(2-Pyridyl)iminopropadienone

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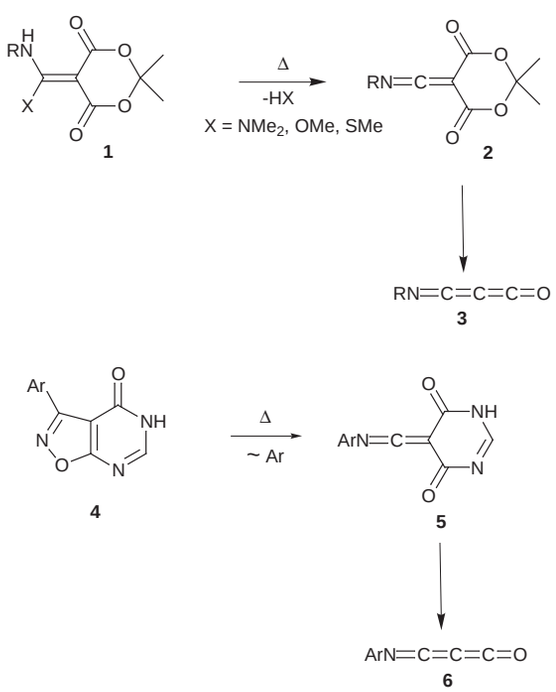
(2-Pyridyl)iminopropadienone **13** is generated by flash vacuum thermolysis (FVT) of 2-substituted pyrido[1,2-*a*]-pyrimidin-4-ones **9** and observed by IR spectroscopy. Addition of HCl to **13** causes reversion to the starting material **9b**, whereas addition of nucleophiles leads to malonic acid imide derivatives (**23**, **24**, **26**, **27**, **28**). The latter undergo thermal elimination of amines to regenerate 2-substituted pyridopyrimidinones. A competing retro-ene reaction occurs on FVT of 2-(dialkylamino)pyridopyrimidinones **9c**,**d**, presumably in the oxoketenimine intermediates **22**/**25**, with formation of the unsubstituted pyridopyrimidinone **31**.

Introduction

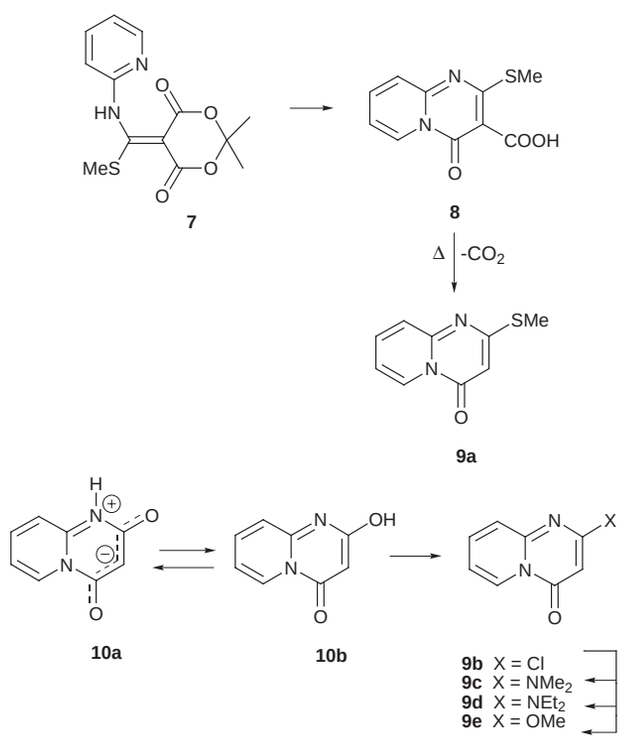
Recently we reported the synthesis and reactivity of a new class of compounds, the iminopropadienones, RN=C=C=C=O.[1,2] In the absence of sterically protecting substituents, these compounds have the character of reactive intermediates and undergo chemical reactions, typically nucleophilic addition reactions to furnish malonic acid imide derivatives, at temperatures below −70 °C.[1–5] There are two methods of formation of iminopropadienones, both using flash vacuum thermolysis (FVT): (i) from Meldrum's acid derivatives **1** (5-methylene-1,3-dioxane-4,6-diones), which undergo elimination of amines, methanol, or methanethiol to generate transient ketenimines **2**, followed by



fragmentation to CO_2, acetone, and the desired iminopropadienone **3**.[1–5] This method is useful for both alkyl and aryl derivatives. (ii) From isoxazolopyrimidinones **4**, which after ring opening by breaking the N–O bond in the isoxazole ring and 1,2-migration of the aryl group provide another transient ketenimine **5**. The latter rapidly fragments to HCN, HNCO, and iminopropadienone **6**.[1] This method is useful for aryl derivatives only. Method (i) cannot be used for the preparation of the 2-pyridyl derivative because the requisite Meldrum's acid derivative **7** is not stable. On attempted synthesis of this compound from 5-[bis(methylthio)methylene]-1,3-dioxane-4,6-dione and 2-aminopyridine, cyclization to the pyrido[1,2-*a*]-pyrimidin-4-one **8** takes place.[6] However, as shown in the present paper, pyridopyrimidinones **9** can be used as a new type of precursor of iminopropadienones. Here we report the first heterocyclic example, 2-pyridyliminopropadienone **13**.

Results and discussion

Flash vacuum thermolysis (FVT) of **8** at 650 °C caused decar-



boxylation and formation of the 2-(methylthio)pyrido[1,2-*a*]-pyrimidinone **9a**, which was isolated as the only product apart from some impurities presumably stemming from the decomposition of a small amount of **13** formed (see below). The other precursors, **9b**–**e**, were synthesized from Tschitschibabin's pyridopyrimidinone **10**.[7–9] On the basis of UV spectra,

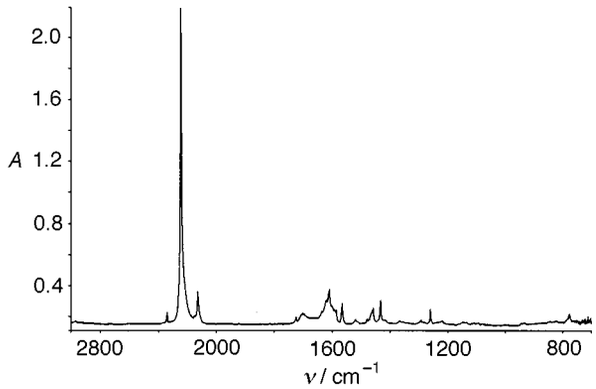


Fig. 1 IR spectrum of **13** (AR, 14 K). The main peak is an intense triplet at 2249, 2247, 2245 cm^{-1}. A weaker peak at 2129 cm^{-1} also belongs to the cumulene. The small peak at 2341 cm^{-1} is due to CO_2.

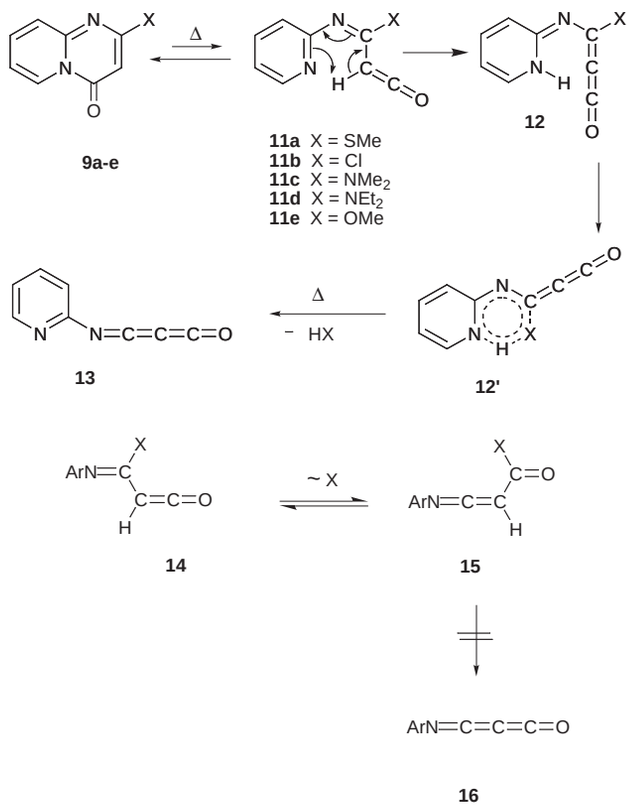
Katritzky and Waring suggested a long time ago that this interesting compound existed as the mesoionic tautomer **10a** in solution;[8a] this was further elaborated by Dvortsak *et al.*,[8b] and the mesoionic structure in the crystal was proved by Thorup and Simonsen.[8c] We have recently confirmed that the structure of the 3-phenyl derivative in the crystal is the mesoion corresponding to **10a**.[9] Nevertheless, it may be that **10** can exist in equilibrium with the hydroxy tautomer **10b**. Reaction with $POCl_3$ gives the chloro derivative **9b**,[10] which reacts with nucleophiles such as dimethyl- and diethylamine or sodium methoxide in methanol[11] to afford **9c**,**d**,**e**. Compound **9e** is also obtained by direct methylation of **10** with dimethyl sulfate–sodium methoxide in methanol. Methylation with MeI–methoxide was reported to give the *N*-methyl isomer.[8]

FVT of **8** at 650 °C with isolation of the thermolysate in Ar matrix at *ca*. 14 K gave rise to a new species exhibiting a prominent triad of bands at 2249, 2247, and 2245 cm^{-1} in the IR spectrum, indicating that iminopropadienone **13** had been formed. In addition, MeSH and CO_2 (2346 and 2341 cm^{-1}) were identified. However, the main product was again the pyridopyrimidinone **9a**. FVT of **8** at 900 °C afforded an increased ratio **13**/**9a**, but **9a** still remained the main product.

FVT of **9b** at 600 °C with Ar matrix isolation of the products gave mainly starting material and only a small amount of (2-pyridyl)iminopropadienone (**13**). To be efficient, this ring opening–HCl elimination requires temperatures of *ca.* 850 °C. Under these conditions, **13** is formed in almost quantitative yield according to IR spectroscopy. Except for bands due to HCl and a small amount of the starting material, no other products were detected. The spectrum is shown in Fig. 1. Apart from the prominent triad at 2249/2247/2245 cm^{-1}, ascribed to the antisymmetric stretching mode of the cumulene, a much weaker absorption at 2129 cm^{-1}, assigned to the symmetric stretching vibration, is also visible. The positions and intensities are typical for iminopropadienones.[1]

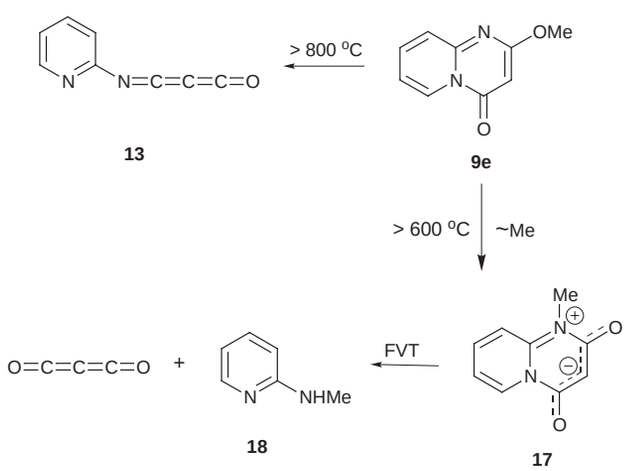
FVT of the dimethylamino derivative **9c** also gave rise to the bands of **13** but even at 850 °C there was still a significant amount of starting material visible in the spectrum, significantly more so than in the case of the chloro compound **9b**. The diethylamino derivative **9d** behaved similarly.

All these reactions are interpreted in terms of reversible ring opening of the starting materials **9** to imidoylketenes **11**. The equilibrium will lie strongly to the side of the pyrimidopyrimidinone **9** at ordinary temperatures. A 1,5-H shift in **11** generates the *NH*-tautomeric methyleneketene **12**, in which facile elimination of HX can now take place *via* a six-membered cyclic transition state **12′**. The step **11**→**12** is similar to the facile ketene formation by FVT of *N*-(2-pyridyl)amides (2–Py–NH–CO–CH_2X→X–CH=C=O + 2-NH_2Py).[13] A direct 1,2-elimination in the imidoylketene **11** is very unlikely because we have shown conclusively that the interconverting imidoyl-



ketenes and oxoketenimines **14** and **15** *do not* undergo such HX elimination to afford aryliminopropadienones **16**, or at best do so only in trace amounts.[5]

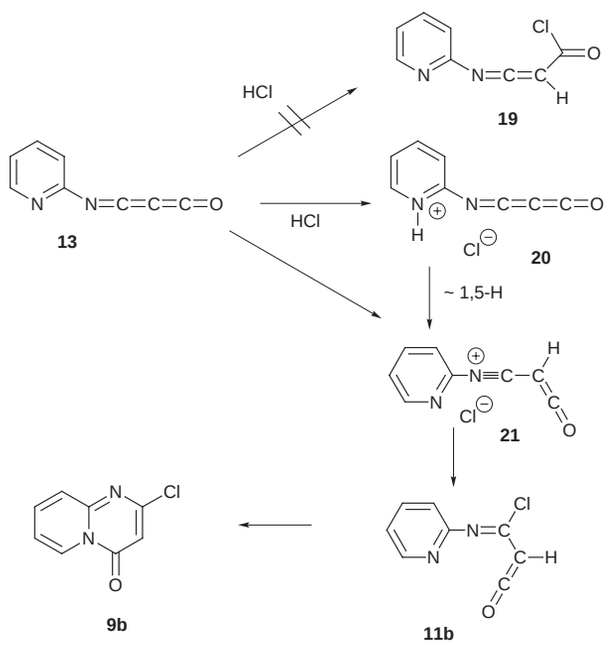
In the case of **9e**, thermolysis proceeds *via* two pathways. The first is the usual ring opening and elimination of methanol to yield **13**. The second gives rise to C_3O_2 and 2-(*N*-methylamino)pyridine (**18**). On thermolysis at 600 °C, mainly starting material, together with absorptions due to C_3O_2 and **18** were



observed by IR spectroscopy. At 800 °C, additional bands due to **13** appeared. At 930 °C, C_3O_2 dominated the spectrum, with significant amounts of **13**, **9e**, and **18** also being observable. Bands at 2150 and 2138 cm^{-1} indicated the formation of small amounts of CO. Chemical proof for the formation of C_3O_2 was given by the isolation of malonic acid bis(dimethylamide) from the 850 °C reaction followed by addition of $HNMe_2$. The ready formation of C_3O_2 is probably due to a competing O-to-N methyl shift reaction generating the mesoionic isomer **17**. We have shown elsewhere that **17** fragments efficiently to C_3O_2 and 2-methylaminopyridine **18** under FVT conditions.[14]

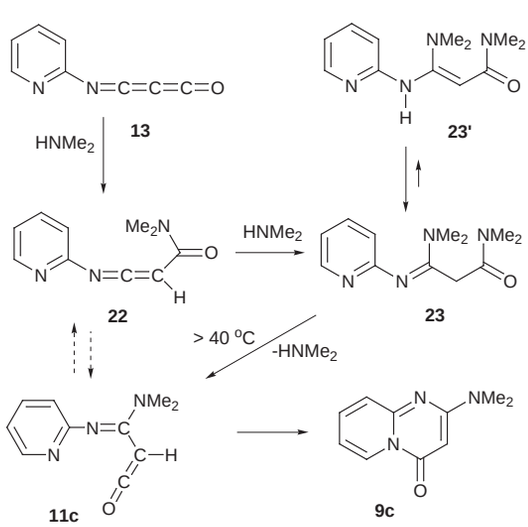
Although the chloro compound **9b** is an excellent precursor of **13** for spectroscopic purposes, **13** reacts very efficiently with

the co-condensed HCl on warmup, thus regenerating the starting material. FVT of **9b** at 850 °C with product isolation at 77 K (*i.e.* neat, no matrix gas) gave rise to an intense band at 2220 and a weaker one at 2119 cm^{-1} ascribed to **13**. On warmup, the two bands started to decrease in intensity at *ca.* −120 °C and had completely disappeared at *ca.* −40 °C. Simultaneously, the bands of the starting material **9b**, which were very weak at 77 K, increased enormously in intensity. This is explained by the reaction between **13** and HCl leading to the formation of imidoylketene **11b** and subsequent ring closure of **11b** to yield **9b**. Since an oxoketenimine **19** could not be detected during this reaction, it appears that, in contrast to the addition of nucleophiles,[1,2,4,5] HCl does *not* add to the 'ketenic' double bond of **13** but to the 'ketenimine' double bond. This will generate the ion



pair **21** by initial protonation of the central C atom of **13** or by a 1,5-H shift of the *N*-protonated tautomer **20**. It is in fact known from MS studies that both iminopropadienones and C_3O_2 are protonated preferentially on the central C atom in the gas phase.[15]

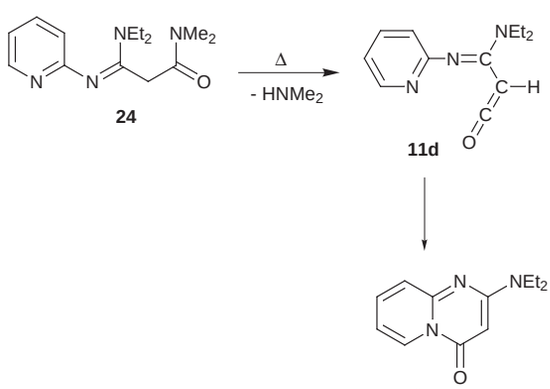
The above reaction makes the trapping of **13** with nucleophiles inefficient when **9b** is used as the precursor. The use of the amine derivative **9c** was investigated for the purpose of such trapping. After FVT at 850 °C and isolation of the products on a 77 K cold finger, injection of a solution of dimethylamine onto the cold finger and warming to room temperature yielded the malonic amidoamidine derivative **23**. The crude ^{1}H NMR



spectrum showed a ratio of **23** to unreacted **9c** of *ca.* 55:45. Raising the temperature to 1000 °C improved the ratio to *ca.* 90:10, but at this temperature the reaction mixture contained considerably more impurities. Therefore, most experiments were carried out at 850 °C. The ^{1}H NMR spectrum of compound **23** shows three singlets for the NMe groups with an integral ratio of 6:3:3, the amidine function appearing at lowest field (3.03 ppm), and the two methyl groups are equivalent at room temperature due to rapid rotation. The two signals at higher field (2.72 and 2.85 ppm) are due to the two non-equivalent methyl groups of the amide function, which experience slow rotation at room temperature. A singlet at 3.50 ppm (CH_2) integrates for two protons, thus indicating that **23** is the only tautomer present in solution; an *NH* tautomer **23′** is not detectable.

We have measured the low and high coalescence temperatures for the amidine and amide functions of **23** (269 and 357 K, respectively) and derived[16] the free energies of activation for the rotation about the amidine and amide C–N bonds as $\Delta G^{\ddagger} = 13.2$ and 17.6 kcal mol^{-1}, respectively. This difference in rotational barriers is a valuable tool for the secure assignment of structures of the 'mixed' compounds **24**, **26**, and **28** described below.

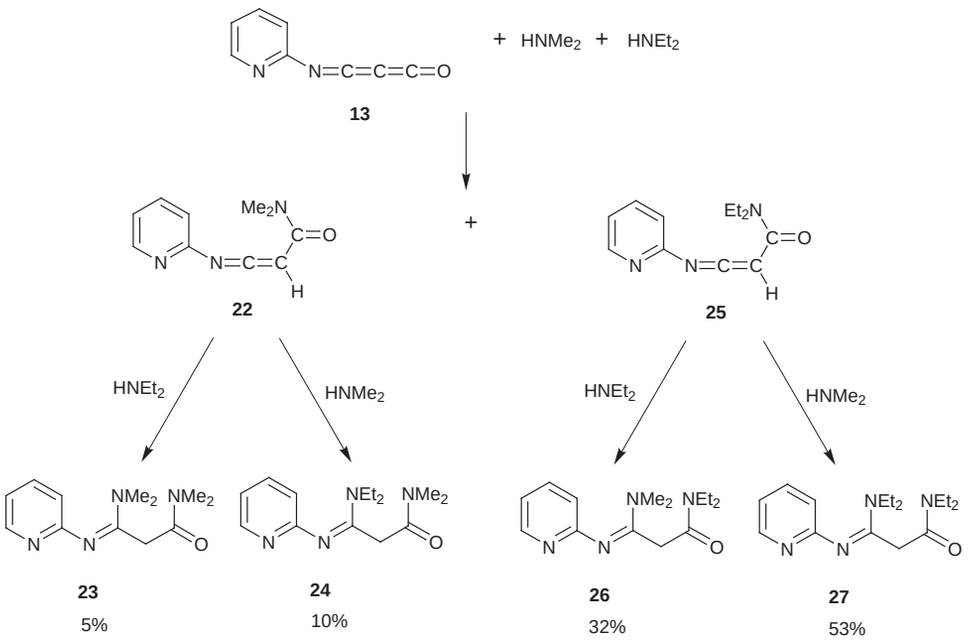
When heated in solution, **23** eliminates dimethylamine to give the imidoylketene **11c** which subsequently yields **9c** by ring closure. Monitoring the warmup by ^{1}H NMR spectroscopy in $CDCl_2CDCl_2$ solution showed that the formation of **9c** started at *ca.* 40 °C and was complete after a few minutes at 100 °C. The formation of **9c** also occured when **23** was examined by GC-MS (injector block 200 °C). Therefore **23** could not be observed under these conditions. When the same GC-MS experiment was carried out with the amidinoamide **24** (described below),



2-(diethylamino)pyridopyrimidinone **9d** was detected by MS. This indicates that $HNMe_2$ is eliminated from the amide group, generating imidoylketene **11d** (X = NEt_2) only.

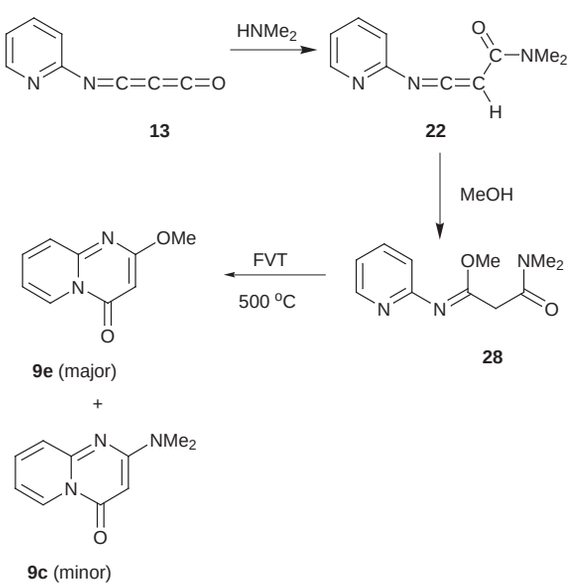
The bis(diethylamino) compound **27** was synthesized in a similar manner from **9d** and subsequent rinsing of the cold finger with diethylamine.

Trapping of **13** (generated from the dimethylamino derivative **9c**) with diethylamine at first produced only a very small amount of the expected malonic acid derivative **27**, almost the only product being the mixed derivative **24**, accompanied by a small amount of **23**. The reason is that **13**, like all iminopropadienones, reacts rapidly and at low temperature with amines at the ketenic terminus of the cumulene. Although the cold finger was rinsed with a large excess of diethylamine, **13** reacts immediately with the co-condensed dimethylamine upon warmup. The diethylamine condensed on top of the initial matrix reaches only a very small amount of still unreacted **13** and thus can only react with the already formed ketenimine **22**. This conjecture is supported by an experiment in which neat $HNEt_2$ was co-condensed with **13** (plus the co-formed $HNMe_2$) on the cold finger throughout the FVT experiment. In this case, the four possible malonic acid derivatives, **23**, **24**, **26**, and **27**

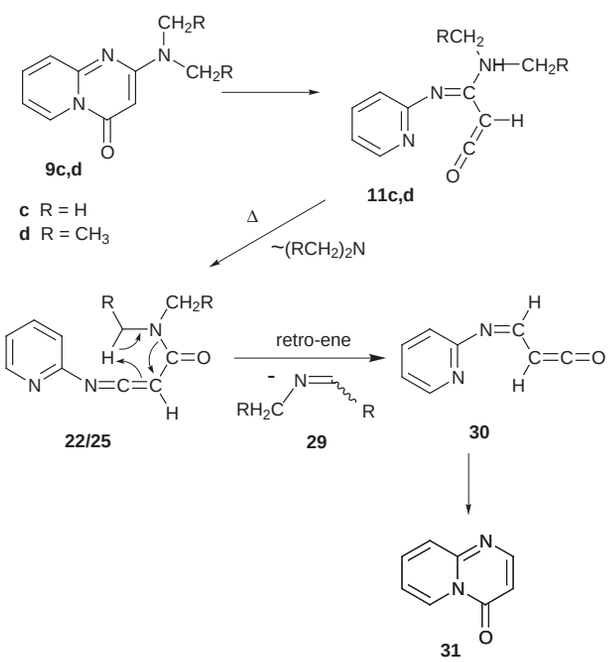


were obtained, in a ratio of approximately 5:10:32:53. The two compounds **26** and **27** having the diethylamino group at the amide moiety were the major products as expected when using an excess of diethylamine. Although diethylamine was in very large excess, there was still some reaction with dimethylamine at the ketenic carbon of **13** and even more with the formed transient ketenimines **22** and **25**, thereby indicating that complete and uniform mixing of **13** with diethylamine was not achieved.

Trapping of **13** with methanol after the end of the thermolysis afforded the malonic acid derivative **28**: **13** reacted first with the co-condensed $HNMe_2$ to give ketenimine **22**. Subsequent addition of methanol affords **28**. This compound is stable under GC-MS conditions, but on FVT at 500 °C, **9e** was obtained as the major, and **9c** as a minor product, according to NMR spectroscopy. This again demonstrates that $HNMe_2$ elimination from the amide group is the dominant reaction.



All FVT experiments using the amines **9c** or **9d** as the starting material at 850 °C led to the formation of *ca.* 5–10% of the unsubstituted parent pyridopyrimidinone **31**, which was identified by ^{1}H NMR and GC-MS. This outcome is presumably the result of a retro-ene reaction in the ketenimine intermediates **22/25** with formation of alkylmethanimines **29** and *N*-(2-pyridyl)imidoylketene **30**, the latter cyclizing to **31**. In the high temperature gas phase reaction, ketenimines **22/25** are easily formed by the 1,3-shift of the dialkylamino group in imidoylketenes **11c,d**.[2,5] Since this is a low-yielding reaction taking place at elevated temperatures, the intermediates, **11**, **22/25** and **30** are not detectable A similar retro-ene reaction was recently proposed for the formation of unsubstituted quinolin-4-one by FVT of 1-aryl-1,2,3-triazole-4-carboxamides.[12] Allenecarboxamides also undergo such a reaction with formation of vinylketenes.[17]



The 9-methyl analogs of **9b** and **9c** were investigated cursorily. FVT generated 3-methyl-2-pyridyliminopropadienone, which could be trapped with dimethylamine to afford the malonic amidoamidine (3-methyl analog of **23**), but the main product in these reactions was the unsubstituted 1,8-naphthyridine. The mechanism of this last reaction requires further investigation.

Experimental

The FVT apparatus and general equipment were as previously reported for Ar matrix,[18] neat film (77 K) deposition,[19] and

preparative scale work (77 K isolation).[20] BaF_2 disks were used for depositions. IR spectra were recorded on Perkin-Elmer 1700 or 2000 FTIR spectrometers. GC-MS: Hewlett-Packard quadrupole detector 5970 with PB-5 capillary column (30 m × 0.25 mm; He carrier at 20 psi head pressure, injector 200 °C, detector 280 °C; column 100–125 °C, programmed at 16 °C min^{-1}). Column chromatography was performed on silica gel 70–230 mesh. Melting points are uncorrected.

Compounds **8**,[6] **10**,[7] and **9b**[10] were prepared according to literature procedures. The following compounds have been prepared before by other means: **9a**,[21] **9c**,[22] and **9d**.[22]

Syntheses

3-Carboxy-2-methylthio-4*H*-pyrido[1,2-*a*]pyrimidin-4-one (8).[6] Mp 264–266 °C (lit.[6] 262.5–263.5 °C); ν_{max}(Ar, 14 K)/cm^{-1} 3505 w, 1750 s, 1657 m, 1521 m, 1515 m, 1508 m, 1453 m, 1428 m, 1250 m, 1146 m, 992 m, 850 m; δ_H(500.1 MHz; DMSO-d_6; 60 °C) 2.52 (3H, s, SMe), 7.53 (1H, m, 7-H), 7.76 (1H, m, 9-H), 8.21 (1H, m, 8-H), 9.00 (1H, m, 6-H), 13.50 (1H, br, COOH); δ_C(125.8 MHz; DMSO-d_6; 60 °C) 13.6 (SCH_3), 99.7 (quat., C-3), 117.7 (C-7), 125.0 (C-9), 128.0 (C-6), 141.3 (C-8), 148.2 (quat., C-2), 158.9, 164.8 (quat., C-4 and C-9a), 172.5 (quat., COOH). The assignments were supported by a 2D HSQC ^1H–^{13}C correlation.

2-Methylthio-4*H*-pyrido[1,2-*a*]pyrimidin-4-one (9a). Compound **8** (100 mg, 0.42 mmol) was sublimed at 160–180 °C and subjected to preparative FVT at 850 °C/8 × 10^{-5} mbar in the course of 4 h. The products were collected on a liquid N_2-cooled cold finger. The system was isolated from the pump and brought to atmospheric pressure with N_2. The cold finger was allowed to warm to rt and subsequently rinsed with CH_2Cl_2. Compound **9a** was the only product besides some red–black impurities; δ_H(200.1 MHz; $CDCl_3$) 2.41 (3H, s, SMe), 6.12 (1H, s, 3-H), 6.96 (1H, ddd, *J* 7.0, 6.7, and 1.4, 7-H), 7.37 (1H, ddd, *J* 9.0, 1.4, and 0.8, 9-H), 7.59 (1H, ddd, *J* 9.0, 6.7, and 1.7, 8-H), 8.82 (1H, ddd, *J* 7.0, 1.6, and 0.8, 6-H); δ_C(50.3 MHz, $CDCl_3$) 13.3 (SMe), 97.7 (C-3), 114.5 (C-7), 124.9 (C-9), 127.1 (C-6), 136.7 (C-8), 149.7, 155.7, 169.0 (quat., C-2, C-4 and C-9a).

2-Chloro-4*H*-pyrido[1,2-*a*]pyrimidin-4-one (9b).[10] Mp 160–162 °C (lit.[10] 159 °C); ν_{max}(Ar, 14 K)/cm^{-1} 1726, 1709, 1639, 1569, 1524, 1521, 1480, 1475, 1462, 1440, 1416, 1339, 1134, 1106, 935, 844, 824, 773; δ_H(200.1 MHz; $CDCl_3$) 6.45 (1H, s, 3-H), 7.22 (1H, ddd, *J* 6.9, 6.9, and 1.4, 7-H), 7.64 (1H, ddd, *J* 8.9, 1.4 and 0.8, 9-H), 7.84 (1H, ddd, *J* 8.9, 6.7, and 1.6, 8-H), 9.03 (1H, ddd, *J* 6.9, 1.6 and 0.8, 6-H); δ_C(125.8 MHz, $CDCl_3$) 102.4 (C-3), 116.3 (C-7), 125.7 (C-9), 127.6 (C-6), 138.1 (C-8), 150.3, 156.9, 158.4 (quat., C-2, C-4 and C-9a). The assignments were supported by a 2D HSQC ^1H–^{13}C correlation.

2-(Dimethylamino)-4*H*-pyrido[1,2-*a*]pyrimidin-4-one (9c). Chloropyridopyrimidinone **9b** (97 mg, 0.54 mmol) was dissolved in 6 ml CH_2Cl_2. A solution of $HNMe_2$ in Et_2O was added in large excess (15 mmol) and the mixture was stirred for 16 h at rt. The solvent was evaporated and the residue subjected to column chromatography to separate **9c** (yield: 98 mg, 0.52 mmol, 96%) from some yellow impurities and dimethylammonium chloride; mp 137–138 °C (lit.[22] mp 137–138 °C); ν_{max}(Ar, 14 K)/cm^{-1} 1711, 1680, 1624, 1593, 1575, 1551, 1454, 1424, 1349, 1170, 1007, 769; δ_H(200.1 MHz; $CDCl_3$) 3.09 (6H, s, NMe_2), 5.49 (1H, s, 3-H), 6.78 (1H, ddd, *J* 7.0, 6.6 and 1.4, 7-H), 7.23 (1H, ddd, *J* 9.0, 1.4 and 0.9, 9-H), 7.50 (1H, ddd, *J* 9.0, 7.0 and 1.7, 8-H), 8.84 (1H, ddd, 6.6, 1.7 and 0.9, 6-H); δ_C(50.3 MHz, $CDCl_3$) 37.1 (NMe_2), 80.0 (C-3), 111.7 (C-7), 123.8 (C-9), 127.1 (C-6), 135.8 (C-8), 150.0, 157.9, 160.9 (quat., C-2, C-4 and C-9a). The assignments were supported by a 2D HSQC ^1H–^{13}C correlation.

2-(Diethylamino)-4*H*-pyrido[1,2-*a*]pyrimidin-4-one (9d). Chloropyridopyrimidinone **9b** (150 mg, 0.83 mmol) was dissolved in 10 ml $CHCl_3$ and $HNEt_2$ (4 ml) was added. The mixture was refluxed for 24 h, the solvent evaporated and the residue subjected to column chromatography to separate **9d** (yield: 132 mg, 0.61 mmol, 73%) from brown impurities and diethylammonium chloride. Unlike the case of **9c**, it was necessary to reflux the mixture for a prolonged time, which led to the formation of more impurities; mp 136–138 °C (lit.[22] 137–138 °C); δ_H(200.1 MHz; $CDCl_3$) 1.18 (6H, t, *J* 7.1, NEt_2), 3.51 (4H, q, *J* 7.1, NEt_2), 5.50 (1H, s, 3-H), 6.78 (1H, ddd, *J* 7.0, 6.6 and 1.4, 7-H), 7.22 (1H, ddd, *J* 9.0, 1.4 and 0.9, 9-H), 7.49 (1H, ddd, *J* 9.0, 7.0 and 1.7, 8-H), 8.84 (1H, ddd, 6.6, 1.7 and 0.9, 6-H); δ_C(100.6 MHz, $CDCl_3$) 12.9 (NEt_2), 42.4 (NEt_2), 80.1 (C-3), 111.7 (C-7), 124.2 (C-9), 127.3 (C-6), 135.8 (C-8), 150.5, 158.4, 159.8 (quat., C-2, C-4 and C-9a).

2-Methoxy-4*H*-pyrido[1,2-*a*]pyrimidin-4-one (9e). (a) In a slight variation of the method of ref. 11, pyridopyrimidinone **9b** (100 mg, 0.55 mmol) was dissolved in 10 ml MeOH containing 0.55 mmol of sodium methoxide. The mixture was stirred for 16 h at rt, the solvent evaporated and the residue subjected to column chromatography to separate **9e** (yield: 90 mg, 0.51 mmol, 93%) from yellow impurities and sodium chloride

(b) Compound **10** (1.62 g, 10.0 mmol) was added to a solution of an equimolar amount of sodium methoxide in MeOH (100 ml) and stirred at rt until a clear solution was formed. Subsequently, dimethyl sulfate (0.95 ml) was added and the mixture was allowed to stand at rt for 3 h. After evaporation of the solvent the residue was taken up in water (20 ml) and extracted with dichloromethane (2 × 20 ml). The combined extracts were dried over $CaCl_2$ and evaporated to dryness. The residue was recrystallized twice from dichloromethane–cyclohexane to yield 0.73 g (4.14 mmol, 41%) of colourless crystals, mp 146–148 °C (lit.[11] mp 146 °C; lit.[8] mp 145–147 °C); δ_H(200.1 MHz; $CDCl_3$) 3.96 (3H, s, OMe), 5.79 (1H, s, 3-H), 7.08 (1H, ddd, *J* 6.9, 6.9, and 1.4, 7-H), 7.50 (1H, ddd, *J* 8.9, 1.4, and 0.9, 9-H), 7.73 (1H, ddd, *J* 8.9, 6.7, and 1.7, 8-H), 9.03 (1H, ddd, *J* 6.9, 1.7, and 0.9, 6-H); δ_C(125.8 MHz, $CDCl_3$) 54.2 (OMe), 84.8 (C-3), 114.5 (C-7), 124.9 (C-9), 127.9 (C-6), 137.2 (C-8), 150.7, 159.3, 168.8 (quat., C-2, C-4 and C-9a). The assignments were supported by a 2D HSQC ^1H–^{13}C correlation.

4*H*-Pyrido[1,2-*a*]pyrimidin-4-one (31). This compound was formed in all FVT reactions where **9c**,**d** were used as starting materials and was isolated in 5–10% yield in admixture with unreacted **9c**,**d** after column chromatography. (Ratio **31/9c** *ca.* 1 : 10 to 1 : 5 by ^1H NMR integration; larger amounts of **31** were formed from **9d**.) GCMS: *m*/*z* 146; δ_H(400.1 MHz; $CDCl_3$) 6.46 (1H, d, *J* 6.4, 3-H), 7.17 (1H, ddd, *J* 7.0, 7.0, and 1.5, 7-H), 7.68 (1H, ddd, *J* 9.0, 1.4, and 0.9, 9-H), 7.76 (1H, ddd, *J* 9.0, 6.6, and 1.6, 8-H), 8.30 (1H, d, *J* 6.4, 2-H), 9.09 (1H, ddd, *J* 7.2, 1.6, and 0.9, 6-H); δ_C(50.3 MHz, $CDCl_3$) 104.7 (C-3), 115.6 (C-7), 126.4 (C-9), 127.3 (C-6), 136.1 (C-8), 151.7, (quat., C-4 or C-9a), 154.7 (C-2), 157.7 (quat., C-4 or C-9a).

3-(Dimethylamino)-3-(2-pyridylimino)-*N*,*N*-dimethylpropanamide (23). 9c (80 mg, 0.42 mmol) was gently sublimed at 50–80 °C and subjected to preparative FVT at 850 °C/8 × 10^{-5} mbar in the course of 4 h. The products were collected on a liq. N_2-cooled cold finger. Upon completion of the thermolysis, the system was isolated from the pump and brought to atmospheric pressure with N_2. The liquid N_2 was removed from the cold finger, which was then rinsed with a solution of 10 mmol $HNMe_2$ in Et_2O–CH_2Cl_2 (5 ml). After warmup to room temperature, the solvent was evaporated and the oily residue subjected to column chromatography. Elution with $CHCl_3$ afforded a mixture of unreacted **9c** (33 mg, 0.174 mmol, 41%) and **31** (4 mg, 0.027 mmol, 6%; identified by NMR and GCMS as described above). Elution with $CHCl_3$–MeOH (10 : 1) gave **23**

(39 mg, 0.166 mmol, 39%) as a yellow–orange oil. (Found: M^+ 234.1477. $C_{12}H_{18}N_4O$ requires M^+ 234.14751); *m/z* (EI) 234 (15%), 162 (30), 148 (18), 145 (25), 93 (30), 78 (83), 72 (100); ν_{max}(neat film)/cm^{-1} 2934, 1636, 1610, 1584, 1553, 1461, 1426, 1398, 1313, 1292, 1236, 1147, 1062, 986, 854, 809, 769, 746; δ_H(200.1 MHz; $CDCl_3$) 2.72 (3H, s, $OCNMe_2$), 2.85 (3H, s, $OCNMe_2$), 3.03 (6H, s, $NCNMe_2$), 3.50 (2H, s, CH_2), 6.76 (2H, m, ar. H-3 and H-5), 7.45 (1H, m, ar. 4-H), 8.22 (1H, m, ar. 6-H); δ_C(50.3 MHz, $CDCl_3$) 33.5 (CH_2), 35.5 ($OCNMe_2$), 37.2 ($OCNMe_2$), 38.2 ($NCNMe_2$), 116.8, 118.0, 137.3, 148.2, 156.0, 163.0, 167.4. The assignment was supported by a ^{13}C DEPT spectrum.

3-(Diethylamino)-3-(2-pyridylimino)-*N*,*N*-diethylpropanamide (27). FVT of **9d** (100 mg, 0.46 mmol) and workup of the products was performed as described above for **23**. The cold finger was rinsed with a solution of 1 ml $HNEt_2$ in 5 ml CH_2Cl_2. Column chromatography afforded unreacted **9d** and **31** in the $CHCl_3$ fraction and **27** (crude yield *ca.* 40 mg) plus **31** in the $CHCl_3$–MeOH fraction. Rechromatography provided a small amount of **27** (5 mg, orange–yellow oil) for NMR spectroscopy. δ_H(200.1 MHz; $CDCl_3$) 0.87 (3H, t, *J* 7.1, $OCNEt_2$), 1.03 (3H, t, *J* 7.1, $OCNEt_2$), 1.20 (6H, t, *J* 7.1, $NCNEt_2$), 2.99 (2H, q, *J* 7.1, $OCNEt_2$), 3.28 (2H, q, *J* 7.1, $OCNEt_2$), 3.43 (4H, br q, $NCNEt_2$), 3.47 (2H, s, CH_2), 6.77 (2H, m, ar. 3-H and 5-H), 7.46 (1H, m, ar. 4-H), 8.26 (1H, m, ar. 6-H); δ_C(125.8 MHz, $CDCl_3$) 12.9 ($OCNEt_2$), 13.7 (br, $NCNEt_2$), 13.9 ($OCNEt_2$), 33.4 (CH_2), 40.5 ($OCNEt_2$), 42.2 ($OCNEt_2$), 42.3 (br, $NCNEt_2$), 116.6, 118.3, 137.4, 148.2, 154.5, 163.3, 166.6.

3-(Diethylamino)-3-(2-pyridylimino)-*N*,*N*-dimethylpropanamide (24). FVT of **9c** (83 mg, 0.44 mmol) and workup of the products was performed as described above for the preparation of **23**. The cold finger was rinsed with a solution of 1 ml $HNEt_2$ in 5 ml CH_2Cl_2. Column chromatography afforded unreacted **9c** and **31** in the $CHCl_3$ fraction, and a mixture of **24**, **23** and **27** (31 mg, 28:2:1) in the $CHCl_3$–MeOH fraction (all compounds identified by ^{1}H NMR spectroscopy). (Found: M^+ 262.1793. $C_{14}H_{22}N_4O$ requires M^+ 262.17881); *m/z* (EI) 262 (22%), 233 (25), 190 (43), 188 (21), 176 (22), 149 (23), 145 (26), 119 (23), 78 (57), 72 (100); ν_{max}(neat film)/cm^{-1} 2974, 2932, 1645, 1607, 1583, 1551, 1457, 1418, 1360, 1262, 1144, 1027, 803, 786, 752; δ_H(200.1 MHz; $CDCl_3$) 1.19 (6H, t, *J* 7.1 $NCNEt_2$), 2.72 (3H, s, $OCNMe_2$), 2.85 (3H, s, $OCNMe_2$), 3.43 (4H, br q, $NCNEt_2$), 3.49 (2H, s, CH_2), 6.76 (2H, m, ar. 3-H and 5-H), 7.46 (1H, m, ar. H-4), 8.24 (1H, m, ar. 6-H); δ_C(50.3 MHz, $CDCl_3$) 13.3 (br, $NCNEt_2$), 33.1 (CH_2), 35.5 ($OCNMe_2$), 37.2 ($OCNMe_2$), 42.2 ($NCNEt_2$), 116.5, 118.1, 137.2, 148.2, 154.3, 163.3, 167.7.

Mixture of malonic imides 23, 24, 26, and 27. Compound **9c** (60 mg, 0.32 mmol) was gently sublimed at 50–80 °C and subjected to preparative FVT at 850 °C/8 × 10^{-5} mbar in the course of 4 h. During this time, $HNEt_2$ (4 ml) was co-condensed with **13** on the cold finger. For this purpose, a flask containing the amine was connected to the cold finger shroud *via* a needle valve. Upon completion of the thermolysis, the system was isolated from the pump and brought to atmospheric pressure with N_2. The liquid N_2 was removed and the cold finger was allowed to warm to room temperature. After thawing, the excess amine was evaporated and the crude oily residue investigated by ^{1}H NMR spectroscopy. The four possible malonic acid derivatives **23**, **24**, **26**, and **27** were formed in ratios of approximately 1:10:2:6. Compounds **23**, **24,** and **27** were identified by comparison with the NMR data reported above; the remaining signals were assigned to **26**: δ_H(400.1 MHz; $CDCl_3$) 0.89 (3H, t, *J* 7.1, $OCNEt_2$), 1.04 (3H, t, *J* 7.1, $OCNEt_2$), 3.01 (2H, q, *J* 7.1, $OCNEt_2$), 3.06 (6H, s, $NCNMe_2$), 3.29 (2H, q, *J* 7.1, $OCNEt_2$), 3.51 (2H, s, CH_2), 6.78 (2H, m, ar. 3-H and 5-H), 7.46 (1H, m, ar. 4-H), 8.23 (1H, m, ar. 6-H).

3-Methoxy-3-(2-pyridylimino)-*N*,*N*-dimethylpropanamide (28). FVT of **9c** (87 mg, 0.46 mmol) and workup of the products was performed as described above for **23**. The cold finger was rinsed with 10 ml MeOH. Column chromatography afforded unreacted **9c** and **31** in the $CHCl_3$ fraction, and **28** (28 mg, 0.13 mmol, 28%) in the $CHCl_3$–MeOH fraction. (Found: M^+ 221.1163. $C_{11}H_{15}N_3O_2$ requires M^+ 221.11588); *m/z* (EI) 221 (3%), 189 (6), 177 (100), 149 (18), 145 (65), 135 (20), 78 (55), 72 (48); ν_{max}(neat film)/cm^{-1} 2927, 1654, 1647, 1589, 1561, 1466, 1427, 1253, 1188, 1145, 1029, 777; δ_H(200.1 MHz; $CDCl_3$) 2.85 (3H, s, NMe_2), 2.87 (3H, s, NMe_2), 3.38 (2H, s, CH_2), 3.85 (3H, s, OMe), 6.92 (2H, m, ar. H-3 and H-5), 7.58 (1H, m, ar. 4-H), 8.32 (1H, m, ar. 6-H); δ_C(50.3 MHz, $CDCl_3$) 35.5 (NMe_2), 36.2 (NMe_2), 37.6 (CH_2), 54.1 (OMe), 117.1, 118.9, 137.9, 148.5, 160.2, 160.3, 166.8.

Preparative FVT of 9e. Preparative FVT of **9e** (50 mg, 0.28 mmol) was performed as described above for **9c**. The cold finger was rinsed with $HNMe_2$ solution. Column chromatography ($CHCl_3$) afforded unreacted **9e** and 2-(methylamino)pyridine (**18**) in the first fraction and malonic acid bis(dimethylamide) plus a small amount of **23** in the second fraction. All compounds were identified by comparison of ^{1}H and ^{13}C NMR spectra with those of authentic materials.

FVT/matrix isolation

The pyridopyrimidinones **8** and **9** (*ca.* 10 mg portions) were placed in the quartz thermolysis tube in an oven directly attached to the vacuum system. After evacuating the oven, the cryostat was turned on and the pressure brought to 2 × 10^{-5} mbar while the BaF_2 disk reached a temperature of 12 K. Argon was passed over the sample while it was sublimed through the FVT tube maintained at different temperatures, and the products were co-deposited on the disk at 12 K for FTIR spectroscopy.

FVT of chloro derivative 9b. This compound was subjected to FVT over the temperature range 600–850 °C (sublimation temperature 50–60 °C). At 600 °C, a small amount of (2-pyridyl)iminopropadienone (**13**) was observed (2249 cm^{-1}) and mainly starting material **7c**. In the range of 650–800 °C, a mixture of **9b** and **13** was obtained. At 850 °C, the formation of **13** (2249, 2247, 2245, 2128, 1611, 1586, 1458, 1433, 1293, 1261, 1219, 776 cm^{-1}) was essentially complete, a small amount of **9b** still being visible.

FVT of dimethylamino derivative 9c. This compound was subjected to FVT at 400 and 850 °C (sublimation temperature 50–60 °C). At 400 °C, only starting material **9c** was visible. At 850 °C, the signals of **13** could be observed but there was still a significant amount of **9c** visible.

FVT of methoxy derivative 9e. This compound was subjected to FVT at 600, 800, and 930 °C (sublimation temperature 50–60 °C). At 600 °C, mainly starting material **9e** was visible (1724, 1722, 1709, 1263, 1261, 1242 cm^{-1}) but also the bands of C_3O_2 (3064, 2379, 2286, 2272 cm^{-1}). At 800 °C, the bands of **9e** were still the most intense signals, but in addition C_3O_2 and **13** could be observed. At 930 °C, the bands of C_3O_2 and **13** dominated the spectrum, a significant amount of **9e** still being visible.

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