Tetrahedron 65 (2009) 8428–8433

Contents lists available at ScienceDirect

Tetrahedron

journal homepage: www.elsevier.com/locate/tet

The conversion of 2-(4-chloro-5*H*-1,2,3-dithiazolylideneamino)benzonitriles into 3-aminoindole-2-carbonitriles using triphenylphosphine

Sophia S. Michaelidou, Panayiotis A. Koutentis *

Department of Chemistry, University of Cyprus, PO Box 20537, 1678 Nicosia, Cyprus

ARTICLE INFO

Article history:
Received 13 May 2009
Received in revised form 26 June 2009
Accepted 23 July 2009
Available online 29 July 2009

ABSTRACT

2-(4-Chloro-5*H*-1,2,3-dithiazolylideneamino)benzonitrile **1a** reacts with triphenylphosphine (4 equiv) in the presence of water (2 equiv) to afford anthranilonitrile **2a**, 3-aminoindole-2-carbonitrile **3a** and (2-cyanoindol-3-yl)iminotriphenylphosphorane **4a**, together with triphenylphosphine sulfide and oxide. The use of polymer bound triphenylphosphine provides cleaner reaction mixtures. 2-(4-Chloro-5*H*-1,2,3-dithiazolylideneamino)-4,5-dimethoxybenzonitrile **1h** does not give the corresponding indole on treatment with triphenylphosphine but gives 6,7-dimethoxyquinazoline-2-carbonitrile **5** (15%) and 2-cyano-4,5-dimethoxy cyanothioformanilide **6** (36%). A total of seven new 3-aminoindole-2-carbonitriles **3a–g** are prepared and fully characterised.

1. Introduction

Neutral 1,2,3-dithiazoles show interesting antitumour,[1] antibacterial,[2] antifungal[3] and herbicidal[4] activities. Furthermore, research in organic conductors based on neutral radicals has led to the preparation of two 1,2,3-dithiazolyl radicals[5] and also a tetrathiadiazafulvalene analogue.[6] Our interest in neutral 1,2,3-dithiazoles focuses on their ring transformations into otherwise difficult to access heteroarene carbonitriles.[7] For example 3-haloisothiazole-4,5-dicarbonitriles,[7a–c] and 3*H*-pyrrolecarbonitriles[7d] can be obtained from (dithiazolylidene)malononitriles while the thermolysis of *N*-aryldithiazolimines can afford benzothiazoles,[8] benzimidazoles,[9] thiazolopyridines[7e] and benzoxazines.[10]

4,5-Dichloro-1,2,3-dithiazolium chloride (Appel salt) can be readily prepared from chloroacetonitrile and disulfur dichloride,[11] and is an important reagent for the preparation of neutral 4-chloro-5*H*-1,2,3-dithiazoles.[11a,12] The chemistry of Appel salt and related 1,2,3-dithiazoles has been extensively reviewed.[13]

During ongoing studies aimed at extending the use of 1,2,3-dithiazoles in such ring transformations, we discovered a route to 3-aminoindole-2-carbonitriles. Indoles are considered important heteroarenes for their extensive biological activities,[14] however, to our knowledge there have only been two reports of substituted 3-aminoindole-2-carbonitriles.[15] In light of this, the scope and usefulness of the 1,2,3-dithiazole into 3-aminoindole-2-carbonitrile transformation was examined. The details of this study are described below.

2. Results and discussion

Cyanothioformanilides can be prepared from (4-chloro-5*H*-1,2,3-dithiazolylideneamino)benzenes (dithiazolimines) on treatment with triphenylphosphine in moist DCM.[2a,3c,7g,16] While the use of triphenylphosphine (2 equiv) was reported to give good yields of the cyanothioformanilides it was not possible to obtain a stable product from the reaction of 2-(4-chloro-5*H*-1,2,3-dithiazolylideneamino)benzonitrile **1a**; readily prepared from the condensation of anthranilonitrile and Appel salt.[2a]

In our hands the addition of PPh_3 (2 equiv) to (dithiazolylideneamino)benzonitrile **1a** in wet DCM at ca. 20 °C gave a significant amount of unreacted starting (dithiazolylideneamino)benzonitrile **1a** (by TLC). In light of this, the reaction was repeated using additional equivalents of triphenylphosphine and to our surprise a complex mixture of products was observed (Table 1).

It was worthy of note that the use of >4 equiv of triphenylphosphine gave no advantage, and in the absence of water the consumption of starting (dithiazolylideneamino)benzonitrile was slow. Furthermore, replacing the triphenylphosphine with either triethyl-, triphenyl- or triisopropylphosphites led to little or no reaction and the starting dithiazole could be recovered almost quantitatively.

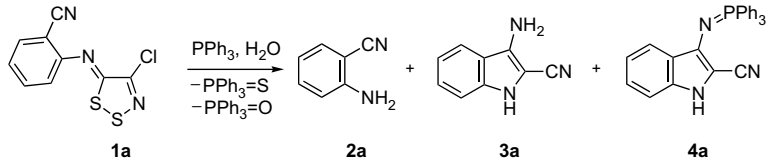
Isolation and characterisation of the main products identified anthranilonitrile **2a**, and the unexpected formation of 3-aminoindole-2-carbonitrile **3a** together with (2-cyano-1*H*-indol-3-yl)-iminotriphenylphosphorane **4a** as well as some unreacted triphenylphosphine, and triphenylphosphine sulfide and oxide.

3-Aminoindole-2-carbonitrile **3a** was obtained as light yellow cotton fibres, mp 172–173 °C, that were stable to solutions (DCM) of either Ph_3P, $Ph_3P{=}S$, $Ph_3P{=}O$ or S_8 at ca. 20 °C. Microanalysis and

* Corresponding author. Tel.: +357 22 892783; fax: +357 22 892809.
E-mail address: koutenti@ucy.ac.cy (P.A. Koutentis).

0040-4020/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tet.2009.07.064

Table 1
Reaction of 2-(4-chloro-5*H*-1,2,3-dithiazolylideneamino)benzonitrile **1a** (0.2 mmol) with PPh_3 (1–4 equiv) and H_2O (0–2 equiv) in dry DCM (2 mL) at ca. 20 °C under a $CaCl_2$ drying tube



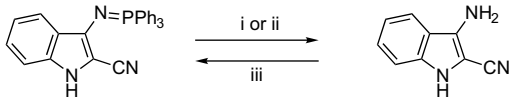
1a **2a** **3a** **4a**

PPh_3 (equiv)	H_2O (equiv)	Time (min)	Yields[a] (%)					
			1a	PPh_3=S	**2a**	**3a**	**4a**	PPh_3=O
1	2	5	36	42	9	—	—	44
2	2	5	17	41	8	—	—	48
3	2	5	—	68	13	10	11	70
4	0	30	—	86	7	18	22	81
4	1	5	—	75	10	38	15	80
4	2	5	—	74	13	39	16	80
4	3	1	—	77	15	40	15	77

[a] Yields based on recovered (dithiazolylideneamino)benzonitrile **1a**.

mass spectrometry supported the formula $C_9H_7N_3$ [*m*/*z* (EI) 157 (M^+, 100%)]. ^{13}C NMR spectrum showed nine separate carbon resonances of which five were quaternary carbons as supported by DEPT studies. The presence of a cyano group was supported by an IR band at 2212 cm^{-1} and a carbon signal at 116.2 ppm. The most up field carbon resonance (86.6 ppm) indicated the absence of any sp^3 hybridised carbons. ^1H NMR identified two D_2O exchangeable broad resonances integrating 1:2 at 10.67 and 5.71 ppm indicating the presence of 2° and 1° amino groups and this was supported by IR bands at 3356 and 3309 cm^{-1}. Two possible structures that fitted this data were the known 2-aminoindole-3-carbonitrile (mp 188 °C)[17] and the unknown isomer 3-aminoindole-2-carbonitrile **3a**. A comparison of the spectroscopic data eliminated the possibility of the former indole structure that also deviated from the carbon and nitrogen connectivity of the starting (dithiazolylideneamino)benzonitrile.

(2-Cyano-1*H*-indol-3-yl)iminotriphenylphosphorane **4a** was obtained as colourless crystals, mp 183–184 °C. Microanalysis and mass spectrometry gave the formula $C_{27}H_{20}N_3P$ [*m*/*z* (EI) 417 (M^+, 100%)]. The presence of the phosphorous atom was supported by ^{31}P NMR spectroscopy, which gave a single phosphorus resonance at 5.48 ppm, typical of a phosphorane. The ^{13}C NMR spectrum, complicated by extensive P–C coupling, identified a total of 13 independent carbon resonances of which six were quaternary (DEPT) and suggested the presence of a triphenylphosphorane group. The presence of a cyano group was supported by an IR band at 2203 cm^{-1} and a carbon signal at 117.4 ppm. The most up field carbon resonance (95.9 ppm) indicated the absence of any sp^3 hybridised carbons. ^1H NMR spectroscopy identified only one D_2O exchangeable signal at 10.75 ppm, that was very similar to the indole NH observed in the 3-aminoindole-2-carbonitrile **3a** described above, however stretching frequencies to support this 2° amino function were notably absent from the IR spectra. Tentatively, the structure of the iminotriphenylphosphorane **4a** was proposed. Confirmation of the assignment was achieved via the clean interconversion of iminotriphenylphosphorane **4a** into 3-aminoindole-2-carbonitrile **3a** (Scheme 1).



4a **3a**

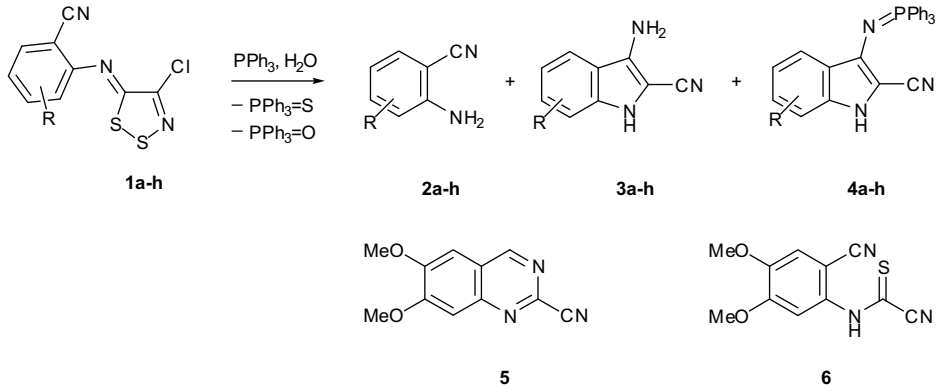
Scheme 1. Reagents and conditions: (i) 0.5 N HCl, MeOH, 80 °C, 32 h, 93%; (ii) 80% AcOH, 80 °C, 6.5 h, 92%; (iii) PPh_3 (2 equiv), C_2Cl_6 (2 equiv), Et_3N (4 equiv), dry PhH, 80 °C, 6 h, 91%.

The dithiazole to indole transformation was broadened to a variety of aryl substituted (dithiazolylideneamino)benzonitriles **1a**–**h**[18] (Table 2). Interestingly the 5-nitro and 4-chloro substituted analogues gave the corresponding indoles in relatively high and preparatively useful yields 75 and 71%, respectively. Nevertheless the electron rich methoxy substituted analogues gave little to no yield of indoles. In the case of the 4,5-dimethoxy substituted (dithiazolylideneamino)benzonitrile **1h** an unexpected 6,7-dimethoxyquinazoline-2-carbonitrile **5** was isolated in 15% yield together with the known 2-cyano-4,5-dimethoxy cyanothioformanilide **6**[7g] (36%).

6,7-Dimethoxyquinazoline-2-carbonitrile **5** was obtained as yellow cotton fibres, mp 170–171 °C. Microanalysis and mass spectrometry supported the formula $C_{11}H_9N_3O_2$ [*m*/*z* (EI) 215 (M^+, 100%)]. The presence of a cyano group was supported by an IR band at 2230 cm^{-1} and stretching frequencies could be not be observed for any 1° or 2° amino functionality. The ^{13}C NMR spectrum showed 11 separate carbon resonances of which six were quaternary carbons as supported by DEPT studies. Three aromatic CH carbon resonances were identifiable (137.4, 114.5 and 101.8 ppm) and ^1H NMR spectrometry confirmed the presence of three aromatic H resonances with singlets at 8.17, 7.51 and 7.31 ppm. Interestingly, to the best of our knowledge, there has been only one reported example of a 4-unsubstituted quinazoline-2-carbonitrile, prepared from 2-chloroquinazoline and tetraethylammonium cyanide.[19] The proposed 6,7-dimethoxyquinazoline-2-carbonitrile **5** maintained the carbon–nitrogen connectivity of the starting (dithiazolylideneamino)benzonitrile **1h**. The formation of 4-alkoxyquinazoline-2-carbonitriles from 2-(4-chloro-5*H*-1,2,3-dithiazolylideneamino)benzonitriles on treatment with alkoxides was known, and a rational mechanism for the transformation has been proposed.[20] The unexpected formation of this 4-unsubstituted analogue however, together with the unusual indole products suggested that (dithiazolylideneamino)benzonitriles are capable of more complex chemistry that remains to be understood and exploited.

In light of the reactions' complexity, we then investigated the use of polymer bound triphenylphosphine as an alternative phosphine source, in the hope that cleaner reaction mixtures could be obtained devoid of 'free' triphenylphosphine sulfide and oxide. In preliminary studies it was advantageous to use at least 5 mol equiv of polymer bound triphenylphosphine in the presence of water (2 equiv) at ca. 20 °C and to allow longer reaction times (24 h). The use of additional

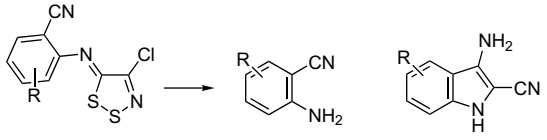
Table 2
Reaction of 2-(4-chloro-5*H*-1,2,3-dithiazolylideneamino)benzonitriles **1a–h** (0.2 mmol) with PPh_3 (4 equiv) and H_2O (2 equiv) in distilled DCM (2 mL) at ca. 20 °C for 5 min under a $CaCl_2$ drying tube



1a–g (R)	PPh_3=S	Yields (%)			
		2a–g	**3a–g**	**4a–g**	PPh_3=O
1a (H)	74	**2a** (13)	**3a** (39)	**4a** (16)	80
1b (5-NO_2)	99	**2b** (8)	**3b** (75)	**4b** (0)	95
1c (3-Br–5-NO_2)	78	**2c** (43)	**3c** (41)	**4c** (15)	67
1d (4-Cl)	92	**2d** (25)	**3d** (71)	**4d** (0)	93
1e (5-Cl)	96	**2e** (27)	**3e** (32)	**4e** (0)	93
1f (6-Me)	79	**2f** (30)	**3f** (6)	**4f** (0)	65
1g (4-MeO)	79	**2g** (14)	**3g** (7)	**4g** (0)	75
1h (4,5-$(MeO)_2$)[a]	77	**2h** (0)	**3h** (0)	**4h** (0)	81

[a] 6,7-Dimethoxyquinazoline-2-carbonitrile **5** and 2-cyano-4,5-dimethoxy cyanothioformanilide **6** were isolated in 15 and 36% yields, respectively.

Table 3
Reaction of 2-(4-chloro-1,2,3-dithiazolylideneamino)benzonitriles **1a–h** (0.2 mmol) with PPh_3 polymer bound (5 equiv) and water (2 equiv) in distilled DCM (2 mL) at ca. 20 °C for 24 h



1 (R)	Yields (%)	
	2	**3**
1a (H)	**2a** (7)	**3a** (26)
1b (5-NO_2)	**2b** (5)	**3b** (55)
1c (3-Br–5-NO_2)	**2c** (27)	**3c** (27)
1d (4-Cl)	**2d** (10)	**3d** (39)
1e (5-Cl)	**2e** (8)	**3e** (13)
1f (6-Me)	**2f** (27)	**3f** (27)
1g (4-MeO)	**2g** (36)	**3g** (29)
1h (4,5-$(MeO)_2$)	**2h** (52)	**3h** (0)

equivalents of water or the use of higher reaction temperatures did not improve the yields of aminoindolecarbonitriles. Under these semi-optimised conditions a variety of substituted 2-(4-chloro-5*H*-1,2,3-dithiazolylidineamino)benzonitriles **1a–h** were reacted with polymer bound triphenylphosphine (Table 3).

The reaction mixtures involving polymer bound triphenylphosphine were less complex, affording only the desired aminoindolecarbonitriles and some anthranilonitriles. Interestingly, the (dithiazolylideneamino)benzonitriles **1c**,**f–h** gave significant recoveries of the corresponding anthranilonitriles **2c**,**f–h**, respectively. While the use of polymer bound triphenylphosphine facilitated the chromatographic isolation of the desired indoles the overall yields were poor to moderate. Further work, to decipher the reaction mechanism, could lead to improved recoveries of indoles.

3. Conclusions

A new transformation of 1,2,3-dithiazolimines into 3-aminoindole-2-carbonitriles has been discovered. The reaction can be performed using either free triphenylphosphine or polymer bound triphenylphosphine. The indole yields are moderate and the electron rich dimethoxy derivative failed to afford the indole product. The scope of this transformation and the reaction mechanism are now under study.

4. Experimental

4.1. General methods and materials

DCM was freshly distilled from CaH_2 under argon. Reactions were protected from atmospheric moisture by $CaCl_2$ drying tubes. Anhydrous Na_2SO_4 was used for drying organic extracts, and all volatiles were removed under reduced pressure. All reaction mixtures and column eluents were monitored by TLC using commercial glass backed thin layer chromatography (TLC) plates (Merck Kieselgel 60 F_{254}). The plates were observed under UV light at 254 and 365 nm. The technique of dry flash chromatography was used throughout for all non-TLC scale chromatographic separations using Merck Silica Gel 60 (less than 0.063 mm). Melting points were determined using a PolyTherm-A, Wagner & Munz, Koefler-Hotstage Microscope apparatus. Solvents used for recrystallisation are indicated after the melting point. UV spectra were obtained using a Perkin–Elmer Lambda-25 UV/vis spectrophotometer and inflections are identified by the abbreviation 'inf'. IR spectra were recorded on a Shimadzu FTIR-NIR Prestige-21 spectrometer with a Pike *Miracle* Ge ATR accessory and strong, medium and weak peaks are represented by s, m and w, respectively. ^1H and ^{13}C NMR spectra were recorded on a Bruker Avance 300 machine (at 300 and 75 MHz, respectively). Deuterated solvents were used for homonuclear lock and the signals are referenced to the deuterated solvent peaks. Low resolution (EI) mass spectra were recorded on

a Shimadzu Q2010 GCMS with direct inlet probe. The polymer bound triphenylphosphine was crosslinked with 2% DVB, 200–400 mesh and contained 3 mmol triphenylphosphine/g resin (Fluka 39319-11-4). 4,5-Dichloro-1,2,3-dithiazolium chloride[11] and the 2-(4-chloro-5*H*-1,2,3-dithiazolylideneamino)benzonitriles **1a**–**h**[18] were prepared according to literature procedures. The isolated reaction by-products, triphenylphosphine sulfide, oxide and the anthranilonitriles **2a**–**h**, and 2-cyano-4,5-dimethoxy cyanothioformanilide **6**[7g] were identical to authentic samples.

4.2. 3-Bromo-2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylideneamino)-5-nitrobenzonitrile 1c: typical procedure

To a stirred solution of 4,5-dichloro-1,2,3-dithiazolium chloride (173.1 mg, 0.83 mmol) in DCM (4 mL) at ca. 20 °C and protected with a $CaCl_2$ drying tube, was added 2-amino-3-bromo-5-nitrobenzonitrile (200 mg, 0.83 mmol). After 1 h, to the reaction mixture was added, dropwise, pyridine (134 μL, 1.66 mmol, 2 equiv) and left to stir at ca. 20 °C for additional 2 h. The reaction mixture was adsorbed onto silica and chromatography (hexane) gave S_8 (traces). Further elution (hexane–DCM, 80:20) gave 4-chloro-5*H*-1,2,3-dithiazole-5-thione (10 mg, 6%) and further elution (hexane–DCM, 20:80) gave the *title compound* **1c** (168.4 mg, 73%) as yellow crystals, mp 171–172 °C (from EtOH); (Found: C, 28.6; H, 0.5; N, 15.0. $C_9H_2BrClN_4O_2S_2$ requires C, 28.6; H, 0.5; N, 14.8%); λ_{max} (DCM)/nm 236 (log ε 3.10), 284 (2.93), 371 (2.76); ν_{max}/cm^{-1} 3080w (Ph CH), 2240w (C≡N), 1591s, 1559s, 1525s, 1514w, 1497w, 1424m, 1343s, 1238m, 1212w, 1174w, 1153m, 1082m, 931w, 918w, 901m, 870m, 845w, 830m, 782s, 742s, 727m; δ_H (300 MHz; DMSO-d_6) 8.90 (1H, d, *J* 2.4, Ph *H*-4 or 6), 8.87 (1H, d, *J* 2.4, Ph *H*-4 or 6); δ_C (75 MHz; DMSO-d_6) 165.9, 157.3, 145.1, 144.4, 133.6 (Ph *C*H), 129.4 (Ph *C*H), 114.2, 113.9, 104.0; δ_C (75 MHz; DEPT-135, DMSO-d_6) 133.6 (Ph *C*H), 129.4 (Ph *C*H); *m*/*z* (EI) 380 (M^++4, 56%), 378 (M^++2, 100), 376 (M^+, 99), 317 (94), 315 (93), 287 (5), 285 (8), 279 (6), 253 (7), 237 (14), 235 (13), 233 (10), 231 (11), 227 (5), 225 (5), 207 (5), 193 (6), 190 (8), 181 (4), 158 (28), 152 (5), 125 (45), 107 (9), 100 (64), 95 (15), 93 (36), 88 (18), 75 (28), 70 (21), 64 (100), 50 (8), 46 (6).

4.3. Reaction of 2-(4-chloro-5*H*-1,2,3-dithiazolylideneamino)-benzonitriles with triphenylphosphine. General procedure (Table 2)

To a stirred solution of 2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylid eneamino)benzonitriles **1a**–**h** (0.20 mmol) in distilled DCM (2 mL) at ca. 20 °C and protected with a $CaCl_2$ drying tube, was added water (7.2 μL, 0.4 mmol, 2 equiv) and then triphenylphosphine (210 mg, 0.8 mmol, 4 equiv). The mixtures were then allowed to stir at ca. 20 °C for 5 min, until no starting material remained (TLC). The reaction mixtures were adsorbed onto silica and chromatography (hexane–DCM, 50:50) gave traces of unreacted Ph_3P, followed by triphenylphosphine sulfide, anthranilonitriles **2a**–**g** (hexane–DCM, 20:80), 3-aminoindole-2-carbonitriles **3a**–**g** (DCM, 100%), (2-cyanoindol-3-yl)iminotriphenylphosphorane **4a** (DCM–*t*-butyl ether, 80:20) and triphenylphosphine oxide (DCM–*t*-butyl ether, 70:30).

4.3.1. 3-Aminoindole-2-carbonitrile ***3a****.* (12.2 mg, 39%) light yellow cotton fibres, mp 172–173 °C (from cyclohexane–EtOH); (Found: C, 68.7; H, 4.5; N, 26.65. $C_9H_7N_3$ requires C, 68.8; H, 4.5; N, 26.7%); λ_{max} (DCM)/nm 233 (log ε 3.36), 245 (3.39), 290 (3.14), 299 inf (3.08), 323 inf (2.85); ν_{max}/cm^{-1} 3356m (NH), 3309 (NH_2), 3231w, 3059 (Ar CH), 2924w, 2212s (C≡N), 1628m, 1597w, 1584w, 1557m, 1493w, 1450w, 1344s, 1310s, 1292w, 1248w, 1182m, 1159s, 1105w, 1090w, 1042w, 1016w, 1009w, 932w, 891w, 814m, 746s, 739s, 727s; δ_H (300 MHz; DMSO-d_6) 10.67 (1H, br s, N*H*), 7.73 (1H, d, *J* 8.1, Ph *H*-4), 7.24 (1H, ddd, 1.1, 7.5, 7.5, Ph *H*-5), 7.18 (1H, d, *J* 7.8, Ph *H*-7), 6.94 (1H, ddd, 1.2, 7.5, 7.5, Ph *H*-6), 5.71 (2H, br s, NH_2); δ_C (75 MHz; DMSO-d_6) 139.0, 136.8, 126.1 (Ph *C*H), 120.2 (Ph *C*H), 118.2, 118.0 (Ph *C*H), 116.2 (*C*≡N), 111.6 (Ph *C*H), 86.6 (*C*C≡N); δ_C (75 MHz; DEPT-135, DMSO-d_6) 126.1 (Ph *C*H), 120.2 (Ph *C*H), 118.0 (Ph *C*H), 111.6 (Ph *C*H); *m*/*z* (EI) 157 (M^+, 100%), 129 (31), 105 (23), 104 (40), 103 (48), 102 (32), 77 (12), 76 (26), 75 (14), 65 (5), 51 (16), 50 (13).

4.3.2. (2-Cyanoindol-3-yl)iminotriphenylphosphorane ***4a****.* (13.3 mg, 16%) colourless crystals, mp 183–184 °C (from benzene); (Found: C, 77.6; H, 4.9; N, 10.1. $C_{27}H_{20}N_3P$ requires C, 77.7; H, 4.8; N, 10.1%); λ_{max} (DCM)/nm 231 (log ε 4.52), 253 inf (4.36), 293 (3.92), 303 inf (3.87), 345 (3.87); ν_{max}/cm^{-1} 3076w, 3059w, 2203m (C≡N), 1614w, 1574w, 1520s, 1464w, 1450w, 1437m, 1383w, 1333m, 1315w, 1265m, 1252m, 1202w, 1188w, 1165w, 1115s, 1103m, 1018w, 993m, 924w, 845w, 746s, 733s, 719s; δ_H (300 MHz; DMSO-d_6) 10.75 (1H, br s, N*H*), 7.80–7.73 (6H, m, Ph_3P *H*), 7.66–7.53 (9H, m, Ph_3P *H*), 7.18–7.11 (3H, m, indole *H*), 6.74 (1H, ddd, 1.8, 6.7, 6.7, indole *H*-5 or 6); δ_C (75 MHz; CD_2Cl_2) 141.7, 137.6, 133.0 (d, J_{PC} 9.75, Ph_3P *C*-3), 132.3 (d, J_{PC} 3.0, Ph_3P *C*-4), 131.85 (d, J_{PC} 101.2, Ph_3P *C*-1), 129.0 (d, J_{PC} 12.0, Ph_3P *C*-2), 126.25 (indole *C*H), 125.5 (d, J_{PC} 11.25, indole *C*-3), 121.5 (indole *C*H), 119.3 (indole *C*H), 117.4 (*C*≡N), 111.8 (indole *C*H), 95.9 (d, J_{PC} 13.5, indole *C*-2, *C*C≡N); δ_C (75 MHz; DEPT-135, CD_2Cl_2) 133.0 (d, J_{PC} 9.75, Ph_3P *C*-3), 132.3 (d, J_{PC} 3.0, Ph_3P *C*-4), 129.0 (d, J_{PC} 12.0, Ph_3P *C*-2), 126.25 (indole *C*H), 121.5 (indole *C*H), 119.3 (indole *C*H), 111.8 (indole *C*H); δ_P (121.5 MHz; CD_2Cl_2) 5.48; *m*/*z* (EI) 417 (M^+, 100%), 390 (14), 340 (5), 313 (7), 262 (11), 232 (14), 209 (12), 205 (23), 183 (84), 170 (3), 152 (9), 141 (6), 115 (4), 108 (17), 89 (3), 77 (17), 51 (7).

4.3.3. 3-Amino-5-nitroindole-2-carbonitrile ***3b****.* (30.3 mg, 75%) red cotton fibres, mp 310–311 °C (from benzene); (Found: C, 53.4; H, 2.9; N, 27.6. $C_9H_6N_4O_2$ requires C, 53.5; H, 3.0; N, 27.7%); λ_{max} (DCM)/nm 225 (log ε 4.14), 237 inf (3.17), 265 (3.19), 268 (3.18), 272 (3.23), 299 (3.49); ν_{max}/cm^{-1} 3463w (NH_2), 3376m and 3279m (NH), 3065w, 2204s (C≡N), 1635m, 1614m, 1588m, 1533m, 1521w, 1476s, 1398w, 1327s, 1244w, 1190m, 1132w, 1064m, 942w, 914w, 846w, 814m, 778w, 755m; δ_H (300 MHz; DMSO-d_6) 11.62 (1H, br s, N*H*), 8.95 (1H, d, *J* 2.4, Ph *H*-4), 8.07 (1H, dd, *J* 2.3, 9.2, Ph *H*-6), 7.33 (1H, d, *J* 9.3, Ph *H*-7), 6.29 (2H, br s, NH_2); δ_C (75 MHz; DMSO-d_6) 141.0, 139.4, 138.5, 120.8 (Ph *C*H), 118.9 (Ph *C*H), 117.2, 115.0 (*C*≡N), 112.1 (Ph *C*H), 87.4 (*C*C≡N); δ_C (75 MHz; DEPT-135, DMSO-d_6) 120.8 (Ph *C*H), 118.9 (Ph *C*H), 112.1 (Ph *C*H); *m*/*z* (EI) 202 (M^+, 100%), 183 (2), 172 (5), 156 (75), 144 (10), 129 (69), 117 (5), 102 (48), 94 (10), 75 (22), 63 (9), 51 (12), 50 (12).

4.3.4. 3-Amino-7-bromo-5-nitroindole-2-carbonitrile ***3c****.* (14.9 mg, 41%), orange cotton fibres, mp 290–291 °C (from benzene); (Found: C, 38.4; H, 1.8; N, 19.8. $C_9H_5BrN_4O_2$ requires C, 38.5; H, 1.8; N, 19.9%); λ_{max} (DCM)/nm 238 inf (log ε 3.25), 265 (3.24), 269 (3.27), 273 (3.29), 294 (3.39), 360 inf (2.73), 414 inf (2.28); ν_{max}/cm^{-1} 3434w (NH_2), 3356w (NH), 3254w, 3090w (Ar CH), 2206s (C≡N), 1647m, 1610w, 1587m, 1560w, 1526s, 1476s, 1424w, 1327s, 1239w, 1207w, 1190s, 1072w, 1045w, 1022m, 990m, 902m, 886w, 870w, 848w, 828w, 787w; δ_H (300 MHz; DMSO-d_6) 11.91 (1H, br s, N*H*), 8.99 (1H, d, *J* 1.8, Ph *H*-4), 8.27 (1H, d, *J* 1.8, Ph *H*-6), 6.41 (2H, br s, NH_2); δ_C (75 MHz; DMSO-d_6) 141.8, 139.6, 136.75, 122.7 (Ph *C*H), 118.2 (Ph *C*H), 117.9, 114.4, 104.3, 89.4 (*C*C≡N); δ_C (75 MHz; DEPT-135, DMSO-d_6) 122.7 (Ph *C*H), 118.2 (Ph *C*H); *m*/*z* (EI) 282 (M^++2, 100%), 280 (M^+, 92), 252 (3), 236 (75), 235 (13), 234 (84), 224 (9), 222 (9), 209 (42), 207 (46), 180 (7), 182 (7), 155 (83), 143 (15), 128 (66), 116 (14), 102 (42), 101 (75), 100 (73), 99 (22), 88 (12), 77 (24), 76 (46), 75 (67), 74 (69), 73 (14), 64 (19), 63 (20), 62 (23), 54 (11), 53 (45), 52 (44), 50 (30).

4.3.5. (7-Bromo-2-cyano-5-nitroindol-3-yl)iminotriphenylphosphorane ***4c****.* (10.5 mg, 15%), red cotton fibres, mp 120–121 °C (from benzene); (Found: C, 60.0; H, 3.2; N, 10.2. $C_{27}H_{18}BrN_4O_2P$ requires C,

59.9; H, 3.35; N, 10.35%); λ_{max} (DCM)/nm 221 (log ε 4.07), 225 (3.81), 264 (3.40), 272 (3.39), 300 (3.51), 365 inf (2.93); ν_{max}/cm^{-1} 3330w (NH), 2923w, 2847w, 2199m (C≡N), 1607w, 1570w, 1533s, 1483m, 1449w, 1445w, 1436m, 1421w, 1325s, 1271s, 1236m, 1209m, 1188w, 1112s, 1074m, 1010w, 1000w, 909w, 887w, 873w, 846w, 742s, 719s; δ_H (300 MHz; DMSO-d_6) 11.99 (1H, br s, N*H*), 8.19 (1H, d, *J* 2.1, indole *H*-4 or 6), 8.04 (1H, d, *J* 2.1, indole *H*-4 or 6), 7.81–7.74 (6H, m, Ph_3P *H*), 7.70–7.56 (9H, m, Ph_3P *H*); δ_C (75 MHz; DMSO-d_6) 143.0, 139.8, 136.65, 132.5 (d, J_{PC} 3.0, Ph_3P *C*-4), 132.1 (d, J_{PC} 10.5, Ph_3P *C*-3), 130.1 (d, J_{PC} 100.5, Ph_3P *C*-1), 129.1 (d, J_{PC} 12.0, Ph_3P *C*-2), 123.7 (d, J_{PC} 12.1, indole *C*-3), 122.0 (Ph *C*H), 117.5 (Ph *C*H), 115.4 (d, J_{PC} 2.3, *C*≡N), 104.7, 98.7 (d, J_{PC} 14.3, indole *C*-2, *C*C≡N); δ_C (75 MHz; DEPT-135, DMSO-d_6) 132.5 (d, J_{PC} 3.0, Ph_3P *C*-4), 132.1 (d, J_{PC} 10.5, Ph_3P *C*-3), 129.1 (d, J_{PC} 12.0, Ph_3P *C*-2), 122.0 (Ph *C*H), 117.5 (Ph *C*H); δ_P(121.5 MHz; DMSO-d_6) 7.24; *m*/*z* (EI) 542 (M$^+$+2, 100%), 540 (M$^+$, 100), 515 (8), 495 (9), 494 (8), 493 (8), 462 (9), 415 (4), 389 (2), 336 (2), 311 (3), 282 (3), 278 (7), 277 (17), 262 (10), 247 (4), 234 (3), 207 (5), 201(7), 185 (15), 184 (15), 183 (88), 152 (13), 132 (7), 108 (14), 77 (12).

4.3.6. 3-Amino-6-chloroindole-2-carbonitrile ***3d***. (27.1 mg, 71%) red powder, mp 210–211 °C (from EtOH); (Found: C, 56.4; H, 3.04; N, 21.8. $C_9H_6ClN_3$ requires C, 56.4; H, 3.2; N, 21.9%); λ_{max} (DCM)/nm 253 (log ε 3.64), 298 (3.17), 309 inf (3.08), 336 (2.88); ν_{max}/cm^{-1} 3411w, 3386w, 3354w (NH), 3335w, 3298w, 3228w, 2221s and 2212s (C≡N), 1617m, 1581m, 1551m, 1507w, 1490w, 1465w, 1458w, 1444w, 1338s, 1290w, 1245w, 1221w, 1188m, 1113w, 1061s, 922m, 859w, 843m, 799s; δ_H (300 MHz; DMSO-d_6) 10.88 (1H, br s, N*H*), 7.75 (1H, d. *J* 8.7, Ph *H*-4), 7.23 (1H, d, *J* 1.8, Ph *H*-7), 6.97 (1H, dd, *J* 1.8, 8.7, Ph *H*-5) 5.83 (2H, br s, NH_2); δ_C (75 MHz; DMSO-d_6) 139.0, 136.8, 131.0, 121.8 (Ph *C*H), 118.5 (Ph *C*H), 117.0, 115.7 (*C*≡N), 111.05 (Ph *C*H), 87.3 (*C*C≡N); δ_C (75 MHz; DEPT-135, DMSO-d_6) 121.80 (Ph *C*H), 118.5 (Ph *C*H), 111.05 (Ph *C*H); *m*/*z* (EI) 193 (M$^+$+2, 32%), 191 (M$^+$, 100), 165 (7), 163 (15), 156 (M$^+$−Cl, 19), 137 (19), 129 (11), 110 (3), 102 (12), 100 (9), 95 (5), 75 (12), 63 (2), 50 (4).

4.3.7. 3-Amino-5-chloroindole-2-carbonitrile ***3e***. (12.2 mg, 32%) light red powder, mp 190–191 °C (from EtOH); (Found: C, 56.4; H, 3.2; N, 21.9. $C_9H_6ClN_3$ requires C, 56.4; H, 3.2; N, 21.9%); λ_{max} (DCM)/nm 221 (log ε 3.65), 223 (3.56), 253 (3.46), 256 (3.43), 299 (3.03), 307 inf (2.98), 341 (2.80); ν_{max}/cm^{-1} 3458w (NH$_2$), 3371w and 3329m (NH), 2202s (C≡N), 1627m, 1581w, 1554m, 1473m, 1447w, 1374w, 1321m, 1292s, 1235w, 1188w, 1140m, 1123m, 1055m, 1025w, 1000w, 924w, 847m, 800s, 782w; δ_H (300 MHz; DMSO-d_6) 10.92 (1H, br s, N*H*), 7.85 (1H, s, Ph *H*), 7.22–7.21 (2H, m, Ph *H*), 5.76 (2H, br s, NH_2); δ_C (75 MHz; DMSO-d_6) 138.3, 135.0, 126.1 (Ph *C*H), 122.4, 119.45 (Ph *C*H), 119.0, 115.6 (*C*≡N), 113.4 (Ph *C*H), 88.1 (*C*C≡N); δ_C (75 MHz; DEPT-135, DMSO-d_6) 126.1 (Ph *C*H), 119.45 (Ph *C*H), 113.4 (Ph *C*H); *m*/*z* (EI) 193 (M$^+$+2, 32%), 191 (M$^+$, 100), 165 (6), 163 (15), 156 (M$^+$−Cl, 33), 138 (17), 137 (16), 136 (11), 129 (14), 112 (2), 102 (14), 100 (11), 95 (4), 75 (13), 62 (2), 50 (6).

4.3.8. 3-Amino-4-methylindole-2-carbonitrile ***3f***. (2.1 mg, 6%) yellow cotton fibres, mp 156–157 °C (from cyclohexane–EtOH); (Found: C, 70.3; H, 5.3; N, 24.55. $C_{10}H_9N_3$ requires C, 70.2; H, 5.3; N, 24.5%); λ_{max} (DCM)/nm 230 inf (log ε 3.35), 242 (3.41), 273 (1.95), 297 (2.85), 331 (2.87); ν_{max}/cm^{-1} 3423w and 3330s (NH$_2$), 3049w and 3018w (Ar CH), 2977w, 2927w, 2202s, (C≡N), 1615m, 1586m, 1546m, 1516w, 1470w, 1439w, 1419w, 1376w, 1358m, 1318m, 1262m, 1245m, 1185m, 1165w, 1133w, 1077w, 1050w, 1030w, 967w, 948w, 864w, 789w, 772s; δ_H (300 MHz; DMSO-d_6) 10.81 (1H, br s, N*H*), 7.07 (1H, dd, *J* 7.5, 7.5, Ph *H*-5), 6.99 (1H, d, *J* 8.1, Ph *H*-7), 6.64 (1H, d, *J* 6.6, Ph *H*-6), 5.16 (2H, br s, NH_2), 3.39 (3H, s, CH_3); δ_C (75 MHz; DMSO-d_6) 139.6, 137.3, 132.1, 126.1 (Ph *C*H), 119.6 (Ph *C*H), 117.3 (*C*-7), 115.95 (*C*≡N), 109.7 (Ph *C*H), 88.3 (*C*C≡N), 19.5 (*C*H$_3$); δ_C (75 MHz; DEPT-135, DMSO-d_6) 126.1 (Ph *C*H), 119.6 (Ph *C*H), 109.7 (Ph *C*H), 19.5 (*C*H$_3$); *m*/*z* (EI) 171 (M$^+$, 100%), 156 (7), 143 (16), 116 (15), 89 (15), 76 (3), 63 (6), 51 (3).

4.3.9. 3-Amino-6-methoxyindole-2-carbonitrile ***3g***. (2.6 mg, 7%) red crystals, mp 179–180 °C (from cyclohexane–EtOH); (Found: C, 64.2; H, 4.7; N, 22.4. $C_{10}H_9N_3O$ requires C, 64.2; H, 4.85; N, 22.5%); λ_{max} (DCM)/nm 230 inf (log ε 4.18), 254 (4.37), 305 inf (4.12), 312 (4.16); ν_{max}/cm^{-1} 3440w (NH$_2$), 3378w and 3348w (NH), 3234w, 2971w, 2936w, 2843w, 2207s (C≡N), 1623s, 1586s, 1556m, 1506m, 1455s, 1441w, 1338m, 1315s, 1251w, 1225s, 1207w, 1185w, 1167s, 1103s, 1021s, 951w, 941w, 823s, 808s; δ_H (300 MHz; DMSO-d_6) 10.46 (1H, br s, N*H*), 7.60 (1H, d, *J* 8.7, Ph *H*-4), 6.61–6.57 (2H, m, Ph *H*-5 and 7), 5.64 (2H, br s, NH_2), 3.76 (3H, s, CH_3O); δ_C (75 MHz; DMSO-d_6) 159.1, 139.4, 137.9, 121.0 (Ph *C*H), 116.55, 112.5, 109.3 (Ph *C*H), 93.3 (Ph *C*H), 85.3 (*C*C≡N), 55.0 (*C*H$_3$O); δ_C (75 MHz; DEPT-135, DMSO-d_6) 121.0 (Ph *C*H), 109.35 (Ph *C*H), 93.3 (Ph *C*H), 55.0 (*C*H$_3$O); *m*/*z* (EI) 187 (M$^+$, 100%), 186 (7), 172 (72), 159 (8), 144 (42), 129 (3), 117 (18), 90 (11), 76 (4), 63 (13), 52 (3).

4.3.10. 6,7-Dimethoxyquinazoline-2-carbonitrile ***5***. (5.2 mg, 15%) yellow cotton, mp 170–171 °C (from cyclohexane); (Found: C, 61.35; H, 4.2; N, 19.5. $C_{11}H_9N_3O_2$ requires C, 61.4; H, 4.2; N, 19.5%); λ_{max} (DCM)/nm 228 (log ε 3.02), 235 (3.21), 261 (3.35), 285 inf (2.88), 363 (3.02); ν_{max}/cm^{-1} 2974w, 2920w, 2851w, 2230m (C≡N), 1597m, 1547w, 1537w, 1516s, 1464m, 1441w, 1396w, 1368m, 1339w, 1287s, 1231s, 1198w, 1109s, 1026w, 993s, 908w, 876m, 837m; δ_H (300 MHz; DMSO-d_6) 8.17 (1H, s, Ph *H*-4), 7.51 (1H, s, Ph *H*-5), 7.31 (1H, s, Ph *H*-8) 3.87 (3H, s, CH_3O), 3.86 (3H, s, CH_3O); δ_C (75 MHz; DMSO-d_6) 152.9, 150.2, 143.85, 137.4 (Ph *C*H), 116.8, 116.0, 114.5 (Ph *C*H), 102.2, 101.8 (Ph *C*H), 56.3 (*C*H$_3$O), 56.25 (*C*H$_3$O); δ_C (75 MHz; DEPT-135, DMSO) 137.4 (Ph *C*H), 114.5 (Ph *C*H), 101.8 (Ph *C*H), 56.3 (*C*H$_3$O), 56.25 (*C*H$_3$O); *m*/*z* (EI) 215 (M$^+$, 100%), 200 (72), 188 (2), 172 (33), 157 (5), 145 (74), 129 (11), 117 (25), 115 (12), 106 (8), 104 (29), 102 (49), 90 (39), 88 (23), 78 (57), 76 (58), 64 (33), 53 (30).

4.4. 3-Amino-1*H*-indole-2-carbonitrile 3a from (2-cyanoindol-3-yl)iminotriphenylphosphorane 4a

4.4.1. Using HCl (0.5 M). To a stirred solution of (2-cyanoindol-3-yl)iminotriphenylphosphorane **4a** (20 mg, 0.05 mmol) in MeOH (1 mL) at ca. 20 °C and protected with a $CaCl_2$ drying tube, was added 0.5 M HCl (1 mL) and the mixture was then heated to ca. 80 °C for 32 h, until no starting material remained (TLC). The reaction mixture was then extracted (DCM), dried (Na_2SO_4) and adsorbed onto silica. Chromatography (DCM, 100%) gave the title compound **3a** (7.3 mg, 93%) as light yellow cotton fibres, mp 172–173 °C (from cyclohexane–EtOH), identical to that described above.

4.4.2. Using AcOH (80%). To a stirred solution of 80% acetic acid (2 mL) at ca. 20 °C and protected with a $CaCl_2$ drying tube, was added (2-cyanoindol-3-yl)iminotriphenylphosphorane **4a** (20 mg, 0.05 mmol) and the mixture was heated to ca. 80 °C for 6.5 h, until no starting material remained (TLC). The reaction mixture was then extracted (DCM), dried (Na_2SO_4) and adsorbed onto silica. Chromatography (DCM, 100%) gave the title compound **3a** (7.2 mg, 92%) as light yellow cotton fibres, mp 172–173 °C (from cyclohexane–EtOH), identical to that described above.

4.5. (2-Cyanoindol-3-yl)iminotriphenylphosphorane 4a from 3-amino-1*H*-indole-2-carbonitrile 3a

To a stirred solution of 3-aminoindole-2-carbonitrile **3a** (20 mg, 0.13 mmol) in distilled benzene (2 mL) at ca. 20 °C and protected with a $CaCl_2$ drying tube, were added triethylamine (72.1 μL, 0.52 mmol, 4 equiv), triphenylphosphine (68.2 mg, 0.26 mmol, 2 equiv) and then hexachloroethane (61.6 mg, 0.26 mmol, 2 equiv).

The mixture was then heated to ca. 80 °C for 6 h, until no starting material remained (TLC). The reaction mixture was directly adsorbed onto silica and chromatography (DCM–*t*-butyl ether, 80:20) gave the title compound **4a** (49.3 mg, 91%) as colourless crystals, mp 183–184 °C (from benzene), identical to that described above.

4.6. 3-Aminoindole-2-carbonitriles 3a–h from triphenylphosphine (polymer bound). General procedure (Table 3)

To a stirred solution of 2-(4-chloro-5*H*-1,2,3-dithiazol-5-ylid eneamino)benzonitrile **1a**–**h** (0.20 mmol) in distilled DCM (2 mL) at ca. 20 °C and protected with a $CaCl_2$ drying tube, was added water (7.2 μL, 0.4 mmol, 2 equiv) and then triphenylphosphine polymer bound (333.3 mg, 1.0 mmol, 5 equiv). The mixtures were then allowed to stir at ca. 20 °C for 24 h. The reaction mixtures were then filtered to remove the triphenylphosphine polymer bound, and adsorbed onto silica. Chromatography gave anthranilonitriles **2a**–**h** (hexane–DCM, 50:50) and 3-aminoindole-2-carbonitriles **3a**–**h** (DCM, 100%) identical to those described above.

Acknowledgements

The authors wish to thank the Cyprus Research Promotion Foundation [Grant No. ΤΕΧΝΟΛΟΓΙΑ/ΘΕΠΙΣ/0308(ΒΕ)/08] and the following organisations in Cyprus for generous donations of chemicals and glassware: the State General Laboratory, the Agricultural Research Institute and the Ministry of Agriculture. Furthermore we thank the A.G. Leventis Foundation for helping to establish the NMR facility in the University of Cyprus.

References and notes

1. Konstantinova, L. S.; Bol'shakov, O. I.; Obruchnikova, N. V.; Laborie, H.; Tanga, A.; Sopéna, V.; Lanneluc, I.; Picot, L.; Sablé, S.; Thiéry, V.; Rakitin, O. A. *Bioorg. Med. Chem. Lett.* **2009**, *19*, 136.
2. (a) Cottenceau, G.; Besson, T.; Gautier, V.; Rees, C. W.; Pons, A. M. *Bioorg. Med. Chem. Lett.* **1996**, *6*, 529; (b) Thiery, V.; Rees, C. W.; Besson, T.; Cottenceau, G.; Pons, A. M. *Eur. J. Med. Chem.* **1998**, *33*, 149; (c) Joseph, R. W.; Antes, D. L.; Osei-Gyimah, P. U.S. Patent 5,688,744, 1997.
3. (a) Moore, J. E. U.S. Patent 4,059,590, 1977; (b) Appel, R.; Janssen, H.; Haller, I.; Plempel, M. DE Pat. 2,848,221, 1980; (c) Besson, T.; Rees, C. W.; Cottenceau, G.; Pons, A. M. *Bioorg. Med. Chem. Lett.* **1996**, *6*, 2343.
4. Mayer, R.; Foerster, E. DD Pat. 212,387, 1984.
5. Barclay, T. M.; Beer, L.; Cordes, A. W.; Oakley, R. T.; Preuss, K. E.; Taylor, N. J.; Reed, R. W. *Chem. Commun.* **1999**, 531; Beer, L.; Cordes, A. W.; Haddon, R. C.; Itkis, M. E.; Oakley, R. T.; Reed, R. W.; Robertson, C. M. *Chem. Commun.* **2002**, 1872.
6. Barclay, T. M.; Cordes, A. W.; Oakley, R. T.; Preuss, K. E.; Reed, R. W. *Chem. Commun.* **1998**, 1039.
7. (a) Emayan, K.; English, R. F.; Koutentis, P. A.; Rees, C. W. *J. Chem. Soc., Perkin Trans. 1* **1997**, 3345; (b) Christoforou, I. C.; Koutentis, P. A.; Rees, C. W. *J. Chem. Soc., Perkin Trans. 1* **2002**, 1236; (c) Koutentis, P. A.; Rees, C. W. *J. Chem. Soc., Perkin Trans. 1* **1998**, 2505; (d) Koutentis, P. A.; Rees, C. W.; White, A. J. P.; Williams, D. J. *J. Chem. Soc., Perkin Trans. 1* **1998**, 2765; (e) Christoforou, I. C.; Koutentis, P. A.; Michaelidou, S. S. *Arkivoc* **2006**, *7*, 207; (f) Lee, H.; Kim, K.; Whang, D.; Kim, K. *J. Org. Chem.* **1994**, *59*, 6179; (g) Besson, T.; Emayan, K.; Rees, C. W. *J. Chem. Soc., Perkin Trans. 1* **1995**, 2097.
8. (a) Rees, C. W. *J. Heterocycl. Chem.* **1992**, *29*, 639; (b) Besson, T.; Dozias, M. J.; Guillard, J.; Rees, C. W. *J. Chem. Soc., Perkin Trans. 1* **1998**, 3925.
9. Rakitin, O. A.; Rees, C. W.; Vlasova, O. G. *Tetrahedron Lett.* **1996**, *37*, 4589.
10. Besson, T.; Guillaumet, G.; Lamazzi, C.; Rees, C. W. *Synlett* **1997**, 704.
11. (a) Appel, R.; Janssen, H.; Siray, M.; Knoch, F. *Chem. Ber.* **1985**, *118*, 1632; (b) Koutentis, P. A. *Molecules* **2005**, *10*, 346.
12. Besson, T.; Rees, C. W. *J. Chem. Soc., Perkin Trans. 1* **1995**, 1659; Rakitin, O. A.; Konstantinova, L. S. *Adv. Heterocycl. Chem.* **2008**, *96*, 175.
13. Rakitin, O. A. (eds. in Chief: Katritzky, A. R.; Ramsden, C. A.; Scriven, E. F. V.; Taylor, R. J. K.) In *Comprehensive Heterocyclic Chemistry III*; Zhdankin, V. V., Ed.; Elsevier: Oxford, 2008; Vol. 6, Chapter 6.01, p 1; Konstantinova, L. S.; Rakitin, O. A. *Russ. Chem. Rev.* **2008**, *77*, 521; Kim, K. *Sulfur Rep.* **1998**, *21*, 147; Kim, K. *Phosphorus, Sulfur Silicon Relat. Elem.* **1997**, *120*, 229.
14. d'Ischia, M.; Napolitano, A.; Pezzella, A. (eds. in Chief: Katritzky, A. R., Ramsden, C. A., Scriven, E. F. V., Taylor, R. J. K.) In *Comprehensive Heterocyclic Chemistry III*; Jones, G., Ramsden, C. A., Eds.; Elsevier: Oxford, 2008; Vol. 3; Chapter 3.04, p 353.
15. Clarke, K.; Fox, W. R.; Scrowston, R. M. *J. Chem. Res., Miniprint* **1980**, 0833; Ryabova, S. Y.; Alekseeva, L. M.; Lisitsa, E. A.; Granik, V. G. *Russ. Chem. Bull.* **2006**, *55*, 1248.
16. Besson, T.; Emayan, K.; Rees, C. W. *J. Chem. Soc., Chem. Commun.* **1995**, 1419; Le, V.-D.; Rees, C. W.; Sivadasan, S. *Tetrahedron Lett.* **2000**, *41*, 9407; Besson, T.; Guillard, J.; Rees, C. W. *J. Chem. Soc., Perkin Trans. 1* **2000**, 563.
17. Eger, K.; Lanzner, W.; Rothenhausler, K. *Liebigs Ann.* **1993**, *1993*, 465.
18. Michaelidou, S. S.; Koutentis, P. A. *Synthesis*, submitted for publication.
19. Hermann, K.; Simchen, G. *Liebigs Ann.* **1981**, *1981*, 333.
20. Besson, T.; Rees, C. W. *J. Chem. Soc., Perkin Trans. 1* **1996**, 2857.