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An Anomalous Intramolecular Conjugate Addition of N-Protected Imidazoles to Vinyliminophosphoranes Promoted by Tetrabutylammonium Fluoride. X-Ray Crystal Structure of 5-Ethoxycarbonyl-5-(triphenylphosphoranylidene-amino)-5,6-dihydroimidazo[2,1-*a*]isoquinoline.

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Abstract: An anomalous intramolecular conjugate addition of N-SEM protected imidazoles to vinyliminophosphoranes proceeds efficiently in the presence of tetrabutylammonium fluoride (TBAF) to afford the corresponding fused imidazoles. The crystal and molecular structure of **4** have been solved by X-Ray analysis. The crystal packing is governed by weak C-H···X (X = O, N or aromatic π system) hydrogen interactions because the absence of more polarized donor groups to form hydrogen bonds.

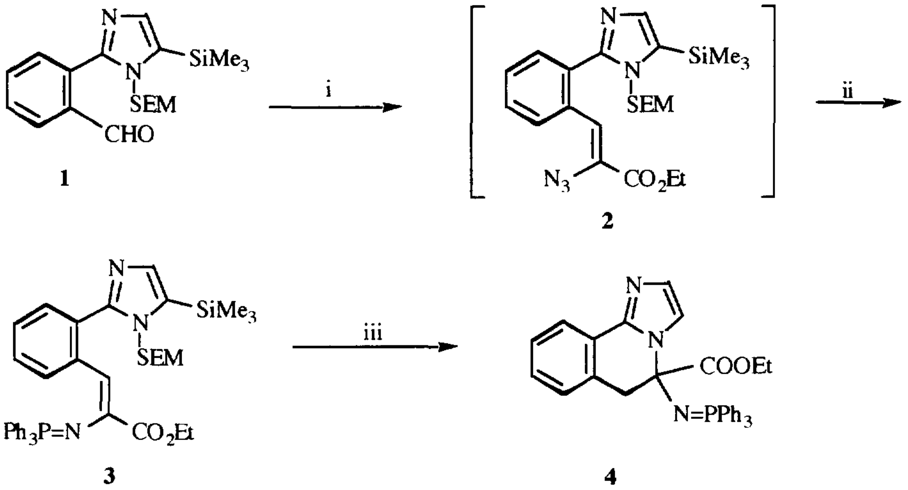
Recently N-vinyliminophosphoranes have received increased attention as useful building blocks for the synthesis of azaheterocycles.[1] These type of compounds may be considered to be equivalents of enamines containing two nucleophilic centers at the β-carbon atom of the vinyl side chain and the nitrogen atom of the iminophosphorane portion. Thus, N-vinyliminophosphoranes undergo a single step reaction with compounds containing two electrophilic centers such as α,β-unsaturated carbonyl compounds and related Michael acceptors to give several types of nitrogen-containing heterocycles.[2] These conversions may take place through two pathways: (i) a Michael type addition followed by proton transfer to generate an intermediate iminophosphorane which then undergoes an intramolecular aza Wittig reaction or (ii) an aza Wittig reaction leading to an intermediate azahexatriene which then undergoes a thermal 6π-electrocyclization.

We wish to report herein an unprecedented reaction of N-vinyliminophosphoranes involving the vinyl side chain as the only reaction center, the iminophosphorane group remaining unaffected. This reaction which involves nucleophilic attack of a pyrrole-like amino group on the α-carbon of the vinyl portion, in the intramolecular version, has been found to be a useful method for the preparation of highly functionalized aza heterocycles.

To this end, an N-vinyliminophosphorane bearing an imidazole ring at an appropriate position was selected as a model. The requisite imidazole **1** was easily prepared from the commercially available 2-phenylimidazole by the following three-step sequence[3]: a) formation of the N-protected imidazole by reaction with BuLi and (trimethylsilyl) ethoxy-methyl chloride (SEM-Cl) (60 %); b) selective formation of the α-lithiated imidazole and subsequent reaction with chlorotrimethylsilane (TMS-Cl) (67'8 %); and c) reaction of the silylated imidazole with BuLi and trapping of the lithiated intermediate with DMF (73 %). Condensation of compound **1** with ethyl azidoacetate in the presence of NaOEt at -15 °C provided the vinylazide **2** in moderate yield

(45%), which was converted, by Staudinger reaction with triphenylphosphine in dichloromethane at room temperature, into the vinyliminophosphorane **3** in excellent yield (81%).

Deblocking of both the SEM and TMS protecting groups on vinyliminophosphorane **3** using tetrabutylammonium fluoride (TBAF) in tetrahydrofuran solution at reflux temperature led to the simultaneous removal of both groups with concomitant ring-closure by nucleophilic attack of the NH group of the imidazole ring on the α-carbon atom of the vinyliminophosphorane moiety (6-endo-trig) to give the iminophosphorane **4** in good yield (75%). (Scheme 1).



Reagents and Conditions: i) $EtO_2C\text{-}CH_2N_3$, NaOEt, -15°C (45%); ii) PPh_3, CH_2Cl_2, 0 °C (81%); iii) TBAF, THF/H_2O, Δ (75%).

Scheme 1

The methylenic protons of compound **4** appeared in the ^{1}H n.m.r. spectrum as two doublets at δ 3.05 and 3.19 respectively (J=15.0 Hz), whereas in the ^{13}C n.m.r. spectrum, the methylenic carbon atom appeared at 43.2 ppm coupled with the phosphorus atom ($^3J_{P\text{-}C}$ = 5.5 Hz). The ^{31}P n.m.r. spectrum showed one signal at 0.05 ppm which is in good agreement for this type of iminophosphorane.[4] In addition, the ^{13}C n.m.r. spectrum indicated that the α-methine group in **4** is now an sp^3-hybridized quaternary carbon atom.

In order to identify unambiguously the structure of the reaction product, the X-ray structure determination of crystalline compound **4** was performed (Fig 1). A search for the three-ring fused system that is present in the title compound using the Cambridge Structural Database[5] (CSD Version 5.11, April 1996) has been performed and no matching structure has been found. Table 1 displays selected parameters describing the intramolecular geometry and the C-H···X hydrogen interactions, X corresponding to O, N or an aromatic ring centroid.

The four phenyl rings do not deviate significantly from planarity, however, the imidazole one is not planar, with a χ^2 coefficient of 25.96 vs. a theoretical value of 5.99, showing an envelope conformation with the flap located at N4. This nitrogen deviates 0.034(3)Å from the plane defined by the remaining four atoms. The heterocyclic six-membered system presents a diplanar 1, 3 conformation according to the ring puckering

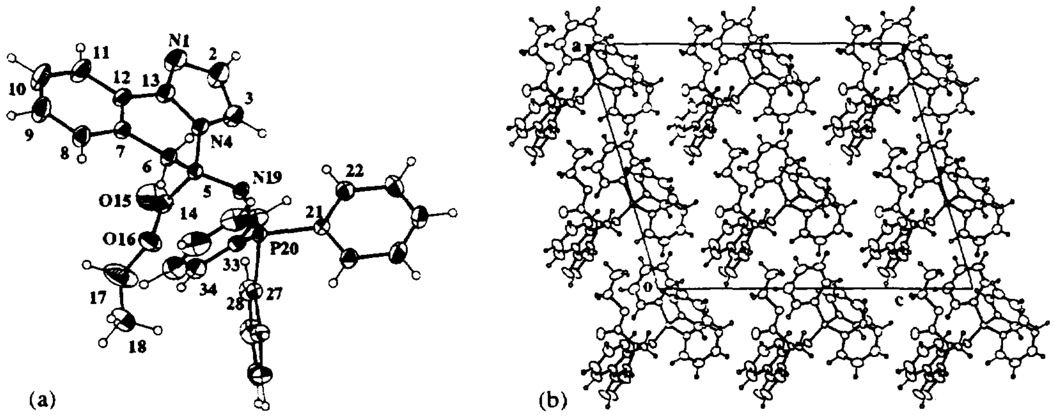


Figure 1. (a) Molecular structure of the title compound with the atomic numbering scheme. Anisotropic displacement parameters are drawn at the 30% level and the hydrogen atoms are shown as spheres of arbitrary radii. (b) View of the crystal packing down the b axis.

Table 1. Selected geometrical parameters (Å,°). C(V-W) stand for the centroids of the rings formed by atom V to W.

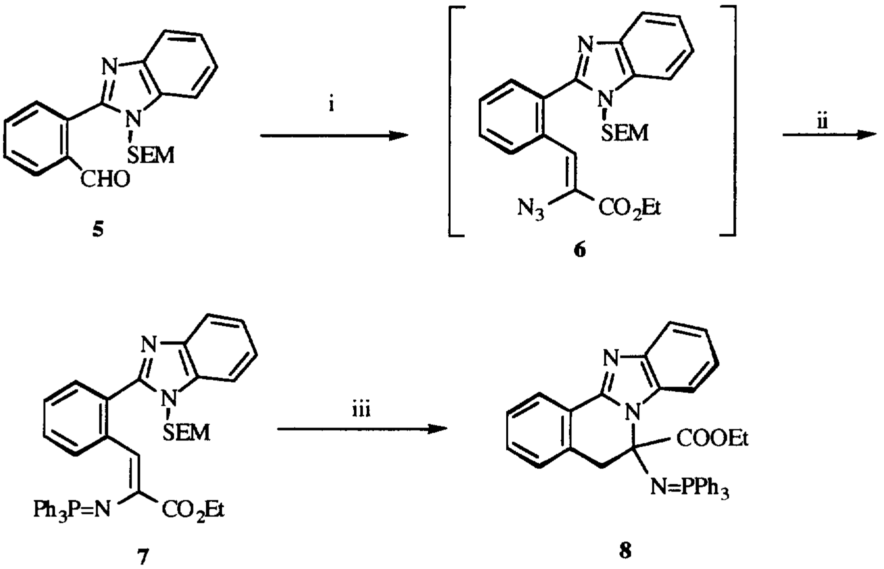
N1-C2	1.377(7)	N4-C5	1.476(4)	C5-N19	1.425(4)
C2-C3	1.362(7)	C5-C6	1.533(5)	N19-P20	1.573(3)
C3-N4	1.363(5)	C6-C7	1.509(5)	P20-C21	1.790(4)
N4-C13	1.360(5)	C7-C12	1.393(5)	P20-C27	1.828(4)
N1-C13	1.317(6)	C12-C13	1.451(6)	P20-C33	1.805(3)
C13-N1-C2	104.5(4)	C13-N4-C5	123.7(3)	N4-C5-N19	107.2(3)
N1-C2-C3	110.8(5)	N4-C5-C6	105.7(3)	C14-C5-N19	111.5(3)
C2-C3-N4	105.6(4)	C5-C6-C7	112.4(3)	C5-N19-P20	132.2(3)
C3-N4-C13	107.1(3)	C6-C7-C12	119.0(3)	N19-P20-C21	106.5(2)
N4-C13-N1	111.9(4)	C7-C12-C13	117.9(3)	N19-P20-C27	115.9(2)
N4-C5-C14	106.3(3)	C12-C13-N4	119.8(4)	N19-P20-C33	116.2(2)
C6-C5-N19	116.3(3)	C6-C5-C14	109.3(3)		
C13-N4-C5-C6	−39.5(4)	C6-C7-C12-C13	4.0(5)	C5-N19-P20-C21	−164.6(3)
N4-C5-C6-C7	51.6(4)	C7-C12-C13-N4	12.4(6)	C5-N19-P20-C27	81.8(4)
C5-C6-C7-C12	−37.9(5)	C12-C13-N4-C5	7.9(6)	C5-N19-P20-C33	−45.4(4)
C13-N4-C5-C14	76.6(4)	C5-C14-O16-C17	−178.2(5)	C13-N4-C5-N19	−164.1(3)
N4-C5-C14-O16	−170.2(3)	C14-O16-C17-C18	156.3(7)	N4-C5-N19-P20	176.9(3)
N19-P20-C27-C28	19.9(4)	N19-P20-C21-C22	−8.0(4)	C6-C5-N19-P20	59.0(4)

Hydrogen interactions

X-H···Y	X-H	X···Y	H···Y	X-H···Y
C24-H24···O15(x,1-y,½+z)	0.98(-)	3.141(7)	2.51(-)	122(-)
C25-H25···O15(x,1-y,½+z)	0.97(-)	3.134(7)	2.52(-)	121(-)
C37-H37···O15(x,-y,½+z)	1.02(-)	3.597(8)	2.63(-)	158(-)
C22-H22···N19	0.98(-)	2.960(6)	2.51(-)	108(-)
C26-H26···N1(½+x,½-y,½+z)	0.96(-)	3.575(6)	2.67(-)	158(-)
C32-H32···N1(½+x,½-y,½+z)	0.97(-)	3.629(7)	2.77(-)	147(-)
C18-H183···C(7-12)(½+x,½+y,z)	1.00(-)	3.737(10)	2.78(-)	161(-)
C29-H29···C(1-13)(½+x,½+y,z)	0.98(-)	4.015(8)	3.23(-)	139(-)
C10-H10···C(21-26)(x,½+y,z)	0.99(-)	3.987(7)	3.30(-)	128(-)
C2-H2···C(33-38)(-½+x,½-y,-½+z)	1.00(-)	3.990(6)	3.13(-)	145(-)

coordinates defined by Cremer and Pople[6] [q_2=0.406(4), q_3=0.218(4)Å and ϕ_2=92.5(5), θ_2=61.8(5)° vs. theoretical values of 90.0 and 67.5° for a pure $3S_2$ (diplanar 1,3) conformation]. There are steric hindering interactions between the ester and the iminophosphorane substituents located at C5 as can be observed by the opening of the C14-C5-N19-P20 bond angles, Table 1.

The only possible hydrogen interactions are those where the C-H group acts as a hydrogen bond donor. The three dimensional network is stabilized by these kind of weak interactions, Table 1. Those involving an oxygen atom as acceptor present H···O distances close to 2.55Å that is the position of the maximum in the distribution of this distance obtained by neutron diffraction data of carbohydrates.[7] In order to characterize the H···N distribution in the Csp^2-H···Nsp^2 intermolecular interactions, a search in the CSD has been carried out.[8] The query was not restricted to neutron diffraction experiments, since not enough structures were recorded. For this interaction the maximum of the H···N distribution is located at 2.80Å, longer than the values reported in Table 1. The small value of the N19-P20-C21-C22 torsion angle could be due to the C22-H22···N19 intramolecular interaction. When an aromatic ring is the acceptor, the strongest interaction is that involving the C18 methyl group. Its influence can be observed in the lowering of the equivalent isotropic displacement parameter for this C atom as compared with the previous ones that increase along the ester chain, Table 3.

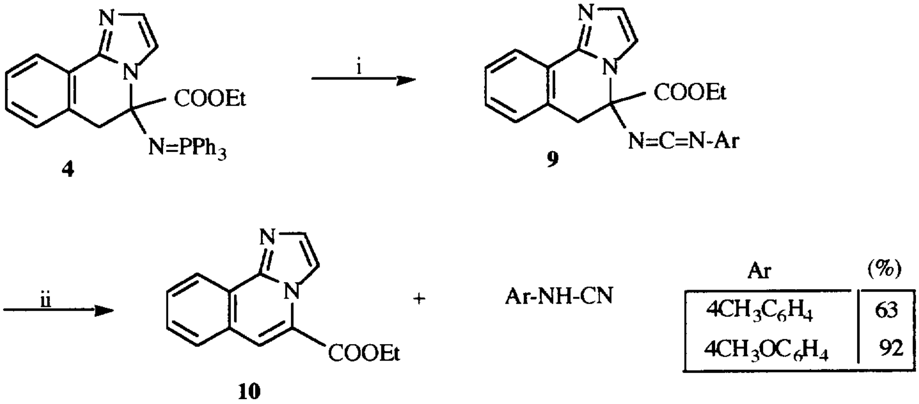


Reagents and conditions i) $EtO_2C\text{-}CH_2N_3$, NaOEt, -15°C (45%); ii) PPh_3, CH_2Cl_2, 0 °C (75%); iii) TBAF, THF/H_2O, Δ (65%).

Scheme 2

The success of this anomalous intramolecular conjugate addition that ultimately led to iminophosphoranes derived from fused imidazoles prompted us to attempt this conversion in the related compound 2-phenylbenzimidazole. Compound **5** was easily prepared from 2-phenylbenzimidazole in an overall yield of 53% by initial protection of the imidazole ring with the BuLi/SEM-Cl system and further lithiation with BuLi and trapping of the lithiated intermediate with DMF. Condensation of **5** with ethylazidoacetate under standard conditions provided the vinyazide **6** (45%), which was converted into the iminophosphorane **7** (75%) by reaction with triphenylphosphine in dichloromethane at 0°C. When iminophosphorane **7** was treated with a solution of TBAF in THF at reflux temperature the cyclized product **8** was obtained (65%) as the sole reaction product. (Scheme 2). Spectroscopic data of compound **8** are very similar to those reported for **4**. Thus in the ^{1}H n.m.r. spectrum the methylenic protons appear at δ 3.10 and δ 3.22 as two doublets (J = 15.1 Hz), whereas in the ^{13}C n.m.r. spectrum the methylenic carbon atom appears at 43.75 ppm ($^3J_{P\text{-}C}$ = 4.2 Hz) and the sp^3-hybridized quaternary carbon atom appears at 74.86 ppm ($^2J_{P\text{-}C}$ = 5.5 Hz).

Both iminophosphoranes **4** and **8** showed the characteristic behaviour in aza Wittig-type reaction towards isocyanates. Thus, iminophosphorane **4** reacted with aryl isocyanates in toluene at room temperature to give the corresponding carbodiimides **9**, which by heating at 140°C underwent a retro-ene reaction to give **10** (62-92%) and the corresponding arylcyanamide. (Scheme 3). Some derivatives of the otherwise not readily available imidazo[2,1-*a*]isoquinoline ring system **10**, such as SDZ 62-434, have been identified as platelet-activating factor (PAF) antagonists and also show antiproliferative activity.[9]



Ar	(%)
$4CH_3C_6H_4$	63
$4CH_3OC_6H_4$	92

Reagents and Conditions: i) Ar-NCO, r.t.; ii) 140 °C.

Scheme 3

EXPERIMENTAL

All melting points were determined on a Kofler hot-plate melting point apparatus and are uncorrected. IR spectra were obtained as nujol emulsions or film on a Nicolet 5DX spectrophotometer. NMR spectra were recorded on a Brucker AC-200 (200 MHz) or a Varian Unity-300 (300 MHz). Mass spectra were recorded on a Hewlett-Packard 5993C spectrometer. Microanalyses were performed on a Perkin-Elmer 240C instrument.

X-ray Analysis.- A summary of data collection and the refinement process is given in Table 2. The structure was solved by direct methods (SIR92)[10] and refined by least-squares procedures on Fobs. All hydrogens were obtained from difference Fourier synthesis and included as isotropic and kept fixed in the last cycles of refinement. Six reflections were affected by secondary extinction and were considered as unobserved. The

Table 2. Crystal analysis parameters at room temperature.

Crystal data

Chemical formula	$C_{32}H_{28}N_3O_2P$	Crystal system	Monoclinic
Mr	517.57	Space group	*Cc*
a (Å)	16.0600(9)	α (°)	90
b (Å)	9.1304(3)	β (°)	106.707(4)
c (Å)	19.8682(12)	γ (°)	90
Z	4	*Dx* (gr/cm³)	1.23
V (Å³)	2790.4(3)	Radiation	CuKα
Wavelength (Å)	1.5418	No. of reflections for	
θ range for lattice parameters (°)	2-45	lattice parameters determination:	78
Absorption coefficient (cm^{-1})	11.14	Temperature (K)	295
Crystal colour	Colourless	Crystal description	Prism
Crystal size (mm)	0.50 x 0.50 x 0.17		

Data collection

Diffractometer type	Philips PW1100, four circle. Graphite oriented monocromator.		
Measurement time	1 min./reflection	Detector apertures (°)	1 x 1
Collection method	ω/2θ scans	θmax (°)	65
No. of standard reflections (interval)	2 (90 min.). No variation	Scan width (°)	1.5
No. of independent reflections	2370	No. of observed reflections, I>3σ(I)	2334

Refinement

Treatment of hydrogen atoms	See experimental part	Refinement: Least-Squares on *Fo*. Full matrix	
R	0.053	No. of parameters refined	341
wR	0.055	Degrees of freedom	1993
(Δρ)max (e/Å³)	0.28	Ratio of freedom	6.8
<Shift/error>	0.02	Max. thermal value (Å²)	U22[C17]=0.32(2)

Weighting scheme: Empirical as to give no trends in <ωΔ²F> vs. <|Fobs|> and <sinθ/λ>.

Table 3. Final atomic coordinates and $Ueq=(1/3)\Sigma[Uij\cdot a_i{}^*\cdot a_j{}^*\cdot a_i\cdot a_j\cdot \cos(a_i,a_j)]x10^4$

Atom	x	y	z	Ueq	Atom	x	y	z	Ueq
N1	0.0658(3)	0.1416(5)	0.2322(2)	775(15)	P20	0.3500(0)	0.2952(1)	0.5000(0)	315(2)
C2	0.0652(4)	0.2860(6)	0.2522(3)	820(19)	C21	0.3072(2)	0.4172(4)	0.5523(2)	396(11)
C3	0.1338(3)	0.3149(5)	0.3093(3)	630(15)	C22	0.2266(3)	0.4815(6)	0.5246(3)	649(16)
N4	0.1772(2)	0.1855(3)	0.3260(2)	427(9)	C23	0.1957(3)	0.5795(7)	0.5649(3)	814(21)
C5	0.2634(2)	0.1600(3)	0.3765(2)	341(9)	C24	0.2426(3)	0.6122(6)	0.6321(3)	692(18)
C6	0.2629(2)	0.0000(4)	0.3998(2)	380(10)	C25	0.3226(3)	0.5474(5)	0.6603(2)	599(16)
C7	0.2354(2)	-0.1040(4)	0.3384(2)	411(11)	C26	0.3551(3)	0.4514(4)	0.6205(2)	484(12)
C8	0.2725(3)	-0.2419(5)	0.3406(2)	561(14)	C27	0.4447(2)	0.3946(4)	0.4903(2)	417(11)
C9	0.2434(4)	-0.3368(5)	0.2843(3)	744(19)	C28	0.4350(3)	0.4774(4)	0.4304(2)	549(15)
C10	0.1780(4)	-0.2958(6)	0.2265(3)	807(21)	C29	0.5004(4)	0.5697(5)	0.4235(3)	732(22)
C11	0.1412(3)	-0.1578(6)	0.2226(3)	697(17)	C30	0.5774(4)	0.5774(6)	0.4771(4)	793(24)
C12	0.1699(2)	-0.0615(4)	0.2789(2)	472(12)	C31	0.5886(3)	0.4937(7)	0.5362(3)	764(20)
C13	0.1352(3)	0.0856(4)	0.2773(2)	495(13)	C32	0.5223(3)	0.4010(5)	0.5437(2)	555(14)
C14	0.3302(3)	0.1784(4)	0.3348(2)	478(13)	C33	0.3901(2)	0.1358(4)	0.5532(2)	395(10)
O15	0.3143(3)	0.2262(6)	0.2768(2)	933(18)	C34	0.4570(3)	0.0514(5)	0.5423(2)	551(13)
O16	0.4080(2)	0.1366(5)	0.3709(2)	691(12)	C35	0.4773(4)	-0.0835(5)	0.5762(3)	749(19)
C17	0.4762(4)	0.1550(17)	0.3356(4)	1467(56)	C36	0.4326(4)	-0.1303(6)	0.6209(4)	907(24)
C18	0.5562(4)	0.1646(11)	0.3806(5)	1122(35)	C37	0.3677(4)	-0.0489(7)	0.6329(3)	794(20)
N19	0.2749(2)	0.2678(3)	0.4303(2)	408(9)	C38	0.3450(3)	0.0855(5)	0.5991(2)	572(15)

scattering factors were taken from International Tables for X-Ray Crystallography.[11] Table 3 lists the final atomic coordinates and equivalent thermal factors for non-hydrogen atoms. The calculations were carried out with the XTAL[12], PESOS[13] and PARST[14] set of programs running on a VAX 6410 computer.

1-[(Trimethylsilyl)ethoxymethyl]-2-[*o*-formylphenyl]benzimidazole 5.- To 2-phenylimidazole (1.0 g, 5.1 mmol) in anhydrous tetrahydrofuran (20 ml) at -20 °C under nitrogen with stirring 1.6 M *n*-butyllithium in hexane (3.56 ml, 5.6 mmol) was slowly added. The resultant mixture was stirred for 1h at that temperature and then (trimethylsilyl) ethoxymethyl chloride (SEM-Cl) (0.95 g, 5.7 mmol) was added. The reaction mixture was stirred for one additional hour at -20 °C and then was allowed to warm to room temperature overnight. The solution was cooled to -42 °C and 1.6 M *n*-butyllithium in hexane (5.1 ml, 7.65 mmol) was slowly added under nitrogen. After 2h, anhydrous dimethylformamide (3.2 ml, 2.98 g, 40.8 mmol) was added to the dark orange reaction mixture and stirring was continued for 1h. The reaction mixture was allowed to warm to room temperature, poured into saturated aqueous ammonium chloride (40 ml) and then extracted with diethyl ether (3 x 15 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered and evaporated to dryness. The crude product was purified by column chromatography using a silica gel column eluting with ethyl acetate/*n*-hexane (1:3) (53%), yellow oil; (Found: C, 68.04; H, 6.99; N, 7.82. $C_{20}H_{24}N_2O_2Si$ requires: C, 68.15; H, 6.86; N, 7.95; IR (Nujol): 1698, 1601, 1454, 1348, 1250, 1200, 1084, 837, 748, 694 cm^{-1}. ^1H-NMR ($CDCl_3$, 300 MHz) δ: 10.00 (s, 1H, CHO); 8.10 (d, 1H,^3J = 8 Hz); 7.84 (d, 1H, ^3J = 7.8 Hz); 7.70 (m, 3H); 7.56 (d, 1H, ^3J = 7.8 Hz); 7.37 (m, 2H); 5.39 (s, 2H, NCH_2O); 3.47 (m, 2H); 0.84 (m, 2H); -0.07 (s, 9H $(CH_3)_3Si$). ^{13}C-NMR ($CDCl_3$, 75 MHz) δ: 190.83 (CHO); 150.49 (q); 142.76 (q); 135.82 (q); 135.29 (q); 133.32 (q); 132.24 (q); 131.26; 130.43; 128.68; 123.84; 123.15; 120.16; 110.31; 73.26 (NCH_2O); 66.73 (CH_2O); 17.65 (CH_2Si); -1.51 (CH_3). m/z: 352 (M^+, 1), 223 (70), 195 (34), 149 (20), 73 (100).

General Procedure for the Preparation of Vinyliminophosphoranes 3 and 7.

To a solution cooled at -15 °C of sodium ethoxide (0.73 g, 10.8 mmol) in dry ethanol (25 ml), a mixture of the corresponding aldehyde **1** or **5** (1.00 g), ethyl azidoacetate (1.38 g,10.8 mmol) and dry ethanol (25 ml) was added dropwise under nitrogen. The resultant mixture was stirred at that temperature for 6h, poured into an aqueous ammonium chloride saturated solution (35 ml) and then extracted with diethyl ether (3 x 15 ml), The combined organic layers were washed with aqueous sodium chloride saturated solution (2 x 15 ml), water and then dried over anhydrous$MgSO_4$. After filtration, the solvent was removed under reduced pressure and the corresponding crude azide **2** or **6** was used without further purification.

To a solution cooled at 0 °C of the corresponding azide **2** or **6** (1.5 mmol) in dry dichloromethane (15 ml), triphenylphosphine (0.40 g, 1.5 mmol) was added under nitrogen. The mixture was allowed to warm to room temperature and stirring was continued for 2h. The solution was concentrated to dryness and the residual material was chromatographed on a silica gel columm eluting with ethyl acetate/*n*-hexane (1:1) and then recrystallized from dichloromethane/*n*-hexane (1:1).

Ethyl-β-{*o*-[(5-trimethylsilyl)ethoxymethylimidazol-2-yl)]phenyl}-α-(triphenylphosphoranylidene) amino acrylate 3.- Yield (81%), m.p. 179-180 °C (yellow prisms); (Found: C, 68.50; H, 7.13; N, 5.70. $C_{41}H_{50}N_3O_3PSi_2$ requires: C, 68.40; H, 7.00; N, 5.84). IR (Nujol): 1703, 1607, 1580, 1458, 1433, 1312, 1252, 1233, 1099, 1090, 1038, 922, 841, 772, 756, 714, 694 cm^{-1}. ^{1}H-NMR ($CDCl_3$, 300 MHz) δ: 9.22 (d, 1H, $^{3}J = 8.1$ Hz); 7.75 (m, 6H, $^{3}J_P = 12.3$, $^{3}J = 7.2$, $^{4}J = 2.1$ Hz); 7.43 (m, 12H); 7.34 (s, 1H); 7.24 (m, 1H); 6.23 (d, 1H, $^{4}J_P = 6.9$ Hz); 5.15 (s, 2H, NCH_2O); 3.76 (q, 2H, $^{3}J = 7.1$ Hz, CH_2OCO); 3.12 (t, 2H, $^{3}J = 8.5$ Hz, OCH_2-CH_2Si); 0.92 (t, 3H, $^{3}J = 7.1$ Hz, CH_3-CH_2OCO); 0.69 (t, 2H, $^{3}J = 8.5$ Hz, CH_2Si); 0.36 (s, 9H, $(CH_3)_3Si$); -0.18 (s, 9H, $(CH_3)_3Si$). ^{13}C-NMR ($CDCl_3$, 75 MHz) δ: 167.57 (d, $^{3}J_P = 7.1$ Hz, COO); 152.16 (C2); 138.78; 138.22 (d, $^{4}J = 1.1$ Hz, q); 137.53 (d, $^{2}J_P = 6.5$ Hz, q); 132.73 (d, $^{1}J_P = 102.7$ Hz, C_iPhP); 132.30 (d, $^{2}J_P = 10.0$ Hz, C_oPhP); 130.91 (d, $^{4}J_P = 3.0$ Hz, C_pPhP); 130.51; 130.15 (q); 129.44 ; 128.60; 128.34; 128.07 (d, $^{3}J_P = 12.0$ Hz, C_mPhP); 125.22; 112.00 (d, $^{3}J_P = 19.5$ Hz); 74.74 (NCH_2O); 64.88 (OCH_2-CH_2-Si); 60.57 (CH_2OCO); 17.31 (CH_2Si); 13.85 (CH_3-CH_2OCO); -0.65 ($(CH_3)_3$-Si); -1.62 ($(CH_3)_3$-Si); a quaternary carbon atom is not observed. ^{31}P-NMR ($CDCl_3$, 125 MHz) δ: 4.61; m/z: 719 (M^+, 1), 574 (2), 516 (6), 262 (15), 183 (35), 147 (13), 108 (19), 73 (100).

Ethyl-*β*-{*o*-[(5-trimethylsilyl)ethoxymethylbenzimidazol-2-yl)]phenyl}-*α*-(triphenylphosphoranylidene) amino acrylate 7.- Yield (75%), m.p. 198-200 °C (white prisms); (Found: C, 72.46; H, 6.59; N, 5.86. $C_{42}H_{44}N_3O_3PSi$ requires: C, 72.28; H, 6.35 N, 6.02. IR (Nujol): 1705, 1603, 1585, 1256, 1102 cm^{-1}. ^{1}H-NMR ($CDCl_3$, 300 MHz) δ: 9.24 (d, 1H, $^{3}J = 7.8$ Hz), 7.81 (m, 7H); 7.44 (m, 16H); 6.39 (d, 1H, $^{3}J_{P\text{-}H} = 6 .9$ Hz); 5.45 (s, 1H, NCH_2O); 3.68 (q, 2H, $^{3}J = 7.1$ Hz, CH_2OCO); 3.24 (m, 2H); 1.31 (t, 3H, $^{3}J = 7.1$ Hz, CH_3); 0.77 (m, 2H); -0.11 (s, 9H, $(CH_3)_3Si$). ^{13}C-NMR ($CDCl_3$, 75 MHz) δ: 163.06 (CO); 152.17 (q); 134.87 (q); 133.33 (q); 130.25; 129.85; 128.700; 127.02 (q); 123.40; 122.92; 121.67; 119.96; 110.49; 73.29 (NCH_2O); 66.31 (CH_2OCO); 66.15 (OCH_2); 17.58 (CH_2Si); 13.77 ($(CH_3)_3Si$); one quaternary carbon is not observed. ^{31}P-NMR ($CDCl_3$, 125 MHz) δ: 4.61; m/z: 517 (M^+, 1), 262 (5), 222 (4), 183 (100), 181 (20), 156 (8), 152 (10), 129 (6), 115 (5), 108 (24), 107 (17), 77 (8), 73 (7).

General Procedure for the Preparation of Compounds 4 and 8.

To a solution of the corresponding iminophosphorane **3** or **7** (1.3 mmol) in tetrahydrofuran (20 ml), a 1M solution of tetrabutylammonium fluoride (5.2 ml, 5.2 mmol) was added under nitrogen atmosphere. The resultant mixture was treated at reflux temperature for 6h. After cooling, the solution was treated with Na_2HPO_4 buffer (pH = 7.3 3 x 15 ml) and extracted with ethyl acetate (3 x15 ml). The combined organic layers were dried over anhydrous $MgSO_4$, filtered and concentrated to dryness. The crude product was chromatographed on a silica gel column using ethyl acetate as eluent and then recrystallized from dichloromethane / *n*-hexane (1:1).

Imidazo[2,1-*a*]isoquinoline derivative 4.- Yield (75%), m.p. 181-182 °C (white prisms); (Found: C, 74.08; H, 5.33; N, 8.30. $C_{32}H_{28}N_3O_2P$ requires: C, 74.26; H, 5.45 N, 8.12; IR (Nujol): 1738, 1439, 1331, 1314, 1264, 1248, 1209, 1177, 1101, 1047, 760, 716, 696 cm^{-1}. ^{1}H-NMR ($CDCl_3$, 300 MHz) δ: 7.95 (d, 1H, $^{3}J = 7.8$ Hz); 7.77 (m, 6H, $^{3}J_P = 12.3$, $^{3}J =7.2$, $^{4}J = 2.1$ Hz, H_oPhP); 7.71 (d, 1H, $^{3}J = 1.3$ Hz); 7.48 (m, 9H); 7.21 (dd, 1H, $^{3}J = 7.8$, $^{3}J = 7.5$ Hz); 7.13 (d, 1H, $^{2}J = 1.3$ Hz); 7.09 (dd, 1H, $^{3}J = 7.5$ Hz); 6.90 (dd, 1H, $^{3}J = 7.5$ Hz); 3.55 (m, 2H, CH_2OCO); 3.19 (d, 1H, $^{2}J = 15.0$ Hz); 3.05 (d, 1H, $^{2}J = 15.0$ Hz); 0.80 (t, 3H, $^{3}J = 7.1$ Hz, CH_3). ^{13}C-NMR ($CDCl_3$, 75 MHz) δ: 171.17 (d, $^{3}J = 6.8$ Hz, CO); 143.58 (d, $^{2}J_P = 1.6$ Hz, q); 132.37 (d, $^{2}J_P = 10.0$ Hz, C_oPhP); 132.25 (d, $^{1}J_P = 102.2$ Hz, C_iPhP); 131.43 (q); 131.31 (d, $^{4}J_P = 2.9$ Hz, C_pPhP); 128.29 (d, $^{3}J_P = 12.2$ Hz, C_mPhP); 127.77; 127.74; 127.19; 127.00 (q); 123.10; 118.10; 77.54 (d, $^{2}J_P = 5.4$ Hz, C5); 60.65 (CH_2O); 43.23 (d, $^{3}J_P = 5.5$ Hz, C6); 13.47 (CH_3). ^{31}P-NMR ($CDCl_3$, 125 MHz) δ: 4.61; m/z: 517

(M^+,1), 445 (5), 262 (5), 222 (4), 183 (100), 181 (20), 156 (8), 152 (10), 129 (6), 115 (5), 108 (24), 107 (17), 77 (8), 73 (7).

Benzimidazo[2,1-*a*]isoquinoline derivative 8.- Yield (65%), m.p. 213-214 °C (white prisms); (Found: C, 76.37; H, 5.40; N, 7.52. $C_{36}H_{30}N_3O_2P$ requires: C, 76.18; H, 5.33; N, 7.40. IR (Nujol): 1738, 1439, 1336, 1308, 1264, 1234, 1104, 779 cm^{-1}. ^1H-NMR ($CDCl_3$, 300 MHz) δ: 8.38 (d, 1H, ^3J = 8.1 Hz); 8.22 (d, 1H, ^3J = 7.3 Hz); 7.80 (m, 6H); 7.33 (m, 14H); 6.85 (d, 1H, ^3J = 7.1 Hz); 3.63 (m, 2H, CH_2O); 3.22 (d, 1H, ^2J = 15.1 Hz); 3.10 (d, 1H, ^2J = 15.1 Hz); 0.74 (t, 3H, ^3J = 7.1 Hz, CH_3). ^{13}C-NMR ($CDCl_3$, 50.32 MHz) δ: 171.66 (d, ^3J_P = 5.6 Hz, CO); 149.34 (d, ^4J_P = 1.6 Hz, q); 143.62 (q); 135.76 (q); 133.08 (q); 132.53 (d, ^2J_p = 10.0 Hz C_oPhP); 132.26 (d, ^1J_P = 101.9 Hz, C_iPhP); 131.42 (d, ^4J_P = 2.6 Hz C_pPhP); 129.57; 128.31 (d, ^3J_P = 12.2 Hz, C_mPhP); 127.74; 127.36; 126.30 (q); 125.45; 122.24; 121.64; 118.92; 115.05; 74.86 (d, ^2J_P = 5.5 Hz, q); 61.12 (CH_2O); 43.75 (d, ^3J_P = 4.2 Hz, CH_2); 13.52 (CH_3). m/z: 495 (42), 494 (100), 262 (10), 183 (17), 108 (2).

Reaction of Iminophosphorane 4 with Isocyanates.

To a solution of iminophosphorane **4** (0.21 g, 0.4 mmol) in dry toluene (15 ml), the appropriate aryl isocyanate (0.4 mmol) was added. The solution was stirred at room temperature for 2h and then concentrated to dryness. The crude product was chromatographed on a silica gel column eluting with ethyl acetate/*n*-hexane to give the corresponding carbodiimide **9** as a viscous oil.

A solution of carbodiimide **9** (0.4 mmol) in dry toluene (10 ml) was treated at 140 °C in a sealed tube for 36h. After cooling, the solvent was removed and the residue was chromatographed on a silica gel column eluting with ethyl acetate/*n*-hexane to give **10** which was recrystallized from diethyl ether/*n*-hexane (1:1), (62%), m.p. 168-169 °C (white prisms); (Found: 69.86; H, 5.16; N, 11.79. $C_{14}H_{12}N_2O_2$ requires: C, 69.99; H, 5.03; N, 11.66. IR (Nujol): 1711, 1456, 1242, 1084, 772, 700 cm^{-1}. ^1H-NMR ($CDCl_3$, 200 MHz) δ: 8.76 (d, 1H, ^3J = 1.2 Hz); 8.68 (d, 1H, ^3J = 8.2 Hz); 8.05 (s, 1H); 7.68 (m, 3H); 7.67 (d, 1H, ^3J = 1.2 Hz); 4.50 (q, 2H, ^3J = 7.1 Hz, CH_2);. 1.49 (t, 3H, ^3J = 7.1 Hz, CH_2); ^{13}C-NMR ($CDCl_3$, 50.32 MHz) δ: 161.92 (CO); 143.48 (q); 131.36; 130.61; 128.33; 128.26; 127.46 (q); 125.50 (q); 124.25 (q); 123.45; 120.38; 115.82; 62.08 (CH_2); 14.25 (CH_3). m/z: 240 (M^+, 56), 212 (41), 195 (6), 168 (100), 167 (16), 155 (5), 141 (20), 114 (24).

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