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A Novel Ring Transformation of 5-Azidothiazoles

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Abstract: The 4-oxoalkyl- and 4-iminoalkyl-5-azidothiazoles undergo a ring transformation with nitrogen loss at relatively low temperatures to afford 4-cyanooxazoles and 4-cyanoimidazoles, respectively. The mechanism, which is thought to involve a ring opening-ring closure process, is discussed. © 1999 Elsevier Science Ltd. All rights reserved.

INTRODUCTION

Heterocyclic compounds have an extraordinary ability to give ring transformations¹. During many years we have studied the rearrangements of 1,2,3-thiadiazoles and 1,2,3-triazoles². In the case of 5-azido-1,2,3-triazoles 1, a competition between two different processes can occur³ : a) a rearrangement with ring opening, followed by 1,5-dipolar electrocyclisation⁴, affording a 5-diazoalkyltetrazole 2 and b) a ring opening to a triazene 3 with nitrogen loss. This last process is general for α -azidoazoles⁵ and in a series of articles⁶ we have gained insight in the mechanism by studying the kinetics of the thermal decomposition reaction. In the same manner, 5-azido-4-formyloxazoles 4⁷ either undergo ring opening to carbonylimines 5 or rearrange to oxazoles 6 by the Cornforth rearrangement¹. 2-Alkyl substituents were shown to favor the former pathway and 2-aryl substituents the latter. As a further extension of our ongoing research program on the chemistry and thermal behaviour of heterocyclic azides we have now prepared 5-azidothiazoles and studied their thermal behaviour.



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RESULTS AND DISCUSSION

Azide synthesis

The starting materials for the synthesis of the 5-azidothiazoles in this paper are the 5-bromo-4formylthiazoles **7a,b**. Simiti *et al.* reported a procedure⁶ for the preparation of **7a** starting from 1.3dichloroacetone and thiobenzamide **8a** to give the chloromethylthiazole **9**. This method was rather difficult to reproduce. Alternatively, starting from 1,1,3-trichloroacetone and thioamides **8a,b**, the 4dichloromethylthiazoles **10a,b** could be obtained. Bromination of **10a,b**, followed by hydrolysis of the resulting **11a,b** gave the aldehydes **7a,b** in good overall yield (**Scheme 2**). Nucleophilic substitution of the chloroaldehydes **7a,b** with azide anion finally gave the 5-azido-4-formylthiazoles **12a,b**. These compounds could be smoothly converted to the corresponding anils **13a,b** by treatment with aniline. The aldehyde **7a** was converted with diazomethane to the 5-acetylthiazole **14** which could be converted in the same manner to the corresponding azide **15** (**Scheme 3**).





Scheme 2



(i) sodium azide/dimethylformamide (ii) aniline (iii) diazomethane

Scheme 3

Azide thermolysis: rates and products

The azides 12-13a,b and 15 decompose readily with evolution of nitrogen upon brief heating at 50°C and even on standing for prolonged time at room temperature. The reactions were cleanly first-order as evident from a kinetic study by FTIR. The rates are summarized in Table 1. A comparison can be made between the azides 12-15a,b and 15 and the isomeric 4-azidothiazoles 16a-c we have studied earlier⁸. The latter azides generally decompose at a much slower rate. This fact is in accordance with similar observations⁹ by Zanirato *et al.* in the (benzo)thiophene series. The 5-azidoisothiazole¹⁰ 17 has a decomposition rate which is comparable to those of the compounds 12a,b. This seems to indicate that the location of the nitrogen in the heterocycle does not exert a great influence on the rate of the ring opening.

Azide	Temp(°C)	$10^5 k_1/s^{-1}$
12a	50	10.85
12b	50	6.08
13a	50	64.00
13b	50	35.70
15	50	8.45
16a	50 ^a	0.02
16b	50 ^a	0.08
16c	50 ^a	0.01
17	50 ^a	5.95

Table]	: First-Order	Rate Constants	for Thermal	Decomposition
of 4-, 5-A	Azidothiazoles	and 5-Azidoisc	thiazoles in	p-Xylene

a:Extrapolation from the literature values, which were obtained at $80^{\circ}C$ (division by a factor 27)





The thermolysis reactions of the azides 12-13a,b and 15 were also followed at 50°C by ¹H NMR spectroscopy in CHCl₃-*d* solution. We observed the formation of 4-cyanooxazoles 18a,b and 19 (respectively starting from 12a,b and 15) and 4-cyanoimidazoles 20a,b from azides 13a,b. In the case of azide 15, the isoxazolothiazole 21 is also formed as a result of intramolecular cyclization of the azide and acetyl functions. The 19:21 ratio was 2:1. The thermolysis products 18-20 were isolated in fair to good yields and fully characterized by NMR, IR and MS spectroscopic techniques. Only a small quantitity of 21 could be obtained from the reaction mixtures starting from 15. This is due to decomposition during chromatography . From the same chromatography, the expected amount of the 4-cyanooxazole 19 was isolated. The low stability of isoxazolo[5,4-c]thiazoles is not unexpected, as the same was observed for the isomeric isoxazolo[4,5-c]-thiazoles^{8.11}(Scheme 4).

Mechanism

Two different mechanisms can be put forward to explain the products formed in these thermolysis reactions : a) A Cornforth-type rearrangement¹, followed by immediate ring closure of the azidothiocarbonyl group of 22 to a 1,2,3,4-thiatriazole 23, which then readily extrudes sulfur and nitrogen to form the nitriles $18-20^{12}$; b) a ring opening after or at the same time of the loss of nitrogen, giving initially a thiocarbonyl compound 24 which after a *cis/trans* isomerisation can undergo a 1,6-electrocyclisation to give an unstable oxathiazine or thiadiazine 25 which extrudes sulfur to form a heteroaromatic azole 18-20 (Scheme 5).



Scheme 5 (X = O or NPh)

We can refute the first mechanism because of the following reasons : a) the initial ring opening to a nitrile ylide 22 is energetically unfavored because of the unstable thiocarbonyl bond formed and in all the Cornforth rearrangements reported¹ a carbonyl bond is formed; b) the decomposition reaction occurs at relatively low temperatures, whereas the Cornforth rearrangement normally takes temperatures of well over 100° C; c) 2-alkyl groups on the thiazole ring stabilize the nitrile ylide formed and hence increase the rate, here the opposite is observed and d) no Cornforth rearrangement starting from a thiazole is known so far in the literature¹. In fact, in one case a thiazole was formed starting from an oxazole, which is exactly the reverse result that we obtained¹³.

Additional support for the second mechanism is provided by the fact that a) the isoelectronic 2azidothiophenes undergo facile ring-opening, giving thiocarbonyl compounds¹⁴ and 2-nitreno-3-(phenyliminomethyl)thiophenes give 3-cyanopyrroles¹⁵; b) the driving force for the 1,6-electrocyclization is given by the disappearance of the unstable thiocarbonyl double bond and c) in a similar process, 1,2dithiins are known to undergo facile ringcontraction to thiophenes¹⁶.

EXPERIMENTAL

General

Remarks regarding safety: Sodium azide is extremely poisonous and organic azides are potentially hazardous. Although we never had any explosions occuring with the heterocyclic azides described in this report, caution is always necessary when handling these compounds. Preparation should be carried out only in a fume cupboard (hood) provided with a powerfull exhaust system. The use of a screen of safety glass is recommended.

Mps were determined using a Reichert Thermovar apparatus. IR spectra of the products were recorded with a Perkin-Elmer 1620 FT spectrometer, using KBr pellets unless otherwise specified. NMR spectra were measured on a Bruker AMX-400 spectrometer, using CDCl₃ solutions unless otherwise stated. J values are quoted in Hz. Low resolution mass spectra were measured with a Hewlett Packard 5989A spectrometer and high resolution ones with a Kratos MS50 TC machine, both operated at 70eV and in EI mode unless specified otherwise. Chemical ionization (CI) mass spectra used methane as the reagent gas.

Synthesis of 5-azidothiazoles

4-Dichloromethyl-2-phenylthiazole (10a). A solution of 1,1',3-trichloropropanone (16g, 0.1mol) and thiobenzamide (18g, 0.13mol) in dry acetone (80cm³) was stirred at room temperature for 24h. The light brown precipitate was filtered off, washed with dry acetone and dried. This compound was dissolved in concentrated sulfuric acid (15cm³) and stirred at room temperature for 1h. The brown solution was poured into ice-water (100cm³) and the precipitated thiazole 10a was filtered off, washed with water and dried (9.8g, 40%), mp 56°-57°C (from MeOH); v_{max}/cm^{-1} 3127m, 2969m; δ_{H} (DMSO-d₆) 7.51-7.57 and 7.95-7.99 (3+2 H, 2m, Ph), 7.60 (1 H, s, CHCl₂) and 8.01 (1H, s, H-5); δ_{C} (DMSO-d₆) 66.6 (CHCl₂, ¹J_{CH} 178), 119.4 (C-5), 126.4, 129.4, 131.0 and 132.4 (Ph C-2, C-3, C-4 and C-1), 153.7 (C-4) and 168.9 (C-2); m/z 243/245/247 (M⁺, 32/23/5%), 208/210 (M⁺-Cl, 100/41), 105 (27), 77 (Ph⁺, 11) and 45 (HCS⁺, 35) (Found: M⁺, 242.9697. requires C₁₀H₇Cl₂NS M, 242.9677).

4-Dichloromethyl-2-methylthiazole (10b) was prepared in the same way as 10a starting from thioacetamide (9.8g, 0.13mol). The crude product was purified by column chromatography on silica gel with dichloromethane as the eluent giving white crystals 10b (3.1g, 17%), mp 80.4°-81.5°C (from MeOH); v_{max} /cm⁻¹ 3112m and 2969s; δ_{H} 2.73 (3 H, s, Me), 6.81 (1 H, s, CHCl₂) and 7.41 (1 H, s, H-5); δ_{C} 19.2 (Me), 65.9 (CHCl₂, ¹J_{CH} 179), 117.3 (C-5, ¹J_{CH} 189), 153.1 (C-4) and 167.5 (C-2); m/z 181/183/185

 $(M^+, 19/13/3\%)$, 146/148 $(M^+$ -Cl, 100/51), 105/107 $(M^+$ -Cl-MeCN, 46/19), 69 $(m/z \ 105 - HCl, 35)$ and 45 $(HCS^+, 42)$ (Found: M^+ , 180.9534. requires C₅H₅Cl₂NS M, 180.9520).

5-Bromo-4-dichloromethyl-2-phenylthiazole (11a). To a stirred solution of 10a (2.74g, 11.3mmol) in acetic acid (30cm³) was added dropwise 1.5 equiv. of bromine (2.7g, 17mmol) at 16°C, while protecting the reaction from light. After stirring at room temperature for 18h, the precipitate 11a was filtered off and the filtrate was poured into ice-water (50cm³) to give a second crop of 11a which was filtered off and washed with aqueous Na₂CO₃ (10%, 3x100cm³). Total yield 2.42g, 66%, mp 136.4°-137.2°C (from MeOH); v_{max}/cm^{-1} 3017s and 2966m; δ_{H} 6.91 (1 H, s, CHCl₂), 7.42-7.50 and 7.88-7.93 (3+2 H, 2m, Ph); δ_{C} 63.6 (CHCl₂, ¹J_{CH} 178), 106.1 (C-5), 126.5, 129.1, 131.1 and 132.4 (Ph C-2, C-3, C-4 and C-1), 151.5 (C-4) and 169.4 (C-2); m/z 321/323/325/327 (M⁺, 25/41/20/4%), 286/288/290 (M⁺-Cl, 74/100/31), 183/185/187 (M⁺-Cl-PhCN, 17/22/6), 104/106 (S=C=C=CHCl⁺, 29/9), 103 (PhCN⁺, 18), 77 (Ph+) and 69 (S=C=C=CHC⁺, 45) (Found: M⁺, 320.8787. requires C₁₀H₆BrCl₂NS M, 320.8781).

5-Bromo-4-dichloromethyl-2-methylthiazole (11b). To a stirred solution of 10b (3.25g, 18mmol) in acetic acid (30cm³) was added dropwise 1.5 equiv. of bromine (4.32g, 27mmol). After stirring at room temperature for 15h, the reaction mixture was poured into ice-water (100cm³) and the resulting red oil was extracted with dichloromethane (3x100cm³). The combined extracts were washed with aqueous Na₂CO₃ (10%, 4x100cm³), dried (MgSO₄) and evaporated. The crude product was purified by column chromatography on silica gel with dichloromethane as the eluent to give 11b (2.4g, 51%), mp 79.1°-79.5°C (from MeOH); $\delta_{\rm H}$ 2.73 (3 H, s, Me) and 6.83 (1 H, s, CHCl₂); $\delta_{\rm C}$ 19.9 (Me), 63.4 (CHCl₂, ¹*J*_{CH} 178), 105.2 (C-5), 15.2 (C-4) and 168.2 (C-2); m/z 259/261/263/265 (M⁺, 17/28/15/3%), 224/226/228 (M⁺-Cl, 80/100/43), 183/185/187 (M⁺-Cl-MeCN, 29/38/12), 104/106 (S=C=C=CHCl⁺, 28/11) and 69 (S=C=C=CH⁺, 59) (Found: M⁺, 258.8625. requires C₅H₄BrCl₂NS M, 258.8625).

5-Bromo-2-phenylthiazole-4-carbaldehyde (7a). A suspension of 11a (500mg, 1.6mmol) and CaCO₃ (2.5g, 25mmol) in water (20cm³) was refluxed for 15h under a nitrogen atmosphere. The reaction mixture was extracted with chloroform (3x100cm³) and the combined extracts were dried (MgSO₄) and evaporated. The crude product was chromatographed on silica gel with dichloromethane as the eluent to give bromo-aldehyde 7a (385mg, 86%), mp 93.5°-94.1°C (from EtOH; lit.,⁷ 94°-95°C); v_{max} /cm⁻¹ 3046w, 2975m, 2852m, 2803m and 1679s (C=O); δ_{H} 7.43-7.52 and 7.90-7.95 (3+2 H, 2m, Ph) and 10.1 (1 H, s, CH=O); δ_{C} 119.2 (C-5, ³J_{CH} 2 Hz), 126.7, 129.2, 131.4 and 132.0 (Ph C-2, C-3, C-4 and C-1), 150.0 (C-4.

 ${}^{2}J_{CH}$ 26 Hz), 168.9 (C-2) and 183.3 (CHO, ${}^{1}J_{CH}$ 184 Hz); m/z 268/270 (M⁺+H, 19/18%), 267/269 (M⁺. 40/44), 188 (M⁺-Br, 100), 160 (M⁺-Br-CO, 46), 133 (M⁺-Br-CHO-CN, 22) and 77 (Ph⁺) (Found: M⁺. 266.9358. requires C₁₀H₆BrNOS M, 266.9353).

5-Bromo-2-methylthiazole-4-carbaldehyde (7b). Compound 11b (500mg, 1.9mmol) in ethanol (20cm³) was mixed with an aqueous solution of NaHCO₃ (075g in 4cm³) and the whole was heated at 80°C for 15h under a nitrogen atmosphere. The reaction mixture was then extracted with dichloromethane (3x100cm³) and the combined extracts were dried (MgSO₄) and evaporated to give 7b (340mg, 86%), mp 71.5°-72°C (from n-hexane); v_{max} /cm⁻¹ 2975m, 2915m, 2856, 2514m and 1679s (C=O); δ_{H} 2.73 (3 H, s, Me) and 10.0 (1 H, s, CHO); δ_{C} 19.7 (Me, ¹J_{CH} 131), 119.7 (C-5, ³J_{CH} 1.25), 149.2 (C-4, ²J_{CH} 28), 167.4 (C-2, ²J_{CH} 7) and 182.6 (CHO, ¹J_{CH} 183 Hz); m/z 205/207 (M⁺, 14/15%), 126 (M⁺-Br, 100), 98 (M⁺-Br-CO, 65); 71 (M⁺-Br-CO-CN, 14), 59 (MeCS⁺, 23) and 57 (94) (Found: M⁺, 204.9215. requires C₅H₄BrNOS M, 204.9197).

4-Acetyl-5-bromo-2-phenylthiazole (14). This compound was prepared following the literature procedure (yield: 57 %), mp 133°-134°C (from MeOH, lit.,⁷ 136°C); ν_{max}/cm^{-1} 3050w, 2926w and 1682s (C=O); δ_{H} 2.75 (3 H, s, Me) and 7.45-7.50 and 7.85-7.93 (3+2 H, 2m, Ph); δ_{C} 29.0 (Me), 114.3 (C-5), 126.4, 129.2, 131.0 and 132.4 (Ph C-2, C-3, C-4 and C-1), 149.6 (C-4), 166.9 (C-2) and 193.5 (C=O); m/z 281/283 (M⁺, 29/30), 202 (M⁺-Br, 100), 160 (M⁺-Br-CH₂CO, 53), 159 (M⁺-Br-COCH₃, 12), 77 (Ph⁺, 25), 51 (C₄H₃⁺, 19) and 43 (COCH₃⁺, 45) (Found: M⁺, 280.9522. requires C₁₁H₈BrNOS M, 280.9510).

5-Azido-2-phenylthiazole-4-carbaldehyde (12a). To an ice-cooled solution of 7a (300mg, 1.12mmol) in DMF (5cm³) was added 5 equiv. of sodium azide (320mg). After stirring at 0°C for 2h, the reaction mixture was poured into ice-water (50cm³) and the precipitate was filtered off. A second crop was obtained by extraction of the filtrate with dichloromethane (3x100cm³), drying (MgSO₄) and removal of the solvent. The azide **12a** was purified by column chromatography on silica gel with diethyl ether/n-hexane (1/1) as the eluent (180mg, 70%), mp 85°-86°C (decomposition); v_{max}/cm^{-1} 2135s (N₃) and 1686s (C=O); $\delta_{\rm H}$ 7.4-7.5 and 7.83-7.9 (5 H, 2m, Ph) and 10.05 (1 H, s, CHO); $\delta_{\rm C}$ 126.5, 129.2, 131.1 and 132.2 (Ph), 141.8 (C-4, d, ²J_{CH} 26 Hz), 148 (C-5, d, ³J_{CH} 4 Hz), 160.0 (C-2, t) and 183.4 (CHO, d, ¹J_{CH} 182 Hz): m/z 230 (M⁺, 0.4%), 202 (M+.-N₂, 7), 174 (M⁺-N₂-CO, 19), 121 (PhCS⁺, 100) 103 (PhCN⁺, 10), 77 (Ph⁺, 74) and 51 (C₄H₃⁺, 59) (Found: M⁺, 230.0258. requires C₁₀H₆N₄OS M, 230.0262).

1985

5-Azido-2-methylthic. $7 \circ le$ -4-carbaldehyde (12b) was synthesized in the same way as 12a starting from 7b (490mg, 2.3mmol) and purified by chromatography on silica gel with diethyl ether/n-hexane (4/1) as the eluent to give 12b (273mg, 68%), mp 53°-55°C; v_{max} /cm⁻¹ 2966w, 2830m, 2112s (N₃) and 1963s (C=O); $\delta_{\rm H}$ 2.68 (3 H, s Me) and 9.94 (1 H, s, CHO); $\delta_{\rm C}$ 19.7 (Me, ¹J_{CH} 120), 140.7 (C-4, ²J_{CH} 25), 148.3 (C-5), 158.6 (C-2, ²J_{CH} 7) and 182.6 (CHO, ¹J_{CH} 181); m/z 168 (M⁺, 3%), 140 (M⁺-N₂, 4). 112 (M⁺-N₂-CO, 15) and 59/61 (MeCS⁺, 61/6) (Found: M⁺, 168.0014. requires C₅H₄N₄OS M, 168.0106).

4-Acetyl-5-azido-2-phenylthiazole (15) was prepared as 12a starting from 14 (200mg, 0.57mmol), but with stirring for 1h at 0°C and further at RT for another 6h. Compound 15 was purified by chromatography on silica gel with dichloromethane as the eluent (120mg, 69%), mp 80°-81°C; v_{max}/cm^{-1} 3058w, 3016w, 2965w, 2174s/2141m (N₃) and 1681s (C=O); $\delta_{\rm H}$ 2.70 (1 H, s, Me), 7.40-7.55 and 7.80-7.90 (3+2 H, 2m, Ph); $\delta_{\rm C}$ 29.2 (Me, ¹*J*_{CH} 128), 126.2, 129.1, 130.7 and 132.6 (Ph C-2, C-3, C-4 and C-1), 141.5 (C-4, q), 145.5 (C-5, s), 157.9 (C-2, t) and 193.9 (C=O, ²*J*_{CH} 6 Hz); m/z 244 (M⁺, 1%), 216 (M⁺-N₂, 27), 184 (M⁺-N₂-S, 46), 174 (M⁺-N₂-CH₂CO, 11), 142 (M⁺-N₂-S-CH₂CO, 26), 121 (PhCS⁺, 79), 77 (Ph⁺, 37) and 43 (CH₃CO⁺, 100) (Found: M+., 244.0408. requires M, 244.0419).

5-Azido-2-phenyl-4(N-phenyliminomethyl)thiazole (13a). A solution of the aldehyde 12a (160mg, 0.069mmol) and aniline (72mg, 0.69mmol) in ethanol (20cm³) containing a few drops of acetic acid was stirred at 0°C for 1h and left overnight in the refrigerator. The precipitated crystals were collected, washed with aqueous Na₂CO₃ (10%, 50cm³) and dried (MgSO₄) to give the imine 13a (117mg, 55%), mp 154°-156°C (decomposition); v_{max}/cm^{-1} 3062w, 2120s (N₃) and 1620m (C=N); δ_H 7.18-7.50 and 7.88-7.95 (8+2 H, 2m, 2 Ph) and 8.57 (1 H, s, CH=N); δ_C 121.1, 126.4, 126.5, 129.0, 129.1, 130.7, 132.8 and 151.6 (2 Ph), 141.5 (C-4), 151.3 (CH=N) and 160.5 (C-2) (C-5 not observed); m/z 306 (M⁺+H, 0.1%), 277 (M⁺-N₂, 10), 245 (4-cyano-1,2-diphenylimidazole), 193 (22), 115 (10), 77 (Ph⁺, 17) and 51 (C₄H₃⁺, 11).

5-Azido-2-methyl-4(N-phenyliminomethyl)thiazole (13b) was prepared in the same way as 13a starting from 12b (400mg, 2.4mmol). After standing overnight, the solvent was removed and the red oil washed with water (3x50cm³) and characterized as 13b (345mg, 59%); v_{max} (CCl₄)/cm⁻¹ 3065w, 3031w, 2977w and 2132s (N₃); δ_{H} 2.69 (3 H, s, Me), 7.19-7.30 and 7.31-7.42 (3+2 H, 2m, Ph) and 8.43 (1 H, s, CH=N); δ_{C} 19.8 (Me, ¹J_{CH} 131), 121.0, 126.2 and 128.9 (Ph C-2, C-3 and C-4), 139.9 (C-4, d, ²J_{CH} 13), 141.5 (C-5), 149.9 (CH=N, d, ¹J_{CH} 167), 151.4 (Ph C-1), 159.4 (C-2, q, ²J_{CH} 7); m/z 243 (M⁺, 1%), 215

 $(M^+-N_2, 20)$, 201 $(M^+-N_2+H, 29)$, 183 (4-cyano-2-methyl-1-phenylimidazole, 100), 130 (44) and 51 $(C_4H_3^+, 49)$.

Products of thermolysis

4-Cyano-2-phenyloxazole (18a). A solution of the azide 12a (150mg, 0.65mmol) in chloroform (10cm³) was heated at 50°C for 2 days and the resulting black solution was chromatographed twice on silica gel, first with diethyl ether/n-hexane (1/1) and then with dichloromethane as the eluents to give the oxazole 18a (50mg, 45%), mp 117°C (decomposition, lit.,¹⁷ 118°-119°C); v_{max} (CCl₄)/cm⁻¹ 3160w, 3068w and 2291m (CN); δ_{H} 7.45-7.58 and 8.05-8.1 (3+2 H, 2m, Ph) and 8.21 (1 H, s, H-5); δ_{C} 111.8 (CN), 116.2 (C-4, ²J_{CH} 14), 125.5, 126.9, 129.1 and 131.9 (Ph C-1, C-2, C-3 and C-4), 145.8 (C-5, ¹J_{CH} 215) and 163.1 (C-2); m/z 245 (M⁺, 96), 244 (M⁺-H, 100), 193 (M⁺-H-HCCCN, 18), 115 (193-C₆H₆,14). 103 (13), 89 (10), 77 (C₆H₅⁺, 51), 63 (16), 51 (C₄H₃⁺, 50) and 39 (C₃H₃⁺,18) (Found: M⁺, 245.0953).

4-Cyano-2-methyloxazole $(18b)^{17}$. A solution of the azide 12b (120mg, 0.7mmol) in chlororform (10cm³) was heated at 50°C for 36h. After evaporating the solvent, the oxazole 18b was purified by column chromatography on silica gel with diethyl ether/n-hexane (4/1) as the eluent gave an oil (35mg, 46%); 2.53 (1H, s, Me) and 8.07 (1 H, s, H-5); δ_{C} 13.7 (Me, q, ¹J_{CH} 131), 111.8 (CN), 114.9 (C-4, d, ²J_{CH} 14), 146.1 (C-5, d, ¹J_{CH} 215) and 163.1 (C-2); m/z 183 (M⁺, 88), 182 (M⁺-H, 16), 142 (10), 131 (M⁺-H-HCCCN, 44), 130 (49), 115 (31), 104 (12), 77 (C₆H₅⁺, 74), 51 (C₄H₃⁺, 100) and 39 (C₃H₃⁺, 32) (Found: M⁺, 183.0800. requires C₁₁H₉N₃ M, 183.0796).

5-Methyl-4-cyano-2-phenyloxazole (19). A solution of the azide 15 (100mg, 0.4mmol) in chloroform (10cm³) was heated at 50°C for 15h and the crude product was chromatographed on silica gel with dichloromethane as the eluent to give 19 (43mg, 56%), mp 128.1°-129.5°C (from ethanol); (Found: C, 72.14; H, 4.88. C₁₁H₈N₂O requires C, 71.8; H, 4.4); v_{max}/cm^{-1} 3059w, 2958w and 2237s (CN); δ_{H} 2.59 (3 H. s, Me) and 7.45-7.52 and 7.98-8.05 (3+2 H, 2m, Ph); δ_{C} 11.3 (Me, ¹J_{CH} 131), 112.4 (C-4, ³J_{CH} 4), 112.6 (CN, ⁴J_{CH} 1), 125.8, 126.5, 129.0 and 131.4 (Ph C-1, C-2, C-3 and C-4), 158.4 (C-5, ²J_{CH} 7) and 161.2 (C-2); m/z 184 (M⁺, 100), 169 (M⁺-CH₃), 155 (M⁺-CHO), 115 (M⁺-CO-CN-CH₃), 77 (Ph⁺, 21), 51 (C₄H₃⁺, 21), 43 (COCH₃⁺, 30) and 39 (C₃H₃⁺, 10) (Found: M⁺, 184.0633. requires C₁₁H₈N₂O M. 184.0637).

The ¹H-and ¹³C-NMR-spectra from the crude reaction mixture showed also the formation of some bicyclic product **21** (ratio 19:21 was 2:1). We were not able to separate this compound from the mixture. 4-Methyl-2-phenylisoxazole[3,4-d]thiazole (**21**): $\delta_{\rm H}$ 2.78 (3 H, s, Me) and 7.4-7.55 and 7.93-7.97 (3+2 H. 2m, Ph); $\delta_{\rm C}$ 11.3 (Me), 127.6, 129.1, 131.9 and 133.0 (Ph C-2, C-3, C-4 and C-1), 141.8 (C-3a), 158.2 (C-4, q), 163.9 (C-6a) and 171.2 (C-2).

4-Cyano-1,2-phenylimidazole (20a). A solution of the azide 13a (100mg, 0.33mmol) in chloroform (10cm³) was heated at 50°C for 10h and then chromatographed on silica gel with diethyl ether/n-hexane (1/1) as the eluent to give the imidazole 20a (56mg, 69%), mp 163.6°-164.3°C (from n-hexane); (Found: C, 78.53; H, 4.77. C₁₆H₁₁N₃ requires C, 78.3; H, 4.5); v_{max}/cm^{-1} 3085m, 3024m and 2233m (CN); $\delta_{\rm H}$ 7.2-7.5 (2+2+3+3 H, 4m, 2Ph) and 7.67 (1 H, s, H-5); $\delta_{\rm C}$ 114.4 (C-4, ²J_{CH} 8), 114.6 (CN, ³J_{CH} 1), 125.8, 128.4 (x2), 128.8, 129.4, 129.6, 129.9 and 136.9 (Ph), 130.5 (C-5, ¹J_{CH} 197) and 148.4 (C-2); m/z 245 (M⁺, 96), 244 (M⁺-H, 100), 193 (M⁺-H-HCCCN, 18), 142 (M⁺-PhCN, 8), 103 (PhCN⁺, 13) and 77 (Ph⁺, 51).

4-Cyano-2-methyl-1-phenylimidazole (20b). A solution of the azide 12b (300mg, 1.2mmol) in chloroform (10cm³) was heated at 50°C for 4h and the crude product purified on silica gel with diethyl ether/n-hexane (3/1) as the eluent to give the imidazole 20b (175mg, 80%), mp 113°C (decomposition, from n-hexane); (Found: C, 72.01; H, 4.97 $C_{11}H_9N_3$ requires C, 72.1; H, 5.0); v_{max}/cm^{-1} 3110m (H-5), 3052w, 2924w and 2235m (CN); δ_H 2.36 (3 H, s Me), 7.27-7.32 (2 H, m, Ph_{ortho}), 7.52-7.57 (3 H, m, Ph_{meta+para}) and 7.56 (1 H, s, H-5); δ_C 13.3 (Me), 112.6 (C-4, ²J_{CH} 7.5), 114.4 (CN), 129.0 (C-5, ¹J_{CH} 197), 125.4, 129.5, 129.8 and 135.9 (Ph C-2, C-4, C-3 and C-1) and 147 (C-2); m/z 183 (M⁺, 88), 142 (M⁺-CH₃-CN, 10), 131 (M⁺-H-HCCCN, 44), 104 (M⁺-H-C₆H₆, 12), 91 (M⁺-HNPh, 15), 77 (Ph⁺, 74), 51 (C₄H₃⁺, 100) and 39 (C₃H₃⁺, 32).

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