Tetrahedron Vol. 46, No. 3, pp. 1063-1078, 1990
Printed in Great Britain

0040-4020/90 $3.00+.00

NEW METHODOLOGY FOR THE PREPARATION OF PYRROLE AND INDOLE DERIVATIVES VIA IMINOPHOSPHORANES:SYNTHESIS OF PYRROLO[1,2-a]QUINOXALINES, INDOLO[3,2-c]QUINOLINES AND INDOLO[1,2-c]QUINAZOLINES[1].

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(*Received in UK* 20 *October* 1989)

Abstract.- *The aza-Wittig reaction of iminophosphorane N-[o-(triphenylphosphoranylidene)amino]-phenyl pyrrole 4 with heterocumulenes leads to functionalized pyrrolo[1,2-a]quinoxalines. Iminophosphorane 19, derived from 2-(o-amino)phenyl indole, reacts under mild conditions with isocyanates to form 21 which are converted into 5-amino-11H-indolo[3,2-c]quinolines 22. Iminophosphorane 19 also reacts with carbon dioxide and carbon disulfide to give indolo[3,2-c]quinolines 23. Iminophosphorane 28, derived from 2-(o-azido)-phenyl-3-phenyl indole, reacts with isocyanates, carbon dioxide and carbon disulfide to form indolo[1,2-c]-quinazolines 29 and 30 respectively.*

There is ongoing interest in the development of new and improved methods for the synthesis of the pyrrole and indole derivatives due to the biochemical and pharmacological significance of these ring systems[2]. In the course of our studies directed toward the iminophosphorane-mediated synthesis of polyheterocycles we have found that the tandem aza-Wittig/electrocyclization strategy has shown to be an useful protocol for the preparation of fused indoles[3,4] e.g. α-, β- , γ-carbolines and pyrimido[4,3-b]indoles.

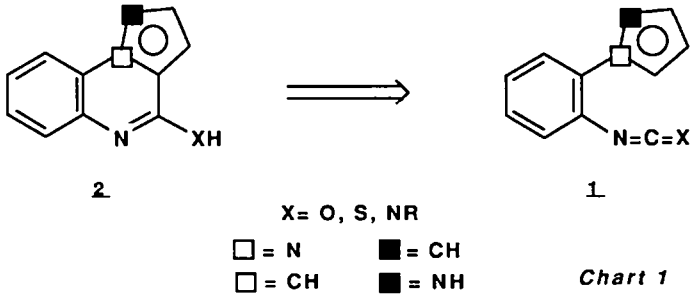
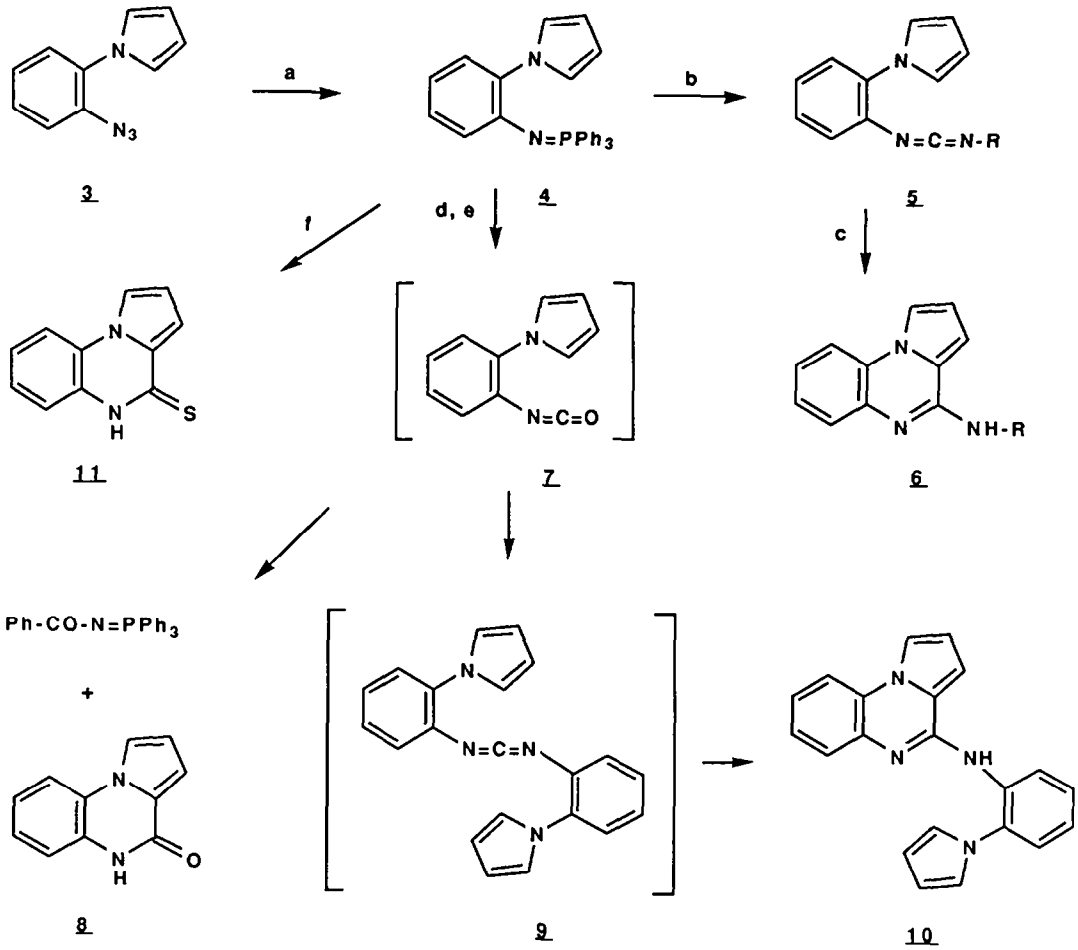


Chart 1

We now report a fundamentally new simple and apparently general method to the synthesis of fused pyrroles, namely, pyrrolo[1,2-a]quinoxalines, indolo[3,2-c]quinolines and indolo[1,2-c]quinazolines. Our approach is centered on the aza-Wittig type reaction of iminophosphoranes with heterocumulenes: e.g. isocyanates, isothiocyanates, carbon dioxide and carbon disulfide to give o-pyrrolylphenyl heterocumulenes 1, which subsequently undergo ring closure leading to the fused pyrroles 2 (Chart 1).

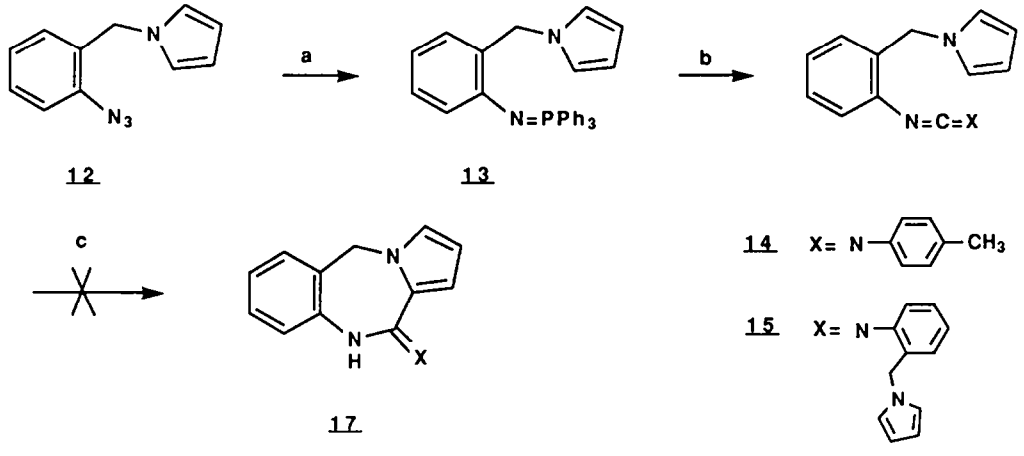
Pyrrolo[1,2-a]quinoxalines. The more convenient method for the preparation of pyrrolo[1,2-a]quinoxalines involves acylation of the N-(2-aminophenyl)-pyrrole followed by cyclization of the N-acyl derivative in boiling phosphorus oxychloride[5,6] to give 4-aryl(alkyl)-pyrrolo[1,2-a]quinoxalines. We now report a simple general procedure for the preparation of pyrrolo[1,2-a]quinoxalines bearing an amino, oxygen, or a sulfur atom at the 4-position, under completely neutral conditions (Scheme 1).



a) Ph_3P, r.t ; b) R-NCO, r,t; c) Δ ; d) Ph-CO-NCO, r.t ⟶ 8 ;
e) CO_2, toluene, 100°C ⟶ 10 ; f) CS_2, toluene, 100°C

Scheme 1

In the present method, the key intermediate 4 was easily prepared in 70% yield by the classical Staudinger reaction of N-(o-azidophenyl)pyrrole 3, available from o-azidoaniline[7] and 2,5-dimethoxytetrahydrofurane, with triphenylphosphine in dry dichlorometane at room temperature. Aza-Wittig reaction of iminophosphorane 4 with aliphatic and aromatic isocyanates in dry dichlorometane at room temperature afforded the corresponding carbodiimides 5, which could be isolated as viscous oils by means of short column chromatography (silica gel, n-hexane: ethyl acetate, 80:20). Upon heating at 180°C compounds 5 undergo ring-closure to give the otherwise not readilly available 4-aminopyrrolo[1,2-a]quinoxalines 6 in good yields. Despite its apparent simplicity, to our knowledge the conversion of 5 into 6 represents the first example reported of heterocyclization based on the intramolecular electrophilic substitution of a pyrrole ring involving a carbodiimide group.
Iminophosphorane 4 also reacted with benzoylisocyanate to give the unexpected product 8 in 91% yield. The conversion 4→8 can be understood by initial abnormal aza-Wittig reaction to give N-benzoylimiphosphorane and the isocyanate 7 as highly reactive intermediate which undergoes ring-closure to give the fused pyrrole 8.
When iminophosphorane 4 was treated with carbon dioxide in dry toluene at 100°C in a sealed tube glass, compound 10 was formed as only product in 93% yield. Presumably the conversion 4 into 10 involves initial formation of the isocyanate 7 which under reaction conditions reacts with a second molecule of the starting iminophosphorane 4 to give a carbodiimide 9 which undergoes ring-closure to give 10. Finally, pyrrolo[1,2-a]-quinoxaline 11 was prepared in 88% yield from iminophosphorane 4 and carbon disulfide.
Mass spectra of compound 6 and 10 showed molecular ion peaks and the I.R. spectra exhibited N-H absorption bands at 3426-3273 cm^{-1}. The ^{1}H-NMR spectra suggest the exocyclic N-H; e.g. for 6a (R= i-C_3H_7) the methine signal appeared as a multiplet, and in the ^{13}C-NMR spectra the quaternary carbons appeared at C_{3a}= 119.1-119.7; C_{9a}= 125.2-125.8; C_{5a}= 135.7-136.7 and C_4= 146.1-148.5 ppm, in agreement with the reported values for the parent compound[8].

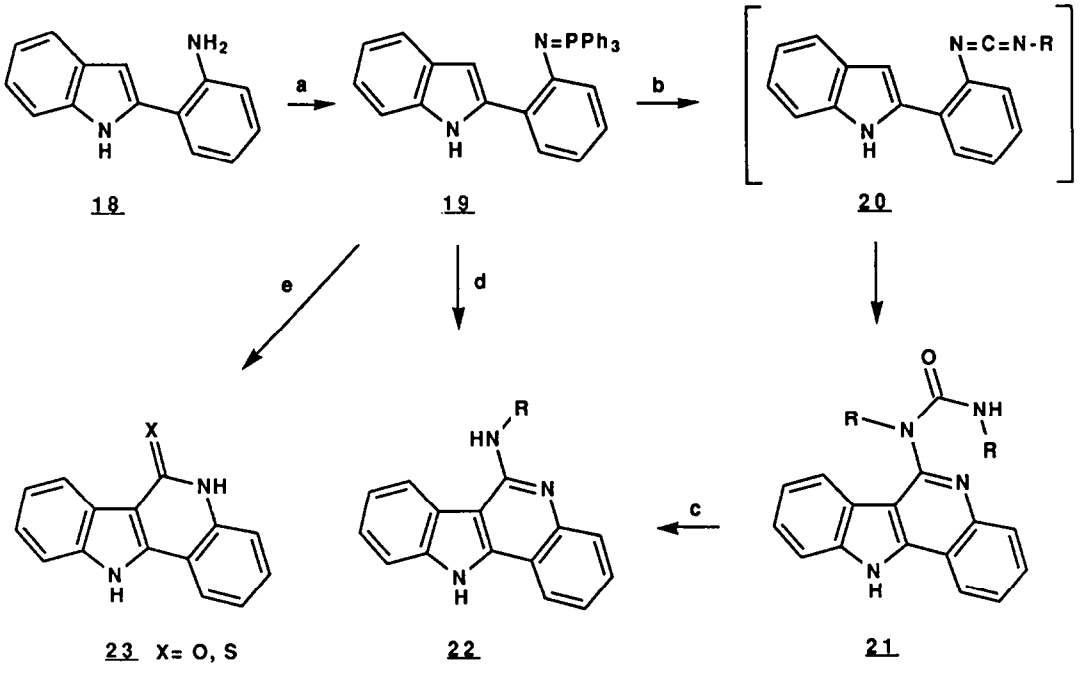


Scheme 2

On the other hand, it was the interest to apply the above methodology for the preparation of pyrrolo[2,1-c]-[1,4]benzodiazepines 17. To this end, we studied the thermal behaviour of o-[(1-pyrrolyl)methyl]phenyl heterocumulenes 14-16. In no cases was intramolecular electrophilic substitution by the heterocumulene moiety into the pyrrole ring observed (Scheme 2).

The azide 12 was prepared from o-azidobenzylamine[9] and 2,5-dimethoxytetrahydrofurane in acetic acid in 46% yield. The preparation of the iminophosphorane 13 was accomplished very easily through the classical Staudinger reaction of 12 with triphenylphosphine at room temprature. Aza-Wittig reactions of iminophosphorane 13 with p-tolylisocyanate, carbon dioxide and carbon disulfide under the usual reaction conditions afforded the heterocumulenes 14, 15, and 16 respectively in 77-95% yields, which were isolated as oils by column chromatography. Upon heating at 180°C these compounds were recovered inalterated.

Indolo[3,2-c]quinolines. Some derivatives of the 11H-indolo[3,2-c]quinoline exhibit relevant biological activities such as: DNA-interaction, inhibition of DNA-polymerase[10] and photodynamic activity[11]. However, no general methods for the preparation of this kind of compounds have been previously described; it has only been



Reagents:

a) Ph_3PBr_2, benzene, Et_3N; b) 2 R-NCO, CH_2Cl_2, r.t; c) EtOH, Δ

d) R-NCS, benzene, Δ e) CO_2 or CS_2, toluene, 90°C

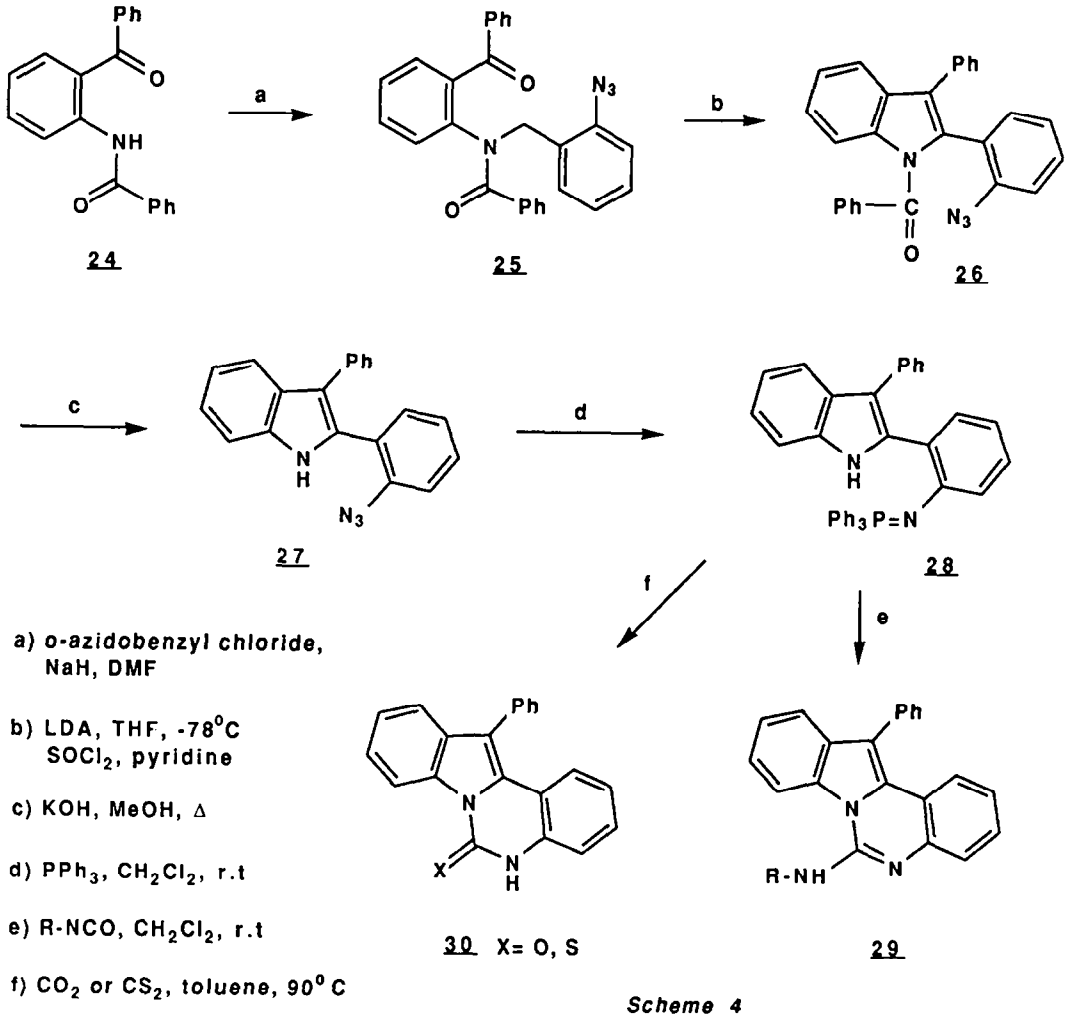
Scheme 3

briefly mentioned the indolization of 1,2,3,4-tetrahydro-4-oxo-quinoline phenylhydrazone[12,13], photocyclization of anilides derived from 3-indolecarboxilic acid[14] and alkylation of oxindoles with p-nitrobenzyl chloride[15], however these approaches are not of general applicability.

Our approach for the preparation of 11H-indolo[3,2-c]quinolines, bearing an amino, oxygen or a sulfur atom at the 5-position, is based on the aza-Wittig type reaction of the appropriate iminophosphorane with heterocumulenes to give the 2-azahexatriene moiety containing a cumulated double bond at one end and the carbon-carbon double bond belonging to the pyrrole ring at the other. Thus, iminophosphorane 19, available from 2-(o-aminophenyl)indole[16] 18 and triphenylphosphine dibromide, reacted with aromatic isocyanates, (1:2) molar ratio, in dry methylene chloride at room temperature to give the corresponding 5-[N-aryl-N(arylcarbamoyl)]-amino-11H-indolo[3,2-c]quinolines 21 in 79-96% yields. When compounds 21 were heated in ethanol they underwent elimination of the isocyanate to furnish 5-arylamino-11H-indolo[3,2-c]quinolines 22 in 78-91% yields. The reaction of iminophosphorane 19 with isopropylisocyanate in dry dichlorometane at room temperature directly led to 22e (R= i-C_3H_7) in 79% yield. Compounds 22 can also be obtained from 19 and isothiocyanates in dry benzene at reflux temperature for 24h. We believe that the mechanism of the conversion 19→21 involves initial aza-Wittig reaction to give a carbodiimide 20 as highly reactive intermediate which undergoes electrocyclic ring closure followed by 1,3-proton shift with concomitant addition of the formed exocyclic NH group to the second molecule of the isocyanate. When iminophosphorane 19 was treated with an excess of carbon dioxide at 90°C in a sealed glass tube or with carbon disulfide in toluene at 90°C compounds 23 were obtained in excellent yields (83-94%) (Scheme 3).

Indolo[1,2-c]quinazolines. This ring system is little known and its synthesis has been achieved in only a limited number of ways, mostly involving the use of 2-(o-amino)phenyl indole as starting material. This substituted indole is converted directly to 6-substituted indolo[1,2-c]quinazolines by action of acyl halides[17]. However, no derivatives of this ring system bearing an amino, oxigen or sulfur atom at the 6-position are known.
The general methods described here use as key intermediate the iminophosphorane 28, available from the azide 27 and triphenylphosphine in 98% yield. Compound 27 was prepared following a previously reported protocol[18]: alkylation of o-(benzoylamino)benzophenone with o-azidobenzyl chloride gave 25 (89%); indolization of 25 by sequential treatment with LDA and thionyl chloride/pyridine led to 26 (73%); and debenzoylation with KOH/methanol afforded 27 (75%). The reaction of iminophosphorane 28 with aromatic isocyanates in dry dichlorometane at room temperature for 24h led directly to the corresponding 6-arylamino-12-phenyl-indolo-[1,2-c]quinazolines 29, the yield of the isolated product being higher than 80%. Presumably the conversion 28→29 involves aza-Wittig type reaction to give a carbodiimide as intermediate which undergoes cyclization by nucleophilic attack of the NH group of the indole ring on the sp-hybridized carbon atom of the carbodiimide moiety to give 29. Although, reactions of carbodiimides with several amino compounds have been reported[19], to our knowledge this is the first example reported of heterocyclization based on the reaction of carbodiimides with the NH group of the indole ring (Scheme 4).

Iminophosphorane 28 also reacted in a similar way with carbon dioxide and carbon disulfide to give the indolo[1,2-c]quinazolines 30 in good yields.



Scheme 4

The present study demonstrate that the heterocumulene-mediated annulation strategy afford a new entry to a variety of substituted fused pyrroles and indoles. Because of their simplicity, the experimental one-pot procedure, mild conditions and good yields the investigated reactions provide a method for the preparation of pyrrolo[1,2-a]-quinoxalines, indolo[3,2-c]quinolines and indolo[1,2-c]quinazolines which compares favourably with other approaches to these ring systems.

EXPERIMENTAL

All melting points were determined on a Kofler hot-plate melting point apparatus and are uncorrected. I.R. spectra were obtained as Nujol emulsions on a Nicolet FT-5DX spectrophotometer. N.M.R. spectra were recorded on a Bruker AC-200 (200 MHz). Mass spectra were recorded on a Hewlett-Packard 5993C spectrometer. Microanalyses were performed on a Perkin-Elmer 240C instrument.

Preparation of N-(o-Azidophenyl)pyrrole 3 and N-(o-Azidobenzyl)pyrrole 12.

Acetic acid (10 ml), 2,5-dimethoxytetrahydrofurane (2.64 g, 20 mmol) and o-azidoaniline[7] or o-azidobenzylamine[9] (20 mmol) were heated at 80°C for 45 min; then the mixture was poured into ice-water (20 ml) and aqueous Na_2CO_3 was added until basic pH. The solution was extracted with chloroform (3x25 ml) and the combined organic layers were dried over anhydrous Na_2SO_4 for 24h. After removal of the solvent under reduced pressure, the product was separated by column chromatography (silica gel, ethyl acetate/n-hexane 1:9). **N-(o-Azidophenyl) pyrrole 3** (80%), oil; i.r. (Nujol): 2127(vs), 2097(vs), 1510(vs), 1477(s), 1335(vs), 1302(vs), 1269(s), 754(vs), 725(vs) and 703 (vs) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 6.34 (m, 2H), 6.92 (m, 2H), 7.14-7.39 (m, 4H, aryl); ^{13}C n.m.r. δ ($CDCl_3$): 109.56, 119.77, 122.25, 125.38, 127.04, 128.03, 132.75, 134.56; m/z (%): 184 (M^+, 67), 168 (5), 157 (18), 156 (96), 155 (100), 130 (17), 129 (62), 103 (38).

N-(o-Azidobenzyl) pyrrole 12 (46%), oil; i.r. (Nujol): 2123(vs), 1498(s), 1301(s), 1283(s), 1086(s), 752(s) and 725(s) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 4.97 (s, 2H), 6.17 (m, 2H), 6.67 (m, 2H), 6.81-6.85 (m, 1H), 6.99-7.16 (m, 2H), 7.23-7.30 (m, 1H); ^{13}C n.m.r. δ ($CDCl_3$): 48.67, 108.50, 118.02, 121.15, 125.08, 128.98, 129.03, 129.53, 137.45; m/z (%): 198 (M^+, 5), 170 (10), 169 (41), 137 (10), 125 (20), 111 (35), 109 (21), 95 (28), 85 (41), 57 (100).

Preparation of Iminophosphoranes 4 and 13.

A solution of triphenylphosphine (5.24 g, 20 mmol) in dry ether (20 ml) was added dropwise under nitrogen at room temperature to a well-stirred solution of the appropriate azide 3 or 12 (20 mmol) in dry methylene chloride (20 ml). The reaction mixture was stirred at room temperature for 3h, and the solvent was removed off under reduced pressure at 25°C. The residual material was recrystallized from benzene/hexane (5:1) to give the corresponding iminophosphorane.

N-[o-(Triphenylphosphoranylidene)amino]phenyl pyrrole 4 (69%), m.p. 124-126°C (white prisms). (Found: C, 80.12; H, 5.73; N, 6.51. $C_{28}H_{23}N_2P$ requires: C, 80.36; H, 5.54; N, 6.69); i.r. (Nujol): 1580(s), 1504(vs), 1438(vs), 1359(vs), 1317(vs), 1109(vs), 1076(s), 1054(s), 1022(s), 745(s) and 732(vs) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 6.20 (m, 2H), 6.46-7.86 (m, 21H); m/z (%): 418 (M^+, 5), 263 (5), 233 (15), 184 (17), 183 (100), 157 (29), 156 (41), 155 (22), 115 (20), 108 (46), 107 (31), 77 (33).

N-[o-(Triphenylphosphoranylidene)amino]benzyl pyrrole 13 (81%), m.p. 135-137°C (white prisms). (Found: C, 80.27; H, 5.98; N, 6.33. $C_{29}H_{25}N_2P$ requires: C, 80.53; H, 5.83; N, 6.48); i.r. (Nujol): 1591(s), 1481(vs), 1450(vs), 1350(s), 1322(vs), 1110(vs), 749(s), 715(vs) and 695(s) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 5.39 (s, 2H), 6.14 (m, 2H), 6.43-6.75 (m, 5H), 6.78 (m, 2H), 7.29-7.77 (m, 14H); ^{13}C n.m.r. δ ($CDCl_3$): 51.06, 117.34, 120.70 (d, J= 10 Hz), 121.40, 127.43, 127.53 (d, J= 2.4 Hz), 128.59 (d, J= 12 Hz), 131.65 (d, J= 2.8 Hz),

132.35, 132.32 (d, J= 105 Hz), 132.48 (d, J= 9.6 Hz), 148.53 (d, J= 1.2 Hz); m/z (%): 432 (M^+, 43), 367 (20), 366 (80), 365 (49), 262 (19), 248 (17), 247 (92), 184 (16), 183 (100), 180 (18), 169 (38), 108 (44), 107 (22), 77 (13).

General Procedure for the Preparation of 4-Alkyl(aryl)amino-pyrrolo[1,2-a]quinoxalines 6.

To a solution of iminophosphorane 4 (0.837 g, 2 mmol) in dry methylene chloride (10 ml) was added the appropriate isocyanate (2 mmol). The reaction mixture was stirred at room temperature for 1h, the solvent was removed off under reduced pressure and the residual oil was identified as the carbodiimide 5 which was used without purification. Compound 5 was heated in a sublimation apparatus at 180°C for 45 min; after cooling, the residual solid was chromatographed on column over silica gel with ethyl acetate/hexane 2:8 as eluent. The first fraction was the corresponding pyrrolo[1,2-a]quinoxaline 6 which was recrystallized from the appropriate solvent. The following derivatives 6 were obtained:

6a 4-Isopropylamino (80%), m.p. 124-125°C (colourless prisms from ether/n-hexane). (Found: C, 74.38; H, 6.88; N, 18.45. $C_{14}H_{15}N_3$ requires: C, 74.64; H, 6.71; N, 18.65); i.r. (Nujol): 3273(s), 1590(s), 1533(vs), 1520(vs), 1491(vs), 1379(vs), 1273(s), 1221(s), 1175(s), 745(vs) and 713(s) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 1.32 (d, 6H, J= 6.6 Hz), 4.56-4.69 (m, 1H), 5.06 (s, 1H), 6.45-6.67 (m, 2H), 7.12-7.32 (m, 2H), 7.62-7.74 (m, 3H); ^{13}C n.m.r. δ ($CDCl_3$): 23.19, 42.35, 102.76, 112.37, 113.33, 114.51, 119.53, 122.77, 125.19, 125.24, 126.55, 136.72, 148.56; m/z (%): 225 (M^+, 37), 224 (6), 210 (20), 184 (15), 183 (100), 168 (38), 155 (18), 140 (23), 129 (13), 104 (24), 102 (12), 58 (71).

6b 4-Phenylamino (91%), m.p. 121-122°C (colourless needles from ether/hexane). (Found: C, 78.47; H, 4.92; N, 16.39. $C_{17}H_{13}N_3$ requires: C, 78.74; H, 5.05; N, 16.20); i.r. (Nujol): 3415(s), 1602(s), 1537(vs), 1488(vs), 1447(vs), 1367(s), 1354(s), 1339(s), 1257(s), 755(vs), 720(s) and 712(s) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 6.55-6.72 (m, 2H), 7.02-7.09 (m, 1H), 7.19-7.38 (m, 5H), 7.63-7.85 (m, 5H); ^{13}C n.m.r. δ ($CDCl_3$): 102.65, 112.67, 113.35, 114.85, 119.56, 120.34, 122.93, 124.02, 125.27, 125.74, 127.68, 128.92, 136.19, 139.81, 146.49; m/z (%): 259 (M+, 63), 258 (100), 257 (16), 205 (10), 140 (13), 129 (26), 128 (23), 115 (15), 102 (10), 77 (26).

6c 4-(p-Chlorophenyl)amino (80%), m.p. 170°C (colourless needles from chloroform/n-hexane). (Found: C, 69.42; H, 3.95; N, 14.22. $C_{17}H_{12}ClN_3$ requires: C, 69.51; H, 4.12; N, 14.30); i.r. (Nujol): 3427(s), 1600(s), 1526(vs), 1489(vs), 1451(s), 1361(s), 1342(s), 754(s) and 710(m) cm^{-1}; ^1H n.m.r. δ (DMSO-d_6): 6.79-6.82 (m, 1H), 7.26-7.44 (m, 5H), 7.62-7.66 (m, 1H), 8.00-8.04 (m, 1H), 8.18-8.23 (m, 3H), 9.27 (s 1H); ^{13}C n.m.r. δ (DMSO-d_6): 105.03, 112.55, 113.95, 115.74, 119.12, 121.72, 123.75, 125.01, 125.47, 125.70, 126.85, 128.13, 135.74, 139.72, 146.65; m/z (%): 295 (M^+ + 2, 11), 293 (M^+, 36), 292 (52), 257 (32), 168 (5), 167 (15), 140 (31), 129 (100), 115 (38), 114 (22), 113 (15), 111 (12), 102 (26), 101 (15).

6d 4-(m-Tolyl)amino (78%), m.p. 96-98°C (colourless needles from acetone/n-hexane). (Found: C, 78.82; H, 5.78; N, 15.22. $C_{18}H_{15}N_3$ requires: C, 79.09; H, 5.53; N, 15.37); i.r. (Nujol): 3426(s), 1606(s), 1504(vs), 1335(vs), 1315(s), 1290(s), 1260(vs), 1209(s), 1174(s), 1104(s), 1039(s), 783(s), 753(vs) 713(vs) and 688(vs) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 2.37 (s, 3H), 6.66-6.74 (m, 2H), 6.86-6.90 (m, 1H), 7.21-7.35 (m, 4H), 7.61-7.79 (m, 5H); ^{13}C n.m.r. δ ($CDCl_3$): 21.58, 102.63, 112.66, 113.35, 114.81, 117.62, 119.65, 121.02, 123.85, 123.96, 125.25, 125.79, 127.70, 128.76, 136.29, 138.71, 139.72, 146.58; m/z (%): 273 (M^+, 76), 272 (100), 257 (20),

205 (10), 167 (15), 140 (18), 135 (20), 129 (32), 115 (12), 108 (10), 91 (8).

6e 4-(p-Tolyl)amino (79%), m.p. 119-120°C (colourless prisms from ether/n-hexane). (Found: C, 78.88; H, 5.72; N, 15.23. $C_{18}H_{15}N_3$ requires: C, 79.09; H, 5.53; N, 15.37); i.r. (Nujol): 3426(s), 1602(m), 1530(vs), 1488(vs), 1450(vs), 1256(m), 754(s) and 719(s) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 2.29 (s, 3H), 6.59-6.65 (m, 2H), 7.08-7.30 (m, 4H), 7.57-7.72 (m, 6H); ^{13}C n.m.r. δ ($CDCl_3$): 20.78, 102.61, 112.54, 113.29, 114.67, 119.57, 120.68, 123.74, 125.17, 125.73, 127.58, 129.37, 132.50, 136.38, 137.18, 146.67; m/z (%): 273 (M^+, 62), 272 (100), 257 (20), 205 (10), 168 (13), 140 (21), 137 (19), 136 (40), 129 (65), 115 (18), 102 (12), 91 (10), 77 (23).

6f 4-(p-Methoxyphenyl)amino (75%), m.p. 190-191°C (white prisms from chloroform/n-hexane). (Found: C, 74.95; H, 5.13; N, 14.61. $C_{18}H_{15}N_3O$ requires: C, 74.72, H, 5.22; N, 14.52); i.r. (Nujol): 3392(s), 1608(m), 1534(vs), 1512(vs), 1489(vs), 1364(s), 1240(s), 1183(m), 1030(m), 747(s) and 719(m) cm^{-1}; ^1H n.m.r. δ (DMSO-d_6): 3.78 (s, 3H), 6.82 (dd, 1H, J= 2.9 Hz, J= 3.8 Hz), 6.97 (d, 2H, J= 9 Hz), 7.22-7.41 (m, 3H), 7.55 (dd, 1H, J= 1.2 Hz, J= 3.8 Hz), 7.99 (d, 2H, J= 9 Hz), 8.04-8.08 (m, 1H), 8.26 (dd, 1H, J= 1.2 Hz, J= 2.9 Hz), 9.07 (s, 1H); ^{13}C n.m.r. δ (DMSO-d_6): 55.24, 104.75, 112.46, 113.72, 113.97, 115.65, 119.11, 122.30, 123.14, 125.00, 125.32, 126.49, 133.70, 136.15, 147.50, 154.83; m/z (%): 289 (M^+, 28), 275 (13), 274 (76), 246 (11), 245 (18), 244 (17), 193 (10), 180 (22), 167 (30), 145 (34), 141 (25), 140 (100), 137 (30), 129 (37), 123 (98), 115 (56), 102 (31), 89 (23), 77 (39).

Reaction of Iminophosphorane 4 with Benzoylisocyanate.

To a solution of iminophosphorane 4 (0.837 g, 2 mmol) in dry methylene chloride (15 ml) was added benzoyl-isocyanate (0.294 g, 2 mmol). The reaction mixture was stirred at room temperature for 2h, and the solvent was removed off under reduced pressure. The residual material was slurried with dry benzene (15 ml) and the separated solid was recrystallized from ethanol to give 8 in 91% yield, m.p. 272-273°C (lit[5] m.p. 268-269°C). From the benzene solution N-benzoyliminophosphorane was isolated.

Reaction of Iminophosphorane 4 with Carbon Dioxide.

Iminophosphorane 4 (0.837 g, 2 mmol) , dry toluene (10 ml), and excess of solid carbon dioxide were heated in a sealed tube at 100°C for 16h. After cooling, the solution was concentrated to dryness and the crude product was chromatographed on column over silica gel with ethyl acetate/n-hexane 2:8 as eluent. The first fraction was 10 (93%), m.p. 148-150°C (colourless needles). (Found: C, 77.51; H, 5.18; N, 17.03. $C_{21}H_{16}N_4$ requires: C, 77.76; H, 4.97; N, 17.27); i.r. (Nujol): 3426(s), 1607(vs), 1535(vs), 1487(vs), 1453(vs), 1358(s), 1342(s), 1041(m), 755 (vs), 732(s) and 712(s) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 6.22 (dd, 1H, J= 1.3Hz, J= 4 Hz), 6.48 (m, 2H), 6.63 (dd, 1H, J= 2.8Hz, J= 4 Hz), 6.88 (m, 2H), 7.03-7.11 (m, 1H), 7.20-7.36 (m, 4H), 7.42-7.50 (m, 1H), 7.62-7.77 (m, 3H), 9.14 (dd, 1H, J= 1.3 Hz, J= 8.4 Hz); ^{13}C n.m.r. δ ($CDCl_3$): 102.44, 110.49, 112.85, 113.39, 114.82, 119.66, 120.43, 121.89, 122.43, 124.32, 125.27, 125.85, 126.67, 127.90, 128.91, 130.15, 136.07, 136.42, 146.07; m/z (%): 324 (M^+, 10), 323 (5), 258 (23), 206 (10), 169 (7), 168 (13), 162 (15), 157 (100), 140 (17), 115 (15), 102 (12), 77 (20).

Reaction of Iminophosphorane 4 with Carbon Disulfide.

Iminophosphorane 4 (0.837 g, 2 mmol), dry toluene (10 ml) and excess of carbon disulfide were heated in a

sealed tube at 100°C for 16h. After cooling, the separated solid was recrystallized from ethanol to give 11 in 88% yield, m.p. 269-270°C (lit[5] m.p. 265°C).

Reaction of Iminophosphorane 13 with Heterocumulenes.

A) Reaction with p-Tolylisocyanate.

To a solution of iminophosphorane 13 (0.43 g, 1 mmol) in dry methylene chloride (10 ml) was added p-tolyl isocyanate (0.13 g, 1 mmol). The reaction mixture was stirred at room temperature for 1h, then the solvent was removed off under reduced pressure and the residual material was extracted with n-hexane (3x15 ml). From the combined extracts the solvent was removed off to give the carbodiimide 14 in 77% yield as oil; i.r. (Nujol): 2140 (vs), 1580(s), 1493(s), 1281(s), 1193(s) and 817(s) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 2.28 (s, 3H), 5.11 (s, 2H), 6.17 (m, 2H), 6.69 (m, 2H), 6.81-6.99 (m, 1H), 7.03-7.20 (m, 5H), 7.38-7.45 (m, 1H), 7.60-7.71 (m, 1H); m/z (%): 287 (M+, 18), 286 (28), 222 (24), 221 (25), 220 (26), 206 (31), 205 (30), 116 (23), 110 (12), 103 (14), 91 (62), 77 (81), 51 (100).

B) Reaction with Carbon Dioxide and Carbon Disulfide.

Iminophosphorane 13 (0.43 g, 1 mmol), dry toluene (10 ml) and excess of solid carbon dioxide or carbon disulfide, were heated in a sealed tube at 100°C for 24h. After cooling the solution was concentrated to dryness and the residue was extracted with n-hexane (3x15 ml). From the combined extracts the solvents was removed under reduced pressure to afford 15 or 16 respectively.

15 (80%), oil; i.r. (Nujol): 2146(s), 1635(m), 1592(s), 1292(m), 1196(s), 1121(s), 1070(m), 996(m), 754 (s) and 696(s) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 5.17 (s, 2H), 6.18-6.20 (m, 2H), 6.72-6.74 (m, 2H), 6.84-6.89 (m, 1H), 7.20-7.25 (m, 1H), 7.77-7.81 (m, 1H); m/z (%): 352 (M^+, 10).

16 (95%), oil; i.r. (Nujol): 2180(vs), 2106(vs), 1582(s), 1497(s), 1483(vs), 1295(s), 1279(s), 1102(s), 1083(s), 1067(s), 932(s), 753(vs) and 720(s) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 5.12 (s, 2H), 6.20 (m, 2H), 6.69 (m, 2H), 6.83-6.86 (m, 1H), 7.16-7.27 (m, 1H), 7.41-7.48 (m, 1H), 7.65-7.77 (m, 1H); m/z (%): 214 (M^+, 10), 148 (11), 125 (15), 111 (20), 99 (7), 97 (30), 81 (25), 57 (100).

When compounds 14, 15 or 16 were heated under nitrogen in a sublimation apparatus at 180°C, the starting materials were recovered inalterated.

Preparation of Iminophosphorane 19.

A solution of bromine (1.598 g, 10 mmol) in dry benzene (10 ml) was added dropwise to a stirred solution of triphenylphosphine (2.62 g, 10 mmol) in the same solvent (30 ml) at 0°C under nitrogen. The mixture was stirred for 1h and then allowed to stand at room temperature for 30 min. A solution of 2-(o-aminophenyl)indole[16] 18 (2.08 g, 10 mmol) and triethylamine (2.02 g, 20 mmol) in dry benzene (20 ml) was added and the mixture was heated at reflux for 12h, whereupon a solid (triethylammonium bromide) precipitates, which was separated by filtration from the warm solution. The filtrate was concentrated to dryness to afford a crude which recrystallized from benzene/n-hexane 1:1 afforded 19 in 89% yield, m.p. 240-241°C (colourles prisms). (Found: C, 81.82; H, 5.16; N, 6.21. $C_{32}H_{25}N_2P$ requires: C, 82.03; H, 5.38; N, 5.98); i.r. (Nujol): 3177(m), 1455(vs), 1438(s), 1331(vs), 1304(s), 1111(s), 1015(m), 755(s), 744(s) and 721(s) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 6.54-6.56 (m, 1H), 6.74-6.78 (m, 3H), 7.03-7.06 (m, 3H), 7.43-7.60 (m, 10H), 7.70-7.80 (m, 7H),

12.76 (s, 1H, NH); ^{13}C n.m.r. δ ($CDCl_3$): 96.65, 110.66, 118.34, 119.62, 119.68, 120.36, 123.26, 127.11, 127.86, 128.32, 128.58, 129.10 (d, J= 12 Hz), 131.04, 131.99, 132.28 (d, J= 3 Hz), 132.52 (d, J= 9.8 Hz), 135.32, 140.49; m/z (%): 468 (M^+, 100), 467 (29), 391 (12), 267 (10), 183 (30), 108 (17), 77 (14).

General Procedure for the Preparation of 5-[N-Aryl-N-(arylcarbamoyl)]-amino-11H-indolo[3,2-c]-quinazolines 21.

To a solution of the iminophosphorane 19 (0.937 g, 2 mmol) in dry methylene chloride (15 ml) was added the appropriate isocyanate (4 mmol). The reaction mixture was stirred at room temperature for 12h. The precipitated solid was separated by filtration and recrystallized from the adequate solvent to give 21 as crystalline solids. The following derivatives 21 were obtained:

21a (R= m-CH_3-C_6H_4) (84%), m.p. 213-214°C (colourless prisms from acetonitrile). (Found: C, 79.16; H, 5.06; N, 12.18. $C_{30}H_{24}N_4O$ requires: C, 78.93; H, 5.30; N, 12.27); i.r. (Nujol): 3239(s), 1665(vs), 1597(s), 1568(s), 1506(s), 1489(s), 1327(s), 1263(s), 1248(s), 742(s) and 719(m) cm^{-1}; ^{1}H n.m.r. δ (DMSO-d_6): 2.06 (s, 3H), 2.20 (s, 3H), 6.72-6.76 (m, 1H), 6.93-7.30 (m, 8H), 7.43-7.51 (m, 1H), 7.68-7.76 (m, 3H), 7.95-8.07 (m, 2H), 8.54-8.59 (m, 1H), 8.87 (s, 1H), 12.93 (s, 1H); ^{13}C n.m.r. δ (DMSO-d_6): 20.92, 20.96, 111.75, 111.81, 116.86, 117.55, 120.71, 120.94, 120.98, 121.31, 121.90, 122.94, 123.24, 125.34, 125.58, 125.74, 126.33, 127.96, 128.31, 128.50, 128.94, 137.25, 137.94, 138.90, 139.46, 142.32, 142.82, 144.89, 149.64, 154.15; m/z (%): 323 (M^+ - R-NCO, 63), 322 (100), 307 (19), 216 (10), 190 (20), 161 (25), 160 (23), 133 (89), 77 (10).

21b (R= 4-CH3-C_6H_4) (90%), m.p. 193-194°C (colourless prisms from acetonitrile). (Found: C, 79.13; H, 5.37; N, 12.16. $C_{30}H_{24}N_4O$ requires: C, 78.93; H, 5.30; N, 12.27); i.r. (Nujol): 3228(s), 1657(vs), 1626(s), 1591(s), 1566(s), 1507(vs), 1454(vs), 1302(s), 1233(s), 1125(m), 758(s), 735(s) and 719(m) cm^{-1}; ^{1}H n.m.r. δ (DMSO-d_6): 2.18 (s, 3H), 2.24 (s, 3H), 6.97-7.76 (m, 13H), 7.97-8.08 (m, 2H), 8.59 (m, 1H), 8.82 (s, 1H), 12.95 (s, 1H); ^{13}C n.m.r. δ (DMSO-d_6): 20.23, 20.37, 111.74, 111.77, 116.83, 120.59, 120.71, 120.95, 121.32, 121.88, 125.33, 125.56, 125.75, 128.30, 128.55, 128.91, 129.22, 131.50, 134.18, 136.97, 138.88, 139.80, 142.82, 144.89, 149.74, 154.23; m/z (%): 323 (M^+ - R-NCO, 65), 322 (100), 307 (20), 216 (10), 190 (20), 160 (27), 159 (17), 154 (89), 140 (14), 77 (10).

21c (R= m-CH_3O-C_6H_4) (79%), m.p. 199-201°C (colourless prisms from acetonitrile). (Found: C, 73.54; H, 5.18; N, 11.31. $C_{30}H_{24}N_4O_3$ requires: C, 73.75; H, 4.95; N, 11.47); i.r. (Nujol): 3199(s), 3171(s), 1655(vs), 1596(s), 1566(s), 1337(s), 1325(s), 1309(s), 1292(s), 1262(s), 755(m) and 746(s) cm^{-1}; ^{1}H n.m.r. δ (DMSO-d_6): 3.64 (s, 3H), 3.67 (s, 3H), 6.51-8.01 (m, 15H), 8.57-8.61 (m, 1H), 9.04 (s, 1H), 12.98 (s, 1H); ^{13}C n.m.r. δ (DMSO-d_6): 54.90, 55.11, 106.25, 108.32, 110.25, 111.77, 111.80, 112.13, 112.72, 116.88, 117.99, 120.77, 120.88, 121.28, 121.92, 125.43, 125.70, 128.38, 128.87, 128.95, 129.43, 138.92, 140.74, 142.87, 143.36, 144.86, 149.44, 154.04, 159.35, 159.55; m/z (%): 339 (M^+ - R-NCO, 79), 338 (100), 223 (13), 294 (15), 217 (16), 190 (23), 169 (24), 162 (20), 154 (22), 149 (59), 147 (62), 140 (10), 77 (5).

21d (R= p-CH_3O-C_6H_4) (96%), m.p. 278-279°C (colourless prisms from dioxane). (Found: C, 73.59; H, 5.16; N, 11.61. $C_{30}H_{24}N_4O_3$ requires: C, 73.75; H, 4.95; N, 11.47); i.r. (Nujol): 3307(m), 1652(vs), 1571(vs), 1512 (vs), 1454(vs), 1249(s), 1120(s), 872(s), 748(s) and 722(m) cm^{-1}; ^{1}H n.m.r. δ (DMSO-d_6): 3.56 (s, 6H), 6.91 (d, 2H, J= 8.9 Hz), 7.01 (d, 2H, J= 8.9 Hz), 7.32-7.78 (m, 7H), 7.96 (d, 2H, J= 8.8 Hz), 8.37 (s, 1H), 8.41-8.54 (m,

3H), 12.67 (s, 1H); ^{13}C n.m.r. δ (DMSO-d_6): 55.21, 55.26, 103.69, 111.47, 113.64, 114.04, 114.83, 120.08, 120.16, 121.18, 121.36, 121.53, 121.91, 122.68, 124.23, 126.76, 128.15, 133.03, 134.60, 138.43, 141.33, 145.26, 150.68, 153.06, 154.51, 154.66; m/z (%): 339 (M^+ - R-NCO, 100), 338 (50), 325 (22), 324 (94), 218 (15), 217 (60), 190 (49), 169 (36), 162 (34), 154 (35), 149 (85), 147 (87), 134 (12), 108 (10).

General Procedure for the Preparation of 5-Alkyl(aryl)amino-11H-indolo[3,2-c]quinolines 22.
Method A.

A solution of the appropriate 11H-indolo[3,2-c]quinoline 21 (2 mmol) in ethanol (20 ml) was heated at reflux temperature for 12h. After cooling, the solvent was removed off under reduced pressure and the residue was slurried with n-hexane (3x25 ml), the solid formed was recrystallized from ethanol to give 22 as crystalline solids. The following derivatives 22 were obtained:

22a (**R= m-CH_3-C_6H_4**) (78%), m.p. 231-232°C (white prisms). (Found: C, 81.59; H, 5.13; N, 13.19. $C_{22}H_{17}N_3$ requires: C, 81.71; H, 5.30; N, 12.99); i.r. (Nujol): 3471(s) 3415(vs), 1611(vs), 1571(vs), 1538(vs), 1508(s), 1399(s), 1208(s), 779(s), 762(s) and 735(vs) cm^{-1}; ^{1}H n.m.r. δ (DMSO-d_6): 2.40 (s, 3H), 6.85 (d, 1H, J= 7.4 Hz), 7.26-8.00 (m, 9H), 8.45-8.53 (m, 3H), 12.76 (s, 1H); ^{13}C n.m.r. δ (DMSO-d_6): 21.43, 104.31, 111.67, 115.17, 117.70, 120.36, 121.06, 121.28, 121.56, 121.73, 122.38, 122.44, 124.49, 127.12, 128.30, 128.35, 137.54, 138.63, 141.58, 141.66, 145.25, 150.44; m/z (%): 323 (M^+, 65), 322 (100), 307 (19), 190 (14), 161 (22), 154 (67), 140 (12), 91 (10), 77 (6).

22b (**R= p-CH_3-C_6H_4**) (85%), m.p. 239-240°C (white prisms). (Found: C, 81.59; H, 5.37; N, 12.83. $C_{22}H_{17}N_3$ requires: C, 81.71; H, 5.30; N, 12.99); i.r. (Nujol): 3426(vs), 1596(s), 1571(vs), 1520(vs), 1505(vs), 1402(s), 1342(s), 1236(s), 1210(s), 749(s) and 738(s) cm^{-1}; ^{1}H n.m.r. δ (DMSO-d_6): 2.32 (s, 3H), 7.19 (d, 2H, J= 8.3 Hz), 7.34-7.64 (m, 4H), 7.74-7.90 (m, 2H), 7.94 (d, 2H, J= 8.3 Hz), 8.45 (s, 1H), 8.41-8.52 (m, 2H), 12.71 (s, 1H); ^{13}C n.m.r. δ (DMSO-d_6): 20.41, 103.98, 111.51, 114.97, 120.20, 120.74, 121.16, 121.39, 121.56, 122.14, 124.30, 126.89, 128.18, 128.72, 130.40, 137.48, 138.99, 141.41, 145.19, 150.44; m/z (%): 323 (M^+, 68), 322 (100), 307 (19), 190 (13), 161 (19), 154 (58), 140 (10), 114 (5), 77 (10).

22c (**R= m-CH_3O-C_6H_4**) (89%), m.p. 215-216°C (colourless prisms). (Found: C, 77.59; H, 4.93; N, 12.48. $C_{22}H_{17}N_3O$ requires: C, 77.86; H, 5.05; N, 12.38); i.r. (Nujol): 3460(s), 3358(s), 1627(s), 1604(vs), 1573(vs), 1538(vs), 1510(s), 1408(s), 1303(m), 1288(s), 1212(s), 1160(s), 768(s), 757(s) and 732(s) cm^{-1}; ^{1}H n.m.r.δ (DMSO-d_6): 3.85 (s, 3H), 6.62 (dd, 1H, J= 2.3 Hz, J= 8.1 Hz), 7.25-7.93 (m, 9H), 8.47 (m, 2H), 8.60 (s, 1H), 12.76 (s, 1H); ^{13}C n.m.r. δ (DMSO-d_6): 54.99, 104.23, 105.94, 107.18, 111.55, 112.62, 115.04, 120.24, 121.05, 121.46, 121.59, 122.48, 124.42, 127.02, 127.02, 128.30, 128.96, 138.48, 141.46, 142.85, 144.98, 150.13, 159.66; m/z (%): 339 (M^+, 82), 338 (100), 323 (13), 294 (11), 217 (17), 190 (23), 169 (26), 154 (27), 147 (71), 133 (10), 114 (8).

22d (**R= p-CH_3O-C_6H_4**) (91%), m.p. 275-276°C (colourless prisms). (Found: C, 77.85; H, 5.16; N, 12.12. $C_{22}H_{17}N_3O$ requires: C, 77.86; H, 5.05; N, 12.38); i.r. (Nujol): 3349(s), 3426(s), 3154(s), 1592(s), 1572(vs), 1516(vs), 1338(vs), 1247(vs), 1226(s), 1123(m), 1034(m), 757(s) and 739(s) cm^{-1}; ^{1}H n.m.r. δ (DMSO-d_6): 3.79 (s, 3H), 6.98 (d, 2H, J= 9 Hz), 7.36-7.61 (m, 4H), 7.71-7.75 (m, 2H), 7.90 (d, 2H, J= 9Hz), 8.36 (s, 1H), 8.35-8.52 (m, 2H), 12.67 (s, 1H); ^{13}C n.m.r. δ (DMSO-d_6): 55.25, 103.64, 111.43, 113.61, 114.83, 120.12, 121.13,

121.33, 121.48, 121.89, 122.64, 124.21, 126.71, 128.12, 134.55, 138.37, 141.28, 145.20, 150.63, 154.62; m/z (%): 339 (M^+, 100), 338 (52), 325 (23), 327 (97), 294 (10), 217 (50), 215 (10), 191 (10), 190 (42), 169 (27), 162 (27), 154 (28), 147 (75), 133 (10), 114 (8).

Method B.

To a solution of the iminophosphorane 19 (0.937 g, 2 mmol) in dry benzene (25 ml) was added the appropriate isothiocyanate. The reaction mixture was heated to reflux for 24h. Similar work-up to the above method led to 22 a-d.

Method C.

To a solution of the iminophosphorane 19 (2 mmol) in dry methylene chloride (15 ml) was added isopropyl isocyanate. The reaction mixture was stirred at room temperature for 24h. The solvent was removed off under reduced pressure and the residual material was chromatographed on column over silica gel with n-hexane/ethyl acetate 6:4 as eluent, to give 22e which was recrystallized from chloroform.

22e (**R= i-C_3H_7**) (79%), m.p. 178°C (colourless prims). (Found: C, 78.35; H, 6.43; N, 15.31. $C_{18}H_{17}N_3$ requires: C, 78.52; H, 6.22; N, 15.26); i.r. (Nujol): 3457(s), 1580(vs), 1529(vs), 1381(s), 1212(s), 1121(m), 740(s) and 735(s) cm^{-1}; ^1H n.m.r. δ (DMSO-d_6): 1.42 (d, 6H, J= 7 Hz), 4.79 (m, 1H), 6.02 (d, 1H, J= 8.3 Hz), 7.24-7.54 (m, 4H), 7.66-7.73 (m, 2H), 8.27-8.38 (m, 2H), 12.46 (s, 1H); ^{13}C n.m.r. δ (DMSO-d_6): 22.82, 41.66, 102.88, 111.37, 114.19, 120.01, 120.67, 120.71, 121.47, 121.53, 123.78, 126.37, 127.84, 138.25, 140.92, 146.16, 152.59; m/z (%): 275 (M^+, 29), 274 (7), 260 (11), 234 (18), 233 (100), 218 (77), 217 (21), 205 (13), 190 (25), 129 (12), 115 (8), 58 (20).

Reaction of Iminophosphorane 19 with Carbon Dioxide and Carbon Disulfide.

Iminophosphorane 19 (0.937 g, 2 mmol), dry toluene (10 ml) and excess of solid carbon dioxide or carbon disulfide, were heated in a sealed tube at 100°C for 12h. After cooling, the separated solid was collected by filtration and recrystallized from ethanol to give 23 as crystalline solid.

23a (**X= O**) (83%), m.p. 280°C (lit.[14] m.p. 280°C).

23b (**X= S**) (94%), m.p. 335-337°C (yellow prisms). (Found: C, 72.18; H, 3.84; N, 11.26. $C_{15}H_{10}N_2S$ requires: C, 71.97; H, 4.03; N, 11.19); i.r. (Nujol): 3233(vs), 3160(vs), 1629(s), 1592(s), 1566(s), 1530(vs), 1400(s), 1324(s), 1270(s), 1194(s), 1083(s), 984(s), 761(s), 740(vs) and 629(s) cm^{-1}; ^1H n.m.r. δ (DMSO-d_6): 7.40-7.76 (m, 5H), 7.79 (d, 1H, J= 8.3 Hz), 8.43 (d, 1H, J= 8 Hz), 9.21 (d, 1H, J= 8 Hz), 12.98 (s, 1H), 13.17 (s, 1H); ^{13}C n.m.r. δ (DMSO-d_6): 111.57, 113.41, 115.72, 116.88, 121.18, 122.25, 122.45, 123.40, 125.09, 125.29, 129.67, 137.38, 137.77, 138.64, 176.49; m/z (%): 250 (M^+, 100), 249 (10), 218 (12), 217 (41), 190 (29), 125 (25), 103 (17), 89 (71).

Preparation of o-[N-Benzoyl-N-(o-azidobenzyl)]amino benzophenone 25.

To a suspension of NaH (0.63 g, 21 mmol) in dry DMF (20 ml) was added at once a solution of o-(benzoylamino) benzophenone 24 (6.02 g, 20 mmol) in the same solvent (20 ml). The reaction mixture was stirred at 50°C for 1h, then o-azidobenzyl chloride (3.35 g, 20 mmol) was added and the resultant solution was stirred a 50°C for 20h. After cooling the solution was poured into ice-water (60 ml) and extracted with methylene chloride

(3x25 ml). The combined extracts were dried over anhydrous Na_2SO_4 for 24h, the solvent removed off under reduced pressure and the residual material recrystallized from methanol to give 25 in 89% yield, m.p. 155-156°C (colourless prisms). (Found: C, 75.19; H, 4.43; N, 13.13. $C_{27}H_{20}N_4O_2$ requires: C, 74.98; H, 4.66; N, 12.95); i.r. (Nujol): 2128(s), 2112(s), 2086(s), 1659(vs), 1642(vs), 1595(s), 1326(s), 1314(s), 1299(s), 1269(vs), 786(s) and 754(m) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 4.46 (d, 1H, J= 15.4 Hz), 5.58 (d, 1H, J= 15.4 Hz), 6.98-7.58 (m, 18 H); ^{13}C n.m.r. δ ($CDCl_3$): 49.49, 117.95, 124.88, 126.52, 127.65, 128.12, 128.72, 129.02, 129.61, 130.18, 130.29, 130.49, 130.62, 131.17, 133.12, 135.65, 136.51, 137.99, 142.91, 170.30, 194.65; m/z (%): 432 (M^+, 5), 404 (10), 208 (5), 153 (8), 106 (15), 105 (65), 77 (100).

Preparation of 1-Benzoyl-2-(o-azido)phenyl-3-phenyl indole 26.

To a solution of diisopropylamine (2.5 g, 25 mmol) in tetrahydrofurane (30 ml) was added n-butyllithium (25 mmol). The mixture was stirred at 50°C under nitrogen for 30 min, then cooled at -78°C. A solution of 25 (4.32 g, 10 mmol) in tetrahydrofuran (20 ml) was added, stirring was continued for 5h. The solution was warm to room temperature and poured into water (100 ml). The organic layer was separated and dried over anhydrous Na_2SO_4 for 24h. The solvent was removed off under reduced pressure and the residue was disolved in dry benzene (20 ml) and pyridine (20 mmol) was added. The resultant solution was cooled at 0°C and thionyl chloride (20 mmol) was added dropwise, and stirred at room temperature for 2h, whereupon water (50 ml) was added. The organic layer was separated and dried over anhydrous Na_2SO_4 for 24h, concentrated to dryness and the residual material was chromatographed on column over silica gel with benzene as eluent and recrystallized from methanol to give 26 (73%), m.p. 153-155°C (colourless prisms). (Found: C, 78.13; H, 4.52; N, 13.31. $C_{27}H_{18}N_4O$ requires: C, 78.24; H, 4.38; N, 13.52); i.r. (Nujol): 2125(vs), 1693(vs), 1318(vs), 1304(s), 1285(s), 743(s) and 714(s) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 6.86-6.91 (m, 2H), 7.06-7.49 (m, 13H), 7.65-7.69 (m, 3H); ^{13}C n.m.r. δ ($CDCl_3$): 123.03, 123.07, 124.16, 124.45, 124.62, 127.00, 128.18, 128.33, 129.18, 129.58, 129.88, 129.98, 132.52, 132.53, 133.05, 133.23, 135.06, 136.99, 138.86, 169.54; m/z (%): 414 (M^+, %), 386 (13), 208 (10), 196 (98), 152 (15), 105 (79), 77 (100).

Preparation of 2-(o-Azido)phenyl-3-phenyl indole 27.

1-Benzoyl-2-(azido)phenyl-3-phenyl indole 26 (4.14 g, 10 mmol), KOH (1.68 g, 30 mmol) and methanol (30 ml) were heated to reflux for 8h. After cooling, the solution was concentrated to dryness and the residual material was washed with water (3x30 ml), the remaining solid was air-dried and recrystallized from methanol to give 27 (75%), m.p. 144°C (colourless prisms). (Found: C, 77.25; H, 4.60; N, 17.83. $C_{20}H_{14}N_4$ requires: C, 77.40; H, 4.54; N, 18.05); i.r. (Nujol): 3403(vs), 2124(vs), 2089(s), 1301(s), 775(m), 738(s) and 710(s) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 6.94-7.02 (m, 1H), 7.10-7.45 (m, 11H), 7.72 (d, 1H, J= 7.8 Hz), 8.68 (s, 1H); ^{13}C n.m.r. δ ($CDCl_3$): 111.00, 116.89, 118.97, 119.76, 120.31, 122.96, 124.19, 124.86, 126.23, 127.69, 128.53, 129.32, 129.97, 130.38, 132.79, 135.26, 135.75, 137.73; m/z (%): 310 (M^+, 17), 282 (80), 254 (28), 226 (12), 205 (75), 176 (27), 165 (36), 151 (35), 140 (100), 127 (90), 113 (66), 100 (43), 77 (60).

Preparation of Iminophosphorane 28.

Iminophosphorane 28 was prepared from azide 27 and triphenylphosphine by the method used for the preparation of iminophosphoranes 4 and 13.

28 (98%), m.p. 208-209°C (colourless prisms from benzene/n-hexane). (Found: C, 84.07; H, 5.36, N, 4.96.

$C_{38}H_{29}N_2P$ requires: C, 83.80; H, 5.37; N, 5.14); i.r. (Nujol): 3182(m), 1454(vs), 1438(vs), 1324(vs), 1112(s), 745(s), 720(s) and 702(s) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 6.40-6.73 (m, 3H), 7.09-7.79 (m, 25H), 12.20 (s, 1H); ^{13}C n.m.r. δ ($CDCl_3$): 127.27, 128.36, 128.46, 128.74, 128.94 (d, J= 12 Hz), 130.46 (d, J= 100 Hz), 130.76, 131.05 (d, J= 2Hz), 132.12 (d, J= 3 Hz), 132.59 (d, J= 10 Hz), 134.64, 135.72 (d, J= 1.5 Hz), 137.34, 148.32 (d, J= 3 Hz); m/z (%): 544 (M+, 64), 543 (23), 281 (23), 267 (10), 183 (100), 165 (10), 108 (39), 107 (21), 77 (20).

General Procedure for the Preparation of 6-Arylamino-indolo[1,2-c]quinazolines 29.

To a solution of iminophosphorane 28 (0.54 g, 1 mmol) in dry methylene chloride (5 ml) was added the corresponding isocyanate (1 mmol). The mixture was stirred at room temperature for 24h, whereupon the solvent was removed off under reduced pressure and the residue was slurried with cold methanol (10 ml). The separated solid was collected by filtration, air-dried and recrystallized from the adequate solvent to give 29 as crystalline solids. The following derivatives 29 were obtained:

29a (R= p-CH_3-C_6H_4) (86%), m.p. 206-207°C (colourless prisms from methanol). (Found: C, 84.21; H, 5.43; N, 10.89. $C_{28}H_{21}N_3$ requires: C, 84.18; H, 5.30; N, 10.52); i.r. (Nujol): 3409(m), 1662(vs), 1603(s), 1483(s), 1451(vs), 743(s) and 703(m) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 2.38 (s, 3H), 6.65-6.79 (m, 1H), 7.00-7.55 (m, 16H), 9.11 (d, 1H, J= 8 Hz); ^{13}C n.m.r. δ ($CDCl_3$): 20.52, 113.27, 114.07, 115.63, 117.39, 117.95, 121.17, 122.08, 122.96, 123.12, 127.67, 127.83, 128.75, 129.18, 129.95, 130.33, 130.72, 130.97, 132.81, 134.08, 134.58, 138.98, 144.49; m/z (%): 399 (M^+, 100), 398 (53), 199 (38), 191 (33), 192 (32), 190 (34), 184 (17), 165 (42), 163 (21), 139 (12), 91 (40), 77 (49).

29b (R= m-CH_3O-C_6H_4) (86%), m.p. 201-202°C (colourless prisms from methylene chloride/ n-hexane). (Found: C, 81.23; H, 4.92; N, 10.26. $C_{28}H_{21}N_3O$ requires: C, 80.94; H, 5.09; N, 10.11); i.r. (Nujol): 3318(s), 1660(vs), 1588(vs), 1480(s), 1451(s), 1223(m), 1130(m), 1031(m), 928(m), 750(s) and 708(m) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 3.83 (s, 3H), 6.69-6.81 (m, 4H), 7.09-7.26 (m, 1H), 7.26-7.56 (m, 12H), 9.10 (d, 1H, J= 8 Hz); ^{13}C n.m.r. δ (CDCl3): 55.24, 108.05, 109.18, 114.03, 114.48, 114.57, 115.87, 117.38, 118.64, 121.87, 123.12, 123.75, 124.46, 127.67, 127.72, 128.51, 129.03, 130.65, 130.72, 131.42, 133.44, 137.47, 137.53, 139.61, 148.60, 161.18; m/z (%): 415 (M^+, 32), 414 (11), 207 (10), 190 (5), 165 (10), 86 (45), 84 (100), 77 (10).

29c (R= p-CH_3O-C_6H_4) (81%), m.p. 230-232°C (colourless prisms from methanol). (Found: C, 81.19; H, 4.93; N, 10.28. $C_{28}H_{21}N_3O$ requires: C, 80.94; H, 5.09; N, 10.11); i.r. (Nujol): 3347(s), 1663(vs), 1616(s), 1601(s), 1508(s), 1327(s), 1239(s), 1031(m), 753(s) and 702(s) cm^{-1}; ^1H n.m.r. δ ($CDCl_3$): 3.85 (s, 3H), 6.70-6.97 (m, 2H), 6.97-7.56 (m, 15H), 9.10 (d, 1H, J= 8.2 Hz); ^{13}C n.m.r. δ ($CDCl_3$): 51.61, 113.89, 114.55, 115.43, 115.91, 117.43, 118.68, 121.85, 123.09, 123.31, 123.79, 124.56, 127.69, 127.74, 128.51, 129.06, 130.71, 131.42, 133.51, 134.62, 140.06, 140.21, 155.89, 155.95; m/z (%): 415 (M^+, 100), 414 (18), 400 (44), 207 (20), 184 (12), 165 (18), 132 (10), 122 (5), 77 (15).

Reaction of Iminophosphorane 28 with Carbon Dioxide and Carbon Disulfide.

Iminophosphorane 28 reacts with carbon dioxide or carbon disulfide under the same conditions as iminophosphorane 19, to give the corresponding indolo[1,2-c]quinazolines 30 as crystalline solids.

30a (X= O) (55%), m.p. 277-279°C (colourless needles from toluene). (Found: 81.36; H, 4.32; N, 8.83. $C_{21}H_{14}N_2O$ requires: C, 81.27; H, 4.55; N, 9.03); i.r. (Nujol): 3216(w), 1698(vs), 1605(m), 1593(m), 1413(s),

1138(w), 1079(m), 749(m) and 706(s) cm^{-1}; ^1H n.m.r. δ (DMSO-d_6): 6.90-6.98 (m, 1H), 7.27-7.62 (m, 11H), 8.67 (d, 1H, J=7.6 Hz), 11.42 (s, 1H); ^{13}C n.m.r. δ (DMSO-d_6): 113.79, 114.67, 115.57, 115.60, 118.32, 122.24, 123.19, 123.58, 123.63, 127.98, 128.40, 129.11, 129.18, 130.22, 130.39, 132.36, 133.55, 134.74, 147.07; m/z (%): 310 (M^+, 100), 309 (12), 267 (15), 205 (10), 165 (43), 163 (11), 155 (17), 145 (11), 140 (15), 133 (30), 127 (28), 113 (14), 112 (7).

30b (X = S) (85%), m.p. 278°C (colourless prisms from toluene). (Found: C, 77.49; H, 4.43; N, 8.31. $C_{21}H_{14}N_2S$ requires: C, 77.27; H, 4.32; N, 8.58); i.r. (Nujol): 3182(s), 1541(vs), 1497(s), 1319(s), 1306(s), 1276(vs), 1216(s), 1155(s),764(s), 737(m) and 707(s) cm^{-1}; ^1H n.m.r. δ (DMSO-d_6): 7.02-7.06 (m, 1H), 7.35-7.63 (m, 11H), 9.89-9.94 (m, 1H), 12.86 (s, 1H); ^{13}C n.m.r. δ (DMSO-d_6): 115.16, 115.24, 115.62, 117.91, 118.37, 123.10, 123.33, 123.88, 124.74, 127.11, 128.26, 129.28, 129.32, 130.14, 131.69, 132.43, 133.15, 134.00, 169.85; m/z (%): 326 (M^+, 100), 325 (15), 268 (19), 267 (24), 239 (10), 166 (15), 165 (63), 163 (42), 146 (16), 133 (85), 132 (61), 119 (22), 118 (23), 106 (12).

Acknowledgement. The authors are indebted to Direccion General de Investigacion Cientifica y Tecnica for financial support., Project Number PB 86-0039.

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