On 1-(3,5-Dimethylpyrazolyl)phenazinyl-2-nitrene

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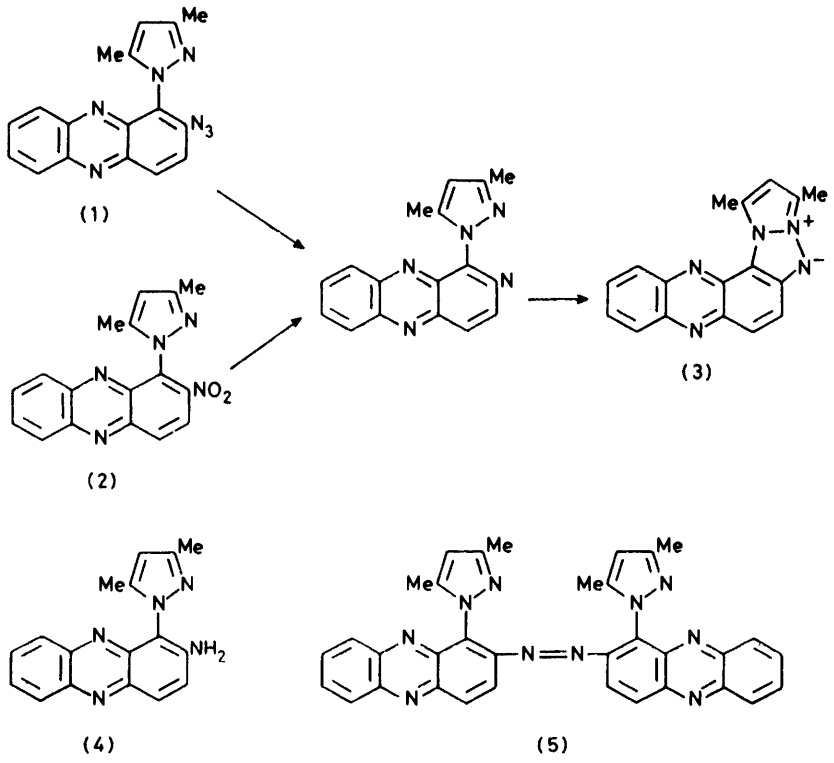
Nucleophilic intramolecular attack leading to 1,3-dimethyl-5*H*-pyrazolo[1',2':1,2][1,2,3]triazolo[3,2-*a*]-phenazin-4-ium inner salt (3) is the fate of the title nitrene with little intermolecular hydrogen abstraction from the solvent and no intramolecular radical attack. The same behaviour is observed from both the singlet and triplet states of this nitrene.

In the framework of our researches on phenazinylnitrenes,[1] we have explored the reactivity of the phenazinyl-2-nitrene bearing in position 1 a dimethylpyrazole ring. This system was thought to offer the chance of distinguishing, *via* intramolecular reactions, the reactivity of the singlet and the triplet states of the nitrene, as the former would react with the lone pair of the pyrazole nitrogen atom,[2] while the latter would react with the activated pyrazole methyl group as a consequence of the well known electrophilic nature of singlet nitrenes, and the radical character of triplet nitrenes.[3] The validity of this model has recently been proved by Suschitzky *et al.*[4] on a series of *o*-nitrenophenyl-pyrazoles.

RESULTS AND DISCUSSION

The title nitrene was generated by the classical procedures of thermal and photochemical decomposition of 2-azido-1-(3,5-dimethylpyrazolyl)phenazine (1) in several hydrocarbon solvents and by the deoxygenation of the corresponding 2-nitro-derivative (2) with triethyl phosphite. In every case 1,3-dimethyl-5*H*-pyrazolo[1',2':1,2][1,2,3]triazolo[3,2-*a*]phenazin-4-ium inner salt (3) was isolated from these reactions as the main product, besides minor amounts of 2-amino-1-(3,5-dimethylpyrazolyl)phenazine (4) and 1,1'-bis-(3,5-dimethylpyrazolyl)-2,2'-azophenazine (5).

Compound (4) was identified by comparison with an authentic sample obtained by catalytic reduction of (2) and the structures of compounds (3) and (5) were established on the basis of elemental and spectroscopic analysis. Compound (3) is a crystalline high-melting solid, with a deep blue colour. In the mass spectrum the base peak is due to the molecular ion (*m/e* 287; $C_{17}H_{13}N_5$); an abundant $M^+ - 1$ ion and the fragment ions at *m/e* 246 ($M - C_2H_3N$) and 245 ($M - C_2H_4N$) are anticipated features due to the presence of the dimethylpyrazole ring, while the loss of 28 (N_2) and 29 m.u. (N_2H) from the molecular ion agree with the proposed structure. In the ^1H n.m.r. spectrum (Table 1) the most characteristic feature is the deshielding of the methyl groups and of the hydrogen atom of the dimethylpyrazole ring in comparison with other derivatives of



1-(3,5-dimethylpyrazolyl)phenazine differently substituted in position 2. This shift is due to the positive charge delocalized on the pyrazole ring in compound (3),

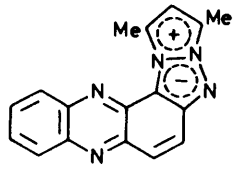
TABLE 1

^{1}H N.m.r. data [a] of compounds (1)—(5)

Compound	4-H	3-Me [b]	5-Me [b]	Aromatics
(3)	6.35	2.6	3.4	7.4—8.4 m
(1)	6.20	2.35	2.05	7.55—8.5
(2)	6.22	2.35	2.2	7.85—8.7
(4)	6.15	2.35	2.05	7.3—8.3
(5)	6.30	2.45	2.15	7.3—8.5

[a] In $CDCl_3$; Internal standard $SiMe_4$. [b] The assignment of the methyl signals were made according to J. Elguero, R. Jacquier, and S. Mondon, *Bull. Soc. chim. France*, 1970, 1346.

which is a mesomeric betaine. The u.v.–visible spectrum of (3) is completely different from that of phenazine, indicating the presence of a new aromatic structure. The first absorption band appears at long wavelength and is characterized by a strong molar



extinction coefficient. A strong shift to the red and a dramatic increase in the intensity of the bands in comparison with the corresponding hydrocarbons has been already reported for other condensed azapentalenes.[5] For compound (5) the most relevant datum is the presence in the mass spectrum of the molecular ion at *m/e* 574 (base peak at *m/e* 286). U.v.–visible, i.r., and ^{1}H n.m.r. spectra are in accordance with the structure shown.

TABLE 2

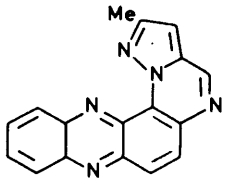
Yields from 1-(3,5-dimethylpyrazolyl)phenazinyl-2-nitrene

Solvent	Time/min	% Yield (3)	(4)	(5)
Thermal decomposition of azide (1) (10^{-1}M) at 150° C				
Cumene	30	92	7	≤1
Acetophenone	51	92	6	≤1
Bromobenzene	40	84	11	≤1
Tetralin	26	69	22	≤1
Acetonitrile	30	50	15	5
Cyclohexane	30	50	25	≤1
Photochemical decomposition of azide (1) (2×10^{-3}M) at 20 °C				
Cyclohexane	2	73	5	≤1
Tetralin	3	71	18	≤1
Acetonitrile	4	41	11	≤1
Deoxygenation with triethyl phosphite of the nitro-compound (2) at 150 °C				
Cumene	840	48	15	*a*

[a] Not determined.

Table 2 shows the yields of compounds (3)—(5) obtained in a set of typical runs. From these data it is seen that the intermolecular reaction, which leads to the amine (4) and to the azo-compound (5), occurs in low yields.*

Of the possible intramolecular reactions, only the formation of the triazapentalene (3), which occurs, according to the literature,[3,4] *via* singlet nitrene, is observed. Compounds such as (6) and (7) which could



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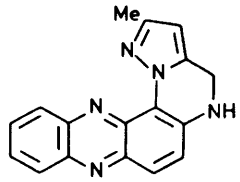


(7)

be formed by intramolecular radical attack of the triplet nitrene on the pyrazole methyl group, have not been isolated, even in those conditions which usually favour intersystem crossing to triplet nitrenes, such as the thermal decomposition of azide (1) in bromobenzene (Table 2), or photochemical decomposition in the presence of methyl iodide (Table 3). Even if the singlet nitrene is bypassed, *i.e.* if the photochemical decomposition of the azide (1) is sensitized in the presence of Michler's ketone, in conditions in which >97% of the light is absorbed by the sensitizer, the prevalent formation of (3) is again observed. Table 3 reports the quantum yields of formation of compounds (3) and (4) in the presence and in the absence of the sensitizer.

TABLE 3

Photochemical decomposition of azide (1) (10^{-4}M) in cyclohexane

Additive	Φ_3	Φ_4
None	0.62	0.018
Michler's ketone (10^{-3}M)	0.47	0.012
MeI (5%)	0.57	0.013

Furthermore, as it may be gathered from the data reported in Table 3, neither sensitization nor the external heavy-atom effect favour the intermolecular hydrogen atom abstraction process [which leads to the amine (4)] over nucleophilic attack.

All the data previously reported thus lead to the conclusion that the triplet nitrene reacts with the lone pair of the pyrazole nitrogen atom.† The radical reactivity of the triplet nitrene is, however, evidenced by its reduction to the amine (4) in the presence of a good hydrogen donor: in fact, at room temperature 18% amine is obtained in tetralin, while only 5% amine is obtained in the less active cyclohexane. Characteristically, thermal activation makes the triplet nitrene a better hydrogen abstractor: at 150 °C the yields of amine are

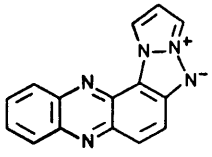
* Control reactions excluded the possibility that products (4) and (5) were formed by thermal decomposition of (3). In any case (3) is stable on irradiation under the experimental conditions (degassed solutions).

† Attack of triplet nitrene on a nitrogen lone pair had been invoked previously (A. Reiser and L. J. Leyshon, *J. Amer. Chem. Soc.*, 1971, **93**, 4051).

22% in tetralin and 25% in cyclohexane. These values are low compared to the 84% amine obtained from the triplet phenazinyl-2-nitrene [1] at room temperature, making it apparent that the formation of compound (3) competes successfully with the intermolecular radical reaction.

To summarize, 1-(3,5-dimethylpyrazolyl)phenazinyl-2-nitrene in its triplet state has little propensity to radical attack. In fact, the major reaction is at the lone pair of the pyrazole nitrogen atom, while it does not react with the pyrazole methyl group, and undergoes significant intermolecular reactions only with very reactive solvents. This may be attributed to the effect of the phenazine ring, which apparently limits the radical reactivity of the triplet nitrene, so that if a site apt to electrophilic attack is at hand, as is the case here, the reactivity of the triplet becomes almost indistinguishable from that of the singlet nitrene. In conclusion the high yields of compound (3) obtained in preparative runs are attributable to the reactivity of the two states of the nitrene, which both lead to the same compound (3), rather than to a low efficiency of the intersystem crossing to the triplet nitrene.*

A high yield of 5*H*-pyrazole[1′,2′:1,2][1,2,3]triazolo-[3,2-*a*]phenazin-4-ium inner salt (8), the analogue of (3),



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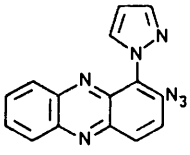

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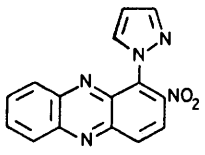

(10)

has been obtained from the thermal decomposition reaction of 2-azido-1-pyrazolylphenazine (9) and from the reduction of 2-nitro-1-pyrazolylphenazine (10). The structure of (8) was established as for compound (3).†

EXPERIMENTAL

The u.v. and the visible spectra were recorded on a Hitachi Perkin-Elmer 200 spectrophotometer, fluorescence measurements were obtained on an Aminco-Bowman SPF spectrofluorimeter, and ^{1}H n.m.r. spectra on a Perkin-Elmer R-12 instrument, using $SiMe_4$ as internal standard. Mass spectra were determined on a Du Pont 492-B spectrometer, operating at a source temperature of 190 °C (75 eV). 2-Azido-1-pyrazolylphenazine (9) and 2-nitro-1-pyrazolylphenazine (10) were prepared and purified as previously described.[6] Pure grade solvents (Carlo Erba) were used without further purification.

1-(3,5-*Dimethylpyrazolyl*)-2-*nitrophenazine* (2).—To the fine suspension obtained by addition of cold water (25 ml) to a hot solution of 3-nitrophenazine 5-oxide (4.82 g) in pyridine (40 ml), 3,5-dimethylpyrazole (3.6 g) and, after cooling to room temperature, a solution of KOH (4.8 g) in water (25 ml) were added. The mixture was stirred for 1 h and the resulting brown-red solution was diluted with water (400 ml). After 14 h, the precipitate was filtered off, washed with water, and dried (5.6 g). The crude product was recrystallized from benzene as light orange *crystals*, m.p. 228—230 °C (4.8 g, 75%) (Found: C, 63.8; H, 4.1; N, 22.1. $C_{17}H_{13}N_5O_2$ requires C, 63.9; H, 4.1; N, 21.9%).

2-*Amino*-1-(3,5-*dimethylpyrazolyl*)*phenazine* (4).—The amino-compound (4) was obtained by catalytic reduction (10% palladium–charcoal) at normal pressure of the nitro-derivative (2) (0.32 g) in ethanol (60 ml). The residue, after evaporation of the solvent, was recrystallized to constant melting point from benzene to yield orange *crystals*, m.p. 205—206 °C (0.16 g, 55%) (Found: C, 70.4; H, 5.4; N, 24.2. $C_{17}H_{15}N_5$ requires C, 70.5; H, 5.2; N, 24.2%); $\lambda_{max.}$ (cyclohexane) 436 nm (log ε 3.07).

2-*Azido*-1-(3,5-*dimethylpyrazolyl*)*phenazine* (1).—To a suspension of (2) (1.28 g) in pyridine (20 ml) and cold water (15 ml), NaN_3 (1.3 g) was added. The resulting mixture was refluxed for 3 h with exclusion of light, and evaporated under reduced pressure. Some benzene was added and the evaporation repeated. The residue was washed with water (25 ml), and the solid filtered off and dried under vacuum. The crude product was purified by chromatography on a silica gel column (Merck 60 HR, 180 g) using benzene–ethyl acetate as eluant (from 9 : 1 to 1 : 1). After a small amount of unreacted starting material and some compound (3), azide (1) (1 g) (87% yield) was collected as yellow *needles*, m.p. 147—149 °C (from ethyl acetate) (Found: C, 64.5; H, 4.2; N, 31.1. $C_{17}H_{13}N_7$ requires C, 64.8; H, 4.2; N, 31.1); $\lambda_{max.}$ (cyclohexane) 371 (log ε 4.12) and 415 nm (3.84).

Thermal Decompositition of* 2-*Azido*-1-(3,5-*dimethylpyrazolyl*)*phenazine (1).—A 10^{-1}M solution of (1) (5 ml) in the appropriate solvent (cumene, acetophenone, bromobenzene, or tetralin) was heated in a thermostatted bath at 155 °C until the reaction was complete, with exclusion of light. The solution was left at room temperature overnight and the deep blue crystalline precipitate of (3) was collected. The filtrate was evaporated under reduced pressure and the residue was chromatographed on a silica gel column (Merck 60 HR, 50 g) eluting with benzene–ethyl acetate (from 9 : 1 to 1 : 1) to give two main fractions. The blue fraction was evaporated and the residue was combined with the previously isolated portion of (3). Crystallization from benzene afforded 1,3-*dimethyl*-5H-*pyrazolo*[1′,2′;1,2]-[1,2,3]*triazolo*[3,2-a]*phenazin*-4-*ium inner salt* (3) as deep blue needles, m.p. 239—240 °C (Found: C, 70.9; H, 4.3; N, 24.2. $C_{17}H_{13}N_5$ requires C, 71.0; H, 4.5; N, 24.4%); $\lambda_{max.}$ (cyclohexane) 552 (log ε 3.93) and 597 nm (3.93).

The orange-yellow solution obtained as the second fraction was evaporated. The azo-compound (5) and the amine (4) were obtained from this residue by further chromatography on a silica gel column (Merck 60 HR, 4 g) eluting with benzene–ethyl acetate (7 : 3). Crystallization from ethanol of the residue obtained from the first fraction, afforded 1,1′-*bis*-(3,5-*dimethylpyrazolyl*)-2,2′-*azophenazine* (5) as brick-red crystals, m.p. 297 °C (Found: M^+, 574.233 7. $C_{34}H_{26}N_{10}$ requires M, 574.234 1).

Crystallization from benzene of the second fraction afforded the amine (4) as orange crystals, m.p. 205—206 °C, undepressed by admixture with an authentic sample.

The decompositions in cyclohexane and in acetonitrile

* Alternatively, it may be considered that the triplet nitrene does not react at all, but a rapid singlet–triplet equilibrium makes only the singlet reaction observable, whether the singlet or the triplet nitrene are initially formed. However, this possibility was not considered for related systems,[1] and has little attraction in the present case.

† On the basis of elemental analysis the structure of 1,1′-bis-pyrazolyl-2,2′-azophenazine has been previously attributed to compound (8).[6]

were performed in a Parr's bomb thermostatted at 155 °C. After cooling to room temperature, the solvent was evaporated and the reaction mixture was worked up as above.

Thermal Decomposition of 2-Azido-1-pyrazolylphenazine (9).—A 10^{-1}M solution of (9) (5 ml) in tetralin was heated in a thermostatted bath at 180 °C until the reaction was complete (20 min). The solution was cooled and 5*H*-pyrazolo[1′,2′:1,2][1,2,3]triazolo[3,2-*a*]phenazin-4-ium inner salt (8) (90% yield) was isolated as described above, to give deep red plates, m.p. 255 °C (from benzene); δ(CD-Cl_3) 7.0 (dd, $J_{3.4} = J_{4.5} = 3$ Hz, 4-H); $\lambda_{max.}$ (cyclohexane) 540 (log ε 4.12) and 504 nm (4.05); *m/e* 259 (M^+, base peak), 258 (16%).

Photochemical Decomposition of 2-Azido-1-(3,5-dimethylpyrazolyl)phenazine (1). To the appropriate solvent (150 ml) degassed by boiling and cooled under a stream of nitrogen, compound (1) was added and the resulting solution was irradiated with a medium-pressure, water-cooled, mercury lamp (Hanau TQ 150) through a Pyrex filter, until disappearance (t.l.c.) of the starting material. The solvent was removed under reduced pressure at room temperature, and the residue was chromatographed on a silica gel column as described for the thermal decomposition. In the case of tetralin, the reaction mixture was directly poured on the chromatographic column and eluted with cyclohexane until the reaction solvent was eliminated, and then worked up as above. For the data see Table 2.

Deoxygenation Procedure for Nitro-compounds (2) *and* (10).—To a solution of the appropriate nitro-compound (5×10^{-2}M) in cumene (200 ml) heated at 150 °C in a thermostatted bath and degassed by flushing with a nitrogen stream for 30 min, triethyl phosphite (4 ml) was added and the resulting solution was heated for 16 h, with exclusion of light. The reaction mixture was left at room temperature for 24 h, then (3) (1.2 g) [or (8) (1.7 g, 66% yield)], which crystallized out, was collected. In the case of the deoxygenation of (2), the filtrate was evaporated under reduced pressure, and the residue chromatographed on silica gel (Merck 60 HR, 60 g) eluting with benzene–ethyl acetate (from 9 : 1 to 1 : 1) to yield, beside some starting material (0.4 g), compounds (3) (0.2 g) and (4) (0.4 g).

Quantum-yield Measurements.—The quantum yields were determined at 366 nm with a super-high-pressure mercury lamp (Osram 200 W/2 lamp; Splinder and Hoyer interference filter). Potassium ferrioxalate was used as actinometer. Samples of the appropriate solution of (1) (3 ml) (10^{-4}M) in spectrophotometric cells (1-cm optical path) were degassed by three or more freeze-thaw cycles at *ca.* 10^{-5} Torr, sealed off, and irradiated. The reaction was quenched at *ca.* 5% conversion of (1). The amount of (3) formed was directly determined on the spectrophotometer by absorbance measurements at 597 nm.

The amine (4) was determined by its fluorescence ($\lambda_{irr.}$ 410, $\lambda_{em.}$ 525 nm) after extraction of the reaction mixture with mineral acid, neutralization, and extraction with cyclohexane.

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