# Thermolysis of polyazapentadienes. Part 12.[1] The 1,1-dialkyl- 5-aryl-1,3,5-triazapentadiene problem

**Hamish McNab* and M. Elizabeth-Ann Murray**

*Department of Chemistry, The University of Edinburgh,*
*West Mains Road Edinburgh EH9 3JJ*
*E-mail: H.McNab@ed.ac.uk*

**Dedicated to Douglas Lloyd, chemist, musician, raconteur, on the occasion of his 80th birthday**

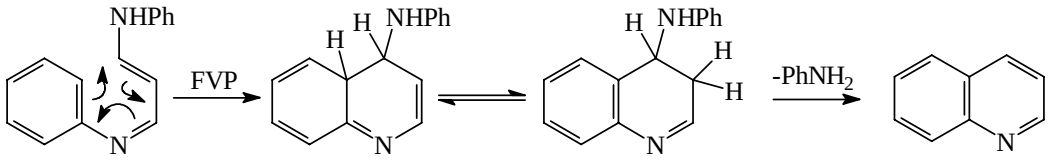
**Abstract**

Flash vacuum pyrolysis (FVP) of the 3-azavinamidine **11** at 850 °C gives 1,4-dimethylimidazole **16** (18%) aniline **18** (*ca*. 24%) and 2-methylquinazoline **17** (7%) as the major products. These results are compared with the thermal behaviour of related vinamidines and 2-azavinamidines.

**Keywords:** Flash vacuum pyrolysis, 3-azavinamidine, 1,4-dimethylimidazole, thermolysis

## Introduction

Under flash vacuum pyrolysis (FVP) conditions a number of competitive routes are available for the thermal cleavage of 1,5-diazapentadienes (vinamidines[2]) and their aza-analogues. First, the 6π 'electrocyclisation with elimination' route to quinolines **2** and related compounds (Scheme 1), pioneered by Jutz and co-workers in condensed-phase,[3] is observed exclusively in the gas-phase only for 1,5-diarylvinamidines **1**.[4]



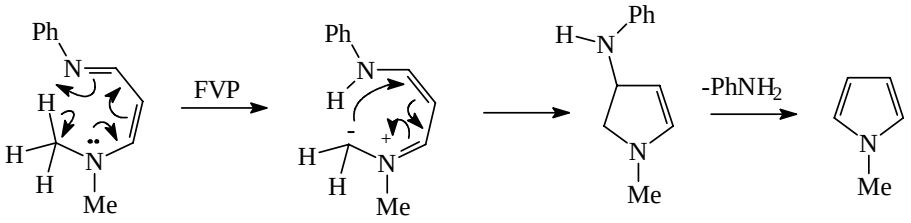

**1** **2**

**Scheme 1**

Unexpectedly, such quinoline formation is usually only a minor pathway for the 1,1-dialkyl-5-phenyl vinamidines **3** which instead undergo elimination of aniline (initiated by hydrogen transfer from the *N*-alkyl group) with concomitant cyclisation to give pyrroles **4**.[5] The relative

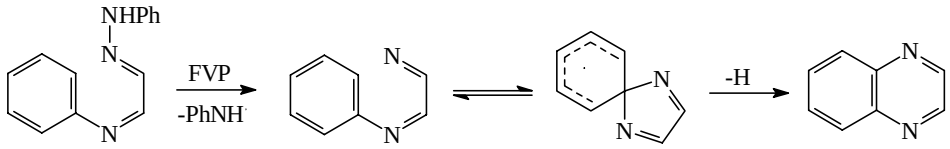
amount of the pyrrole is reduced relative to the quinoline when an alkyl group is present as a *C*-substituent in the vinamidine chain, and this has been interpreted as circumstantial evidence for a dipolar rather than a radical mechanism for the hydrogen transfer as shown in Scheme 2.[5]




**3** **4**

**Scheme 2**

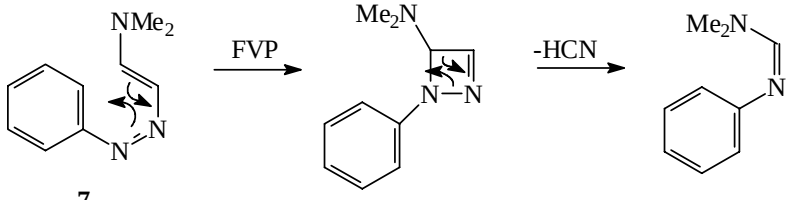
Further complications are possible with 2-azavinamidines. The pyrolysis chemistry of 5-aryl-1*H*-1,2,5-triazapentadienes **5** is dominated by free radical cleavage of the N-N bond to give conjugated iminyl radicals which cyclise to quinoxalines **6** *via* a spirodienyl mechanism (Scheme 3).[6]




**5** **6**

**Scheme 3**

However, 1-aryl-5*H*-1,2,5-triazapentadienes **7** undergo clean loss of HCN under FVP conditions to give the amidine **8**;[7] in this case a 4π electrocyclisation is followed by the elimination step (Scheme 4); similar behaviour is followed by other 2-azadienes.[1,7]

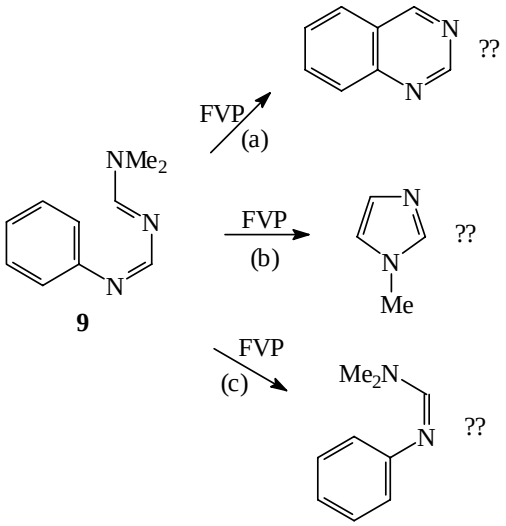



**7** **8**

**Scheme 4**

In view of the diversity of this chemistry, we were intrigued to discover the thermal properties of the 1,3,5-triazapentadiene system **9** (Scheme 5) which has the necessary structural features for (a) 6π electrocyclisation with elimination to give a quinazoline (*c.f.* Scheme 1) (b)

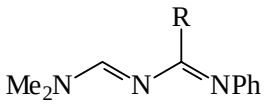
elimination of aniline and cyclisation to give an imidazole (*c.f.* Scheme 2) and (c) 4π electrocyclisation with elimination of HCN to give an amidine (*c.f.* Scheme 4). Here we describe the results of the pyrolysis of such a precursor.



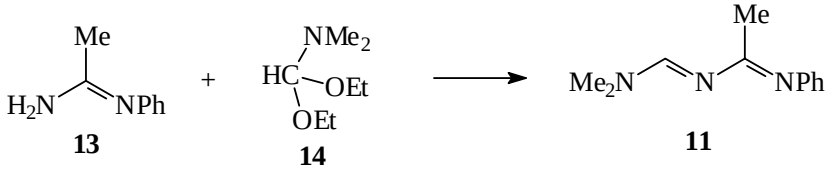

**Scheme 5**

## Results and Discussion

To allow direct comparison with our earlier work,[5] we required a 1,3,5-triazapentadiene system without *C*-substitution or with only *C*-alkyl substitution. Although compounds of these types are not reported in the literature, we were able to adapt the route to well-known 4-aryl compounds **10**[8] to give the 4-methyl derivative **11** (Scheme 6). Thus treatment of *N*-phenylacetamidine **13** with *N,N*-dimethylformamide diethyl acetal **14** provided the pentadiene **11** as a yellow oil in 42% yield. Our attempts to prepare the parent compound **12** by a similar route were not successful (see Experimental section).

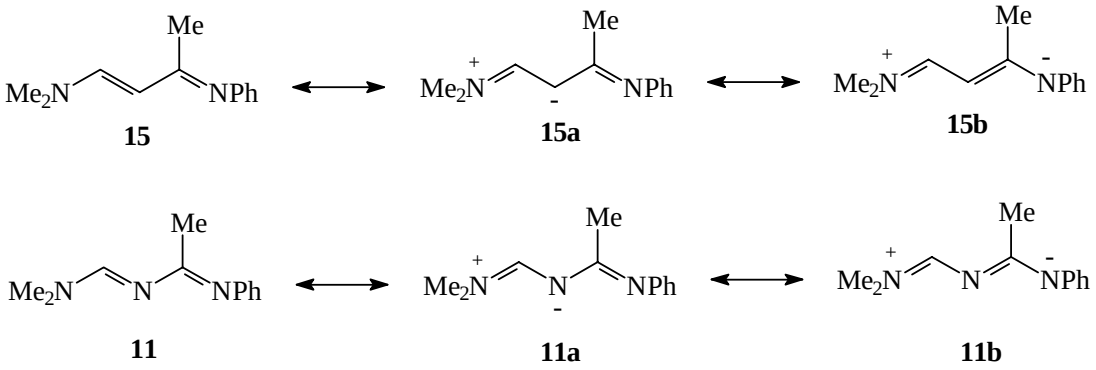



**10** R = Ph
**11** R = Me
**12** R = H

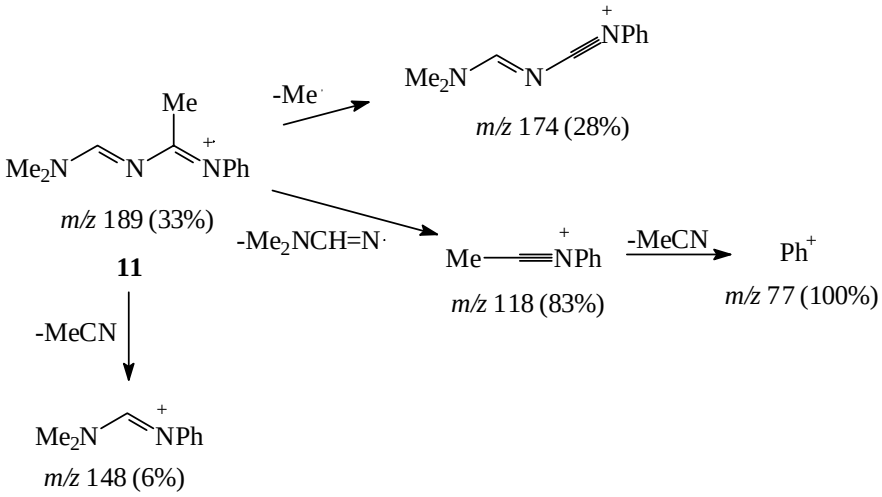



**Scheme 6**

The triazapentadiene **11** was characterised by its spectra and in particular by comparison of its NMR spectra with those of the corresponding 1,5-diazapentadiene **15**.[5] Although these spectra show close similarities, the diazapentadiene **15** is present in solution as two isomers (*E* and *Z* about the C=N unit) whereas the triazapentadiene **11** adopts just one configuration. On the other hand, the *N*-methyl groups of the two isomers of **15** appear as six-proton singlets at room temperature whereas those of **11** are separated into two three-proton singlets due to restricted rotation about the C-N unit. Variable temperature NMR studies of the two isomers of **15** at 200 MHz showed coalescence temperatures of 221 K and 244 ([$^2H_6$]acetone) corresponding to free energies of activation of 44.5 and 48.1 kJ mol$^{-1}$ respectively, whereas the coalescence temperature of **11** was 346 K in [$^2H_6$]DMSO solution ($E_a$ 73.5 kJ mol$^{-1}$). Electron donation from the dimethylamino group is therefore promoted by the presence of the central nitrogen atom in **11** in accord with the relative stability of the resonance structure **11a** compared with that of **15a**.

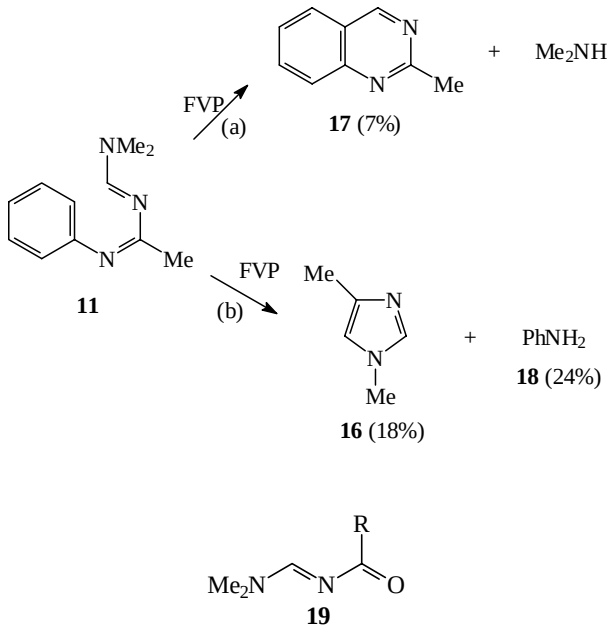



The electron impact mass spectrum of **11** shows a molecular ion of moderate intensity; major breakdown peaks are derived from α-cleavage following ionisation at the imino-nitrogen atom (Scheme 7). In addition a small peak is observed at *m/z* 148 (6%) due to loss of MeCN from the molecular ion. This electron impact induced behaviour is reminiscent of the thermal loss of HCN in 1,2,5-triazapentadiene chemistry (Scheme 4).




**Scheme 7**

Under our standard FVP conditions, a furnace temperature of 800 °C was required for complete transformation of **11** to products. These conditions are comparable to those required for quinoline formation or pyrrole formation from vinamidines (Schemes 1 and 2), [though only 650 °C is required for HCN elimination from 1,2,5-triazapentadienes (Scheme 4)]. Four products were identified in the complex low-yielding pyrolysate (Scheme 8) *viz*. 1,4-dimethylimidazole **16** (18%) (identical with an authentic sample), 2-methylquinazoline **17** (7%) (spectra compatible with those in the literature – see Experimental section), aniline **18** (24%) and a trace of *N*-methylaniline (4%). None of the amidine **8** could be detected by G.C. comparison with an authentic sample,[9] and so the imine **11** does not decompose by a route analogous to Scheme 4. This latter result is also surprising because the analogous azaenaminone **19** (R = Me) cleaves by loss of MeCN in just this way, though at a higher temperature than required for the azoalkenes.[1] Instead, the 1,3,5-triazapentadiene system undergoes pyrolysis preferentially by the hydrogen transfer-cyclisation-elimination sequence to give the imidazole **16**, together with aniline **18** as the co-product (*c.f.* Scheme 2). Electrocyclisation to the quinazoline **17** (*c.f.* Scheme 1) forms a minor component of the reaction profile. The formation of the small amount of *N*-methylaniline may be due to adventitious coupling of anilino and methyl radicals.

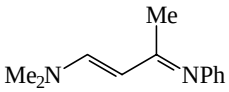
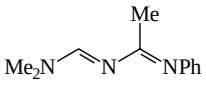
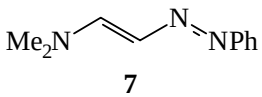



**Scheme 8**

These results are placed in the context of other vinamidine and azavinamidine pyrolyses in Table 1. In these series, the 4π electrocyclisation with elimination route (Scheme 4) is apparently unique to the 2-azavinamidine and other azoalkene units (despite the behaviour of the corresponding azaenaminones.[1]) The 6π electrocyclisation with elimination route (Scheme 1) and azole formation by elimination of aniline (Scheme 2) are in competition in both the vinamidine and 3-azavinamidine series, though the unusual azole formation is either relatively

favoured, or the electrocyclisation is disfavoured, in the 3-azavinamidine case. These results are consistent with the observation that an electron donating 3-methyl substituent causes a relative increase in the electrocyclisation pathway in the vinamidine series.[5] Since an electron withdrawing group at the corresponding position to the additional nitrogen atom apparently causes a small acceleration in hexatriene electrocyclisation processes,[10] we conclude that the additional nitrogen atom in the vinamidine system is able to accelerate the azole formation further, probably by providing additional stability to the dipolar intermediate.

**Table 1.** Ratios of major pyrolysis routes found for the vinamidines and azavinamidines **7**, **11** and **15**

| Precursor | Electrocyclisation route (Scheme 1) | Azole route (Scheme 2) | RCN elimination route (Scheme 4) |
|---|---|---|---|
|  **15** | 69 | 31 | - |
|  **11** | 28 | 72 | 0 |
|  **7** | 0 | 0 | 100 |

## Experimental Section

**General Procedures.** $^{1}$H and $^{13}$C NMR spectra were recorded at 80 (or 200) and 20 MHz respectively for solutions in [$^{2}$H]chloroform. Mass spectra were obtained under electron impact (EI) ionisation conditions.

***N*-Phenylacetamidinium picrate (13).** Following the method of Oxley *et al*,[11] powdered aluminium chloride (13.3 g, 0.1 mol) was added, in small quantities over 45 min, to a mixture of acetonitrile (4.1 g, 0.1 mol) and aniline (9.3 g, 0.1 mol) so that the temperature did not rise above 90-100 °C. After the addition was complete, the semi-solid mixture was kept at 100 °C for 1 h. The reaction product, which consisted of a complex of the amidine with the catalyst, was carefully decomposed by the dropwise addition of water until the vigorous reaction ceased. The amidine base was liberated by the addition of a solution of sodium hydroxide (15 g, 0.38 mol) in water (100 ml) and the mixture was extracted three times with chloroform. The organic extracts were dried ($Na_2SO_4$) and the solvent was removed to give a dark brown liquid (8.84 g) which

was immediately converted into the picrate by the addition of an excess of picric acid in ethanol. A clean yellow solid was obtained (5.50g, 15%).

**5-Phenyl-1,1,4-trimethyl-1,3,5-triazapentadiene (11).** *N*-Phenylacetamidinium picrate (1.81 g, 5 mmol) was suspended in dichloromethane (20 ml) and a solution of sodium hydroxide (1.0 g, 25 mmol) in water (30 ml) was added. The mixture was shaken vigorously and the organic layer was separated off. The aqueous layer was extracted twice more with dichloromethane, the organic extracts were dried ($Na_2SO_4$) and the solvent was removed *in vacuo* (with a cold water-bath). The yellow-brown amidine **13** (0.33 g, 49% recovery) was then used immediately. A solution of *N,N*-dimethylformamide diethylacetal **14** (0.44 g, 3 mmol) in dioxan (1 ml) was added to the amidine **13** (0.33 g, 2.5 mmol) and the mixture was heated at 80 °C for 2 h. The dioxan and the excess of acetal were removed by distillation before the product was purified by bulb to bulb distillation to give the pentadiene **11** as a yellow oil (0.40 g, 42%), bp 106-108 °C (0.2 Torr) (Found: C, 69.8; H, 8.0; N, 22.4. $C_{11}H_{15}N_3$ requires C, 69.85; H, 7.95; N, 22.2%); $\delta_H$ 8.20 (1H, s), 7.3-6.7 (5H, m), 3.02 (6H, s) (*N*-Me signals apparently accidentally equivalent in this solvent) and 1.91 (3H, s); *m/z* 189 ($M^+$, 33%), 174 (28), 148 (6), 134 (24), 119 (50), 118 (83), 93 (29) and 77 (100); $\delta_C$ 165.98 (quat), 154.68, 151.51 (quat), 128.61, 122.21, 121.06, 40.53, 34.57 and 19.77.

**Pyrolysis of 5-phenyl-1,1,4-trimethyl-1,3,5-triazapentadiene (11).** The azavinamidine precursor **11** (0.043 g, 0.23 mmol) was distilled at 110-120 °C and 0.005 Torr over a period of 30 min through an empty silica furnace tube which was maintained at 800 °C. After the pyrolysis, the products were removed from the trap and were identified by g.c., g.c.-m.s. and NMR comparison with authentic samples or with literature data. Yields were estimated by addition of a known amount (5 l) of cyclohexane to provide calibration of the NMR integral values. The following products were obtained: 1,4-dimethylimidazole **16** (18%) *m/z* 96 ($M^+$, 100%), 95 (72) and 68 (43) (identical with an authentic sample – see below): aniline **18** (*ca*.24%) *m/z* 93 ($M^+$, 100%), 66 (36) and 64 (4) (identical with an authentic sample): *N*-methylaniline (4%) (tentatively identified by a peak at $\delta_H$ 2.79 in the $^1H$ NMR spectrum): 2-methylquinazoline **17** (7%) *m/z* 144 ($M^+$, 100%), 117 (69) and 77 (36); although no authentic sample was available this compound showed the correct molecular ion and similar EI fragmentation to that reported.[12] In addition the literature value[13] for the methyl peak in the $^1H$ NMR spectrum is $\delta_H$ 3.02 compared with that at $\delta_H$ 2.97 in the corresponding spectrum of the pyrolysate. No 3,3-dimethyl-1-phenyl-1,3-diazapropene **8** could be detected, by $^1H$ NMR and g.c. comparison with an authentic sample.

**1,4-Dimethylimidazole (16).** Using the method of McLean and Muir,[14] copper(II) acetate (30 g, 0.15 mol) was dissolved in a stirred solution of 20% aqueous ammonia (100 ml) and formaldehyde (12.5 ml, 0.16 mol) was added. Methylamine hydrochloride (20 g, 0.30 mol) and then acetol (10 g, 0.14 mol) were than added to the mixture, which was heated at 100 °C for 15 min, cooled and extracted with chloroform (2×100 ml). The combined organic extracts were dried ($Na_2SO_4$) and the chloroform was removed *in vacuo*. The dark coloured liquid which remained was purified by bulb to bulb distillation to give the imidazole as a colourless liquid

(1.65 g, 11%) bp 193-196 °C (lit.,[14] 195-197 °C) $\delta_H$ 7.06 (1H, s), 6.35 (1H, s), 3.35 (3H, s) and 1.94 (3H, s).

**Attempted preparation of 5-phenyl-1,1-dimethyl-1,3,5-triazapentadiene (12).** Ethyl isoformanilide (4.47 g, 0.03 mol) was added to an equimolar solution of ammonia in ethanol (3 M, 10 ml). The reaction was monitored by $^1$H NMR spectroscopy over a period of 4 days until the isoformanilide peak at $\delta_H$ 7.70 had been replaced by a singlet at 7.65 due to *N*-phenylformamidine (lit.,[15] 7.63). Removal of the solvent gave *N*-phenylformamidine (2.81 g, 79%), $\delta_H$ 7.65 (1H, s), 7.4 – 6.6 (5H, m) and 5.0 (2H, br. s) mp 117-119 °C (lit.,[16] 143 °C). The low melting point suggests that the amidine may have been isolated in impure form.

Unfortunately, **12** could not be obtained by reaction of crude *N*-phenylformamidine (0.36 g, 3 mmol) with *t*-butoxybis-(dimethylamino)methane (Bredereck's reagent) (1.0 g, 6mmol) over a period of 2 h at room temperature followed by Kugelrohr distillation [oven temperature increased to 145-150 °C (0.2 Torr)]. No clearly defined products were isolated.

## Acknowledgements

We are grateful to the SERC (now EPSRC) for a studentship (to M.E-A.M).

## References

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