 1

reduction of the corresponding acyl chloride) with *p*-toluidine (90%). FVP of **8** at 650 °C gave a quantitative yield of a single rearranged pyridone **9** (Scheme 3) whose structure was confirmed by X-ray crystallography† (Fig. 2). Assuming that there is little significant difference in the thermodynamic properties of the acetyl and aldimine substituents, the pyridone ring system appears to be overwhelmingly favoured thermodynamically with respect to the related pyrone.

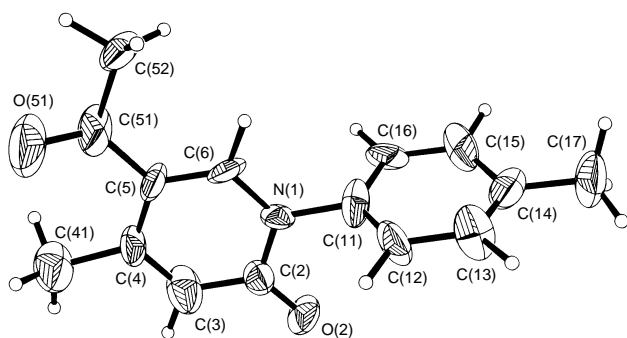
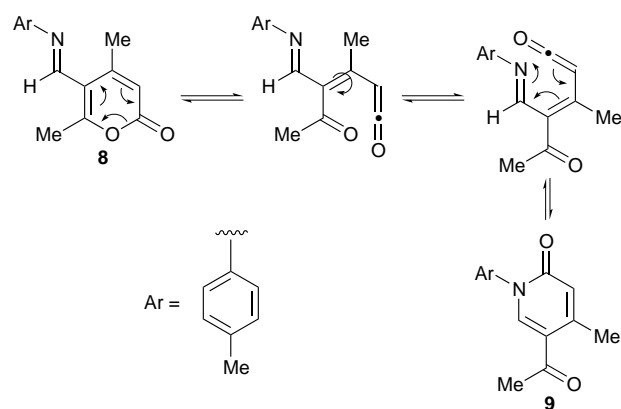
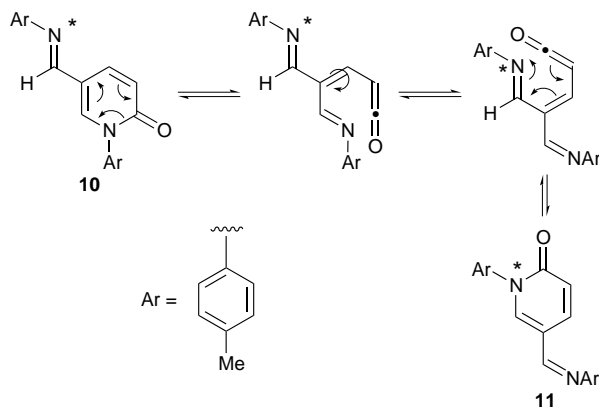


Fig. 2 Thermal ellipsoid plot of **9** showing the crystallographic numbering scheme

In contrast to the situation with pyran-2-one and thiopyran-2-one systems,<sup>3</sup> very little is known of the thermal behaviour of 2-pyridones except for some fragmentation reactions under forcing conditions.<sup>8</sup> It is clear from the above result that 2-pyridones are unlikely to ring open under such mild conditions as their *O*-analogues, but we were interested to determine the general feasibility of this process. Accordingly, we reacted *p*-toluidine with 2-oxopyran-5-carbaldehyde and condensed the resulting oxopyridine carbaldehyde (56%) with <sup>15</sup>N-labelled *p*-toluidine to give the imine **10** (96%) ( $\delta_N$  –63.76



relative to external nitromethane). Reversing this sequence gave an authentic sample of the labelled pyridone **11** ( $\delta_N$  –198.19). FVP of **10** at 750 °C, conditions under which the pyrones were completely equilibrated, gave just 4% of the atomerised species **11** as shown by the small peak at  $\delta_N$  –198.19 in the <sup>15</sup>N NMR spectrum of the pyrolysate (Scheme 4). This result nevertheless establishes for the first time that thermal electrocyclic ring opening of the 2-pyridone system is a viable, albeit high energy, process. The rearrangement was much more pronounced (37%) at 850 °C, but the <sup>15</sup>N NMR spectrum was confounded by many other peaks due to decomposition products.

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## Footnotes

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† All new compounds were characterised by their spectra and by elemental analyses, unless otherwise stated.

‡ Crystal data for **9**. C<sub>15</sub>H<sub>15</sub>NO<sub>2</sub>, *M* = 241.28, orthorhombic, space group *P*2<sub>1</sub>2<sub>1</sub>2<sub>1</sub>, *a* = 5.557(4), *b* = 9.645(4), *c* = 24.272(10) Å, *V* = 1300.9 Å<sup>3</sup> (from setting angles for 10 *h*0*l* and 10 0*kl* data, 2θ = 8–24°, λ = 0.71073 Å), *Z* = 4, *D*<sub>calc</sub> = 1.232 g cm<sup>–3</sup>, *T* = 295K, colourless needle, 0.85 × 0.2 × 0.08 mm, μ = 0.077 mm<sup>–1</sup>, *F*(000) = 512. Data collection and processing—Stoë STADI-2 2-circle diffractometer, graphite monochromated Mo-Kα X-radiation, *T* = 295K, ω-scans with ω-range (2.0 + 0.5 sinα/tanθ)°, 1039 unique reflections (2θ<sub>max</sub> 50°, 0 ≤ *h* ≤ 6, 0 ≤ *k* ≤ 10, 0 ≤ *l* ≤ 26) giving 547 with *F* ≥ 4σ(*F*) for use in all calculations. No significant crystal decay or movement was apparent, and no absorption correction was made. Structure solution and refinement—automatic direct methods<sup>9</sup> located all non-hydrogen atoms which were then refined anisotropically; hydrogen atoms were inserted in calculated positions with fixed atomic displacement parameters of *U* = 0.05 Å<sup>2</sup> (C–H = 1.08 Å). Only the torsion angles of the methyl groups were refined. At final convergence, *R*, *R*<sub>w</sub> = 0.075, 0.026 respectively, *S* = 1.12 for 173 refined parameters and the final difference synthesis showed no peak or trough outside ±0.3 e Å<sup>–3</sup>. An extinction parameter was refined, converging to 4.0 × 10<sup>–4</sup>. No absorption corrections were made. The weighting scheme *w*<sup>–1</sup> = σ<sup>2</sup>(*F*) gave satisfactory agreement analyses; in the final cycle, the maximum δσ was 0.07. Inlaid<sup>10</sup> atomic scattering factors were used, molecular geometry calculations utilised CALC,<sup>11</sup> and Fig. 2 was produced by SHELXTL.<sup>12</sup> Atomic coordinates, bond lengths and angles, and thermal parameters have been deposited at the Cambridge Crystallographic Data Centre (CCDC). See Information for Authors, Issue No. 1. Any request to the CCDC for this material should quote the full literature citation and the reference number 182/477.

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