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A Quick and Clean Procedure for Synthesis of α-Aminophosphonates in Aqueous Media

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ABSTRACT: *A green and efficient procedure for the synthesis of α-aminophosphonates has been developed in water as a green and nonhazardous solvent, from condensation between aromatic aldehydes, aniline, and triphenyl phosphite at 80°C. This methodology has a number of advantages including clean reaction conditions, easy work-up, and environmentally friendly.* © 2015 Wiley Periodicals, Inc. Heteroatom Chem. 0:1–6, 2015; View this article online at wileyonlinelibrary.com. DOI 10.1002/hc.21263

INTRODUCTION

α-Aminophosphonates have received much attention due to their biological activity. Their uses as enzyme inhibitors, antibiotics, peptide mimics, herbicides, pharmacological agents, and many other applications are well documented [1–5]. The traditional Lewis acid–catalyzed addition of diethyl phosphite to aldimines has provided a useful method for the preparation of α-aminophosphonates [6–8]. However, these reactions cannot proceed smoothly by a one-pot method from aldehydes, amines, and diethyl phosphite since the water generated during the reactions can deactivate or decompose the catalysts [9]. Some new type of Lewis acids, such as metal triflates [10], scandium tris(dodecyl sulfate) [11], lithium perchlorate [12], zirconium compounds [13, 14], Bønsted acids [15], lantanide triflate [16], samarium diiodide [17], $InCl_3$ [18], $TaCl_5$–SiO_2 [19], bromodimethylsulfonium bromide [20], montmorillonite KSF [21], alumina-supported reagents as catalysts [22], amberlite-IR 120 [23], $H_3PW_{12}O_{40}$ [24], oxalic acid [25], and TiO_2 [26], were reported to be effective catalysts for this one-pot reaction. However, some of these procedures suffered from drawbacks such as the use of organic solvents, long reaction times, difficulties in work-up procedures, and relatively low yields and generally only dialkyl or trialkyl phosphites were used as phosphorus reagents. According to the wide range of biological properties of α-aminophosphonates, it is still necessary to develop a new simple, efficient, and general method, for this three-component reaction.

Recently, several procedures have been reported for the synthesis of α-aminophosphonates under solvent and catalyst free conditions with excellent yield, or using easily available catalysts; moreover, these procedures seems to be extremely simple [27–33]. In continuation with our investigation on the synthesis of α-aminophosphonates [34–42], herein we report a green and mild protocol for the synthesis of α-aminophosphonates in aqueous media without a catalyst (Scheme 1).

RESULTS AND DISCUSSION

We have performed a set of preliminary experiments in the three-component reaction of benzaldehyde, aniline, and triphenyl phosphite in different solvents at different temperatures (25, 30, 40, 50, 60, 70, 80, 90°C) in the mixture of solvent. As shown in Table 1,

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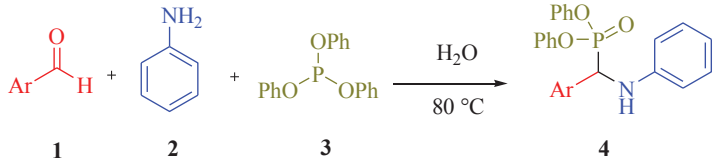
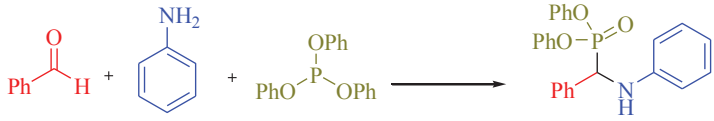


1 2 3 4

SCHEME 1 Synthesis of α-aminophosphonates in aqueous media at 80°C.

TABLE 1 Optimization Reaction Conditions for the Synthesis of α-Aminophosphonates



1 2 3 4a

Entry	*Solvent*	*Temperature (°C)*	*Time (h)*	*Isolated Yield (%)*
1	–	25	72	–
2	Acetonitrile	80	7	78
3	Ethanol	80	10	54
4	Ethanol : H_2O (1:1)	80	16	40
5	Ethanol : H_2O (1:2)	80	16	56
6	H_2O	25	72	–
7	H_2O	30	72	14
8	H_2O	40	40	30
9	H_2O	50	22	68
10	H_2O	60	16	73
11	H_2O	70	8	85
12	**H_2O**	**80**	**3**	**90**
13	H_2O	90	3	91
14	Dichloromethane	40	8	65
15	Ethyl acetate	80	8	62

the best solvent is water and the best temperature is 80°C.

Using this optimized condition, we prepared a wide variety of α-aminophosphonates using arylaldehydes, aniline, and triphenyl phosphite (Table 2).

Interestingly, a variety of aryl aldehydes including electron-withdrawing or -releasing substituents (ortho-, meta-, and para-substituted) participated well in this reaction and gave the product in good to excellent yield.

A plausible mechanism is shown in Scheme 2. It is believed to involve the formation of activated imine **A** by condensation of the aldehyde and amine [43–46]. Then phosphite is added to the C=N bond of imine **A** to give the phosphonium intermediate **B**. This phosphonium intermediate undergoes a reaction with water to give the α-aminophosphonate **4**.

CONCLUSION

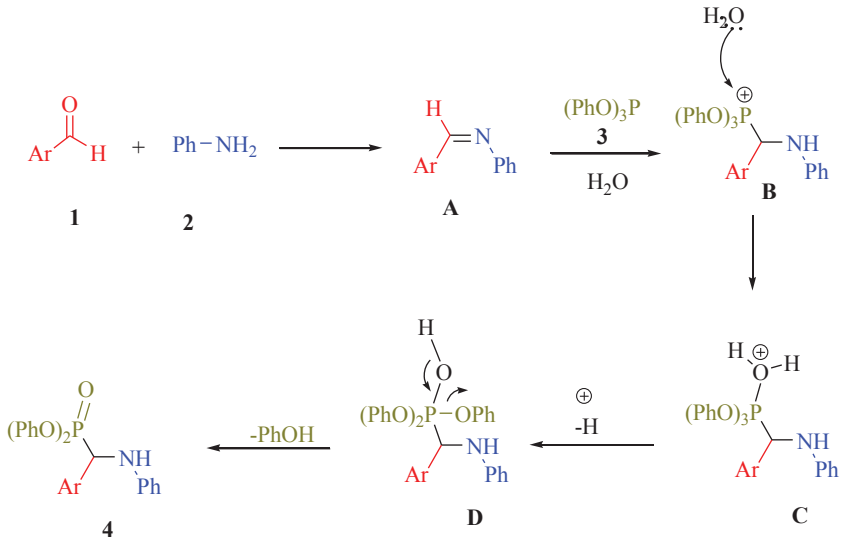
α-Aminophosphonates derivatives have been prepared via the one-pot three component reaction from aromatic aldehydes, aniline, and triphenyl phosphite in water at 80°C. This method has many advantages such as clean reaction conditions, easy work-up, and the absence of hazardous catalyst.

EXPERIMENTAL

Melting points and IR spectra were measured on an Electrothermal 9100 apparatus (UK) and a Shimadzu IR-460 spectrometer (Japan), respectively. ^1H, ^{13}C, and ^{31}P NMR spectra were measured on a Bruker DRX-400 Avance spectrometer (Germany) with $CDCl_3$ as a solvent. All reagents were purchased from Merck (Darmstadt, Germany) and Fluka (Buchs, Switzerland) and used without any purification.

General Procedure for the Synthesis of α-Aminophosphonates **4a–l**

A mixture of arylaldehydes **1** (1.0 mmol), aniline **2** (1.0 mmol), and triphenyl phosphite **3** (1.0 mmol) in H_2O (1 mL) was stirred at 80°C for the appropriate time (Table 2). After completion of the reaction (as indicated by TLC), the solution was filtered and



SCHEME 2 Plausible mechanism for the synthesis of α-aminophosphonates derivatives.

the solid phase (product) was washed with water to afford pure α-aminophosphonates. Spectral data for the selected compounds are presented below.

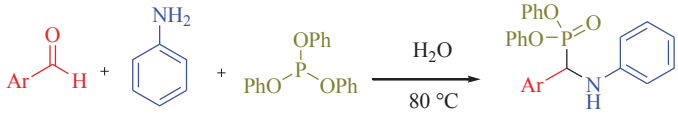
Diphenyl Phenyl(phenylamino)methylphosphonate **4a**. ^{1}H NMR (400 MHz; $CDCl_3$): δ 4.82 (1H, br, NH), 5.21 (1H, d, $^{2}J_{HP}$ = 24.7 Hz, CHP), 6.69–7.62 (20H, m, H_{Ar}); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ: 56.0 (d, $^{1}J_{CP}$ = 154.7 Hz, CHP), 114.0 (s, $2C_{ortho}$, NHPh), 118.8 (s, C_{para}, NHPh), 120.2 (d, $^{3}J_{CP}$ = 4.5 Hz, $2C_{ortho}$, OPh), 120.6 (d, $^{3}J_{CP}$ = 4.5 Hz, $2C_{ortho}$, OPh), 125.1 (s, C_{para}, OPh), 125.3 (s, C_{para}, OPh), 128.1 (d, $^{3}J_{CP}$ = 5.8 Hz, $2C_{ortho}$, C_{Ar}), 128.3 (s, C_{para}, C_{Ar}), 128.7 (d, $^{4}J_{CP}$ = 2.6 Hz, $2C_{meta}$, C_{Ar}), 129.2 (s, $2C_{meta}$, NHPh), 129.5 (s, $2C_{meta}$, OPh), 129.6 (s, $2C_{meta}$, OPh), 134.7 (s, C_1, C_{Ar}), 145.8 (d, $^{3}J_{CP}$ = 15.1 Hz, C_{ipso}, NHPh), 150.1 (d, $^{2}J_{CP}$ = 9.2 Hz, C_{ipso}, OPh), 150.3 (d, $^{2}J_{CP}$ = 9.2 Hz, C_{ipso}, OPh).

Diphenyl(2-nitrophenyl)(phenylamino) methylphosphonate **4b**. ^{1}H NMR (400 MHz; $CDCl_3$): δ 4.59 (1H, br, NH), 6.62 (1H, d, $^{2}J_{HP}$ = 27.0 Hz, CHP), 6.70–8.10 (19H, m, H_{Ar}); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ: 55.5 (d, $^{1}J_{CP}$ = 154.2 Hz, CHP), 113.8 (s, $2C_{ortho}$, NHPh), 119.3 (s, C_{para}, NHPh), 119.9 (d, $^{3}J_{CP}$ = 4.1 Hz, $2C_{ortho}$, OPh), 120.6 (d, $^{3}J_{CP}$ = 4.1 Hz, $2C_{ortho}$, OPh), 125.4 (s, C_{para}, OPh), 125.7 (s, C_{para}, OPh), 125.5 (d, $^{4}J_{CP}$ = 2.1 Hz, C_3, C_{Ar}), 129.1 (s, C_4, C_{Ar}), 129.3 (d, $^{3}J_{CP}$ = 4.6 Hz, C_6, C_{Ar}), 129.5 (s, $2C_{meta}$, NHPh), 129.7 (s, $2C_{meta}$, OPh), 129.8 (s, $2C_{meta}$, OPh), 131.02 (s, C_5, C_{Ar}), 133.8 (d, $^{2}J_{CP}$ = 3.2 Hz, C_1, C_{Ar}), 144.8 (d, $^{3}J_{CP}$ = 14.7 Hz, C_{ipso}, NHPh), 149.3 (d, $^{3}J_{CP}$ = 6.0 Hz, C_2, Ar), 149.9 (d, $^{2}J_{CP}$ = 9.5 Hz, C_{ipso}, OPh), 150.1 (d, $^{2}J_{CP}$ = 9.5 Hz, C_{ipso}, OPh).

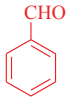
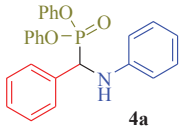
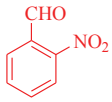
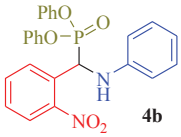
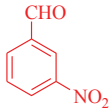
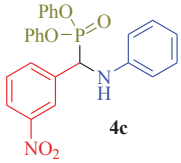
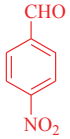
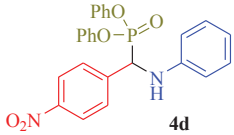
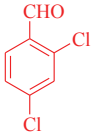
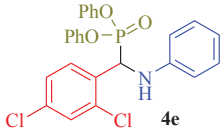
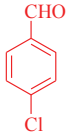
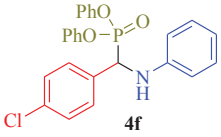
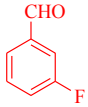
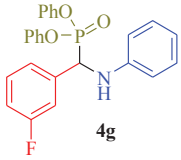
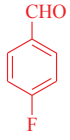
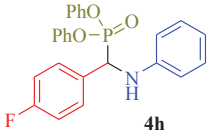
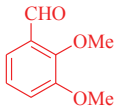
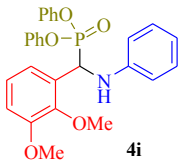
Diphenyl(3-nitrophenyl)(phenylamino) methylphosphonate **4c**. ^{1}H NMR (400 MHz; $CDCl_3$): δ 4.66 (1H, br, NH), 5.27 (1H, d, $^{2}J_{HP}$ = 25.3 Hz, CHP), 6.63–8.46 (19H, m, H_{Ar}); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ: 55.5 (d, $^{1}J_{CP}$ = 152.4 Hz, CHP), 114.0 (s, $2C_{ortho}$, NHPh), 119.5 (s, C_{para}, NHPh), 120.0 (d, $^{3}J_{CP}$ = 4.1 Hz, $2C_{ortho}$, OPh), 120.4 (d, $^{3}J_{CP}$ = 4.1 Hz, $2C_{ortho}$, OPh), 123.1 (d, $^{3}J_{CP}$ = 5.6 Hz, C_2, C_{Ar}), 123.4 (s, C_4, C_{Ar}), 125.6 (s, C_{para}, OPh), 125.7 (s, C_{para}, OPh), 129.4 (s, $2C_{meta}$, NHPh), 129.6 (s, $2C_{meta}$, OPh), 129.7 (s, $2C_{meta}$, OPh), 130.4 (s, C_5, C_{Ar}), 134.0 (d, $^{3}J_{CP}$ = 5.1 Hz, C_6, C_{Ar}), 137.6 (s, C_1, C_{Ar}), 145.1 (d, $^{3}J_{CP}$ = 14.6 Hz, C_{ipso}, NHPh), 148.5 (s, C_3, C_{Ar}), 150.0 (d, $^{2}J_{CP}$ = 9.4 Hz, C_{ipso}, OPh), 150.1 (d, $^{2}J_{CP}$ = 9.4 Hz, C_{ipso}, OPh).

Diphenyl(4-nitrophenyl)(phenylamino) methylphosphonate **4d**. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 5.02 (1H, brs, NH), 5.25 (1H, d, $^{2}J_{PH}$ = 26.0 Hz, CHP), 6.61 (2H, d, J = 8.0 Hz, H_{Ar}), 6.81 (1H, t, J = 8.0 Hz, H_{Ar}), 6.97–7.33 (11H, m, H_{Ar}), 7.78 (2H, dd, J = 8.8, 2.4 Hz, H_{Ar}), 8.22 (2H, d, J = 8.0 Hz, H_{Ar}); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ: 55.2 (d, $^{1}J_{CP}$ = 152.4 Hz, CHP), 113.9 (s, $2C_{ortho}$, NHPh), 119.4 (s, C_{para}, NHPh), 120.0 (d, $^{3}J_{CP}$ = 3.9 Hz, $2C_{ortho}$, OPh), 120.4 (d, $^{3}J_{CP}$ = 3.9 Hz, $2C_{ortho}$, OPh), 123.8 (s, C_{meta}, C_{Ar}), 125.6 (s, C_{para}, OPh), 125.7 (s, C_{para}, OPh), 128.9 (d, $^{3}J_{CP}$ = 5.4 Hz, C_{ortho}, C_{Ar}), 129.3 (s, $2C_{meta}$, NHPh), 129.8 (s, $4C_{meta}$, 2OPh), 142.7 (s, C_{ipso}, C_{Ar}), 145.1 (d, $^{3}J_{CP}$ = 14.6 Hz, C_{ipso}, NHPh), 147.7 (s, C_{para}, C_{Ar}), 149.8 (d, $^{2}J_{CP}$ = 9.1 Hz, C_{ipso}, OPh), 150.0 (d, $^{2}J_{CP}$ = 9.1 Hz, C_{ipso}, OPh); ^{31}P NMR ($CDCl_3$, 161.97 MHz) δ: 13.3.

TABLE 2 Synthesis of α-aminophosphonates derivatives in H_2O at 80°C

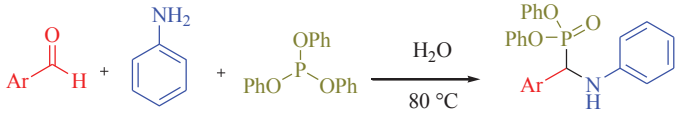


1 2 3 4

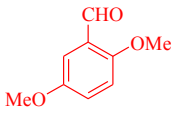
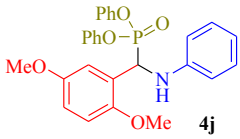
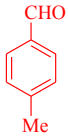
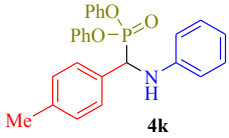
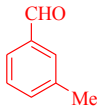
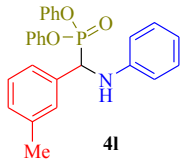
Entry	Aldehyde	Product	Time (h)	Yield (%)[a]	Melting Point (°C) Found	Melting Point (°C) Literature [34]
1		 **4a**	3	90	148–149	134–136
2		 **4b**	4	83	149–150	137–139
3		 **4c**	8	73	128–129	128–129
4		 **4d**	5	85	147–149	147–149
5		 **4e**	8	96	139–140	136–138
6		 **4f**	7	92	130–131	130–132
7		 **4g**	4	71	121–123	119–121
8		 **4h**	6	80	100–103	103–105
9		 **4i**	9	76	111–113	110–112

(*Continued*)

TABLE 2 Continued



1 2 3 4

Entry	Aldehyde	Product	Time (h)	Yield (%)[a]	Melting Point (°C) Found	Melting Point (°C) Literature [34]
10		 **4j**	8	81	118–119	115–117
11		 **4k**	7	80	125–126	124–126
12		 **4l**	7	81	125–126	125–127

[a]Isolated yield.

Diphenyl(2,4-dichlorophenyl)(phenylamino) methylphosphonate **4e**. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 5.14 (1H, t, $^{3}J_{NH}$ = 9.2 Hz, NH), 5.74 (1H, dd, $^{2}J_{PH}$ = 25.6, $^{3}J_{NH}$ = 8.4 Hz, CHP), 6.62 (2H, d, J = 8.0 Hz, H_{Ar}), 6.78 (1H, t, J = 8.0 Hz, H_{Ar}), 6.94–7.42 (14H, m, H_{Ar}), 7.61 (1H, dd, J = 8.0, 2.8 Hz, H_{Ar}); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ: 51.3 (d, $^{1}J_{CP}$ = 157.7 Hz, CHP), 113.9 (s, $2C_{ortho}$, NHPh), 119.4 (s, C_{para}, NHPh), 119.8 (d, $^{3}J_{CP}$ = 4.1 Hz, $2C_{ortho}$, OPh), 120.7 (d, $^{3}J_{CP}$ = 4.1 Hz, $2C_{ortho}$, OPh), 125.3 (s, C_{para}, OPh), 125.6 (s, C_{para}, OPh), 127.9 (d, $^{4}J_{CP}$ = 3.1 Hz, C_5, C_{Ar}), 129.4 (s, $2C_{meta}$, NHPh), 129.6 (s, $2C_{meta}$, OPh), 129.8 (s, $2C_{meta}$, OPh), 130.1 (d, $^{3}J_{CP}$ = 4.12 Hz, C_6, C_{Ar}), 131.7 (s, C_3, C_{Ar}), 134.8 (d, $^{2}J_{CP}$ = 4.2 Hz, C_1, Ar), 134.9 (d, $^{3}J_{CP}$ = 7.8 Hz, C_2, C_4, C_{Ar}), 144.8 (d, $^{3}J_{CP}$ = 16.5, C_{ipso}, NHPh), 150.1 (d, $^{2}J_{CP}$ = 9.7 Hz, C_{ipso}, OPh), 150.2 (d, $^{2}J_{CP}$ = 9.7 Hz, C_{ipso}, OPh).

Diphenyl(4-chlorophenyl)(phenylamino) methylphosphonate **4f**. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 4.97 (1H, brs, NH), 5.15 (1H, d, $^{2}J_{PH}$ = 24.0 Hz, CHP), 6.63–7.54 (19H, m, H_{Ar}); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ: 55.6 (d, $^{1}J_{CP}$ = 153.9 Hz, CHP), 114.3 (s, $2C_{ortho}$, NHPh), 119.3 (s, C_{para}, NHPh), 120.2 (d, $^{3}J_{CP}$ = 4.2 Hz, $2C_{ortho}$, OPh), 120.6 (d, $^{3}J_{CP}$ = 4.2 Hz, $2C_{ortho}$, OPh), 125.4 (s, C_{para}, OPh), 125.5 (s, C_{para}, OPh), 129.0 (d, $^{4}J_{CP}$ = 2.0 Hz, C_3, C_5, C_{Ar}), 129.3 (s, $2C_{meta}$, NHPh), 129.5 (d, $^{3}J_{CP}$ = 5.9 Hz, C_2, C_6, C_{Ar}), 129.7 (s, $2C_{meta}$, OPh), 129.8 (s, $2C_{meta}$, OPh), 133.3 (s, C_4, C_{Ar}), 134.3 (d, $^{2}J_{CP}$ = 4.0 Hz, C_1, C_{Ar}), 145.3 (d, $^{3}J_{CP}$ = 17.1 Hz, C_{ipso}, NHPh), 150.0 (d, $^{2}J_{CP}$ = 9.7 Hz, C_{ipso}, OPh), 150.2 (d, $^{2}J_{CP}$ = 9.7 Hz, C_{ipso}, OPh).

Diphenyl(3-fuorophenyl)(phenylamino) methylphosphonate **4g**. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 4.91 (1H, brs, NH), 5.15 (1H, d, $^{2}J_{PH}$ = 25.2 Hz, CHP), 6.65 (2H, dd, J = 8.4, 0.8 Hz, H_{Ar}), 6.79 (1H, t, J = 8.0 Hz, H_{Ar}), 6.93–7.38 (16H, m, H_{Ar}).

Diphenyl(4-fuorophenyl)(phenylamino) methylphosphonate **4h**. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 4.96 (1H, t, $^{3}J_{NH}$ = 8.8 Hz, NH), 5.16 (1H, dd, $^{2}J_{PH}$ = 24.4, $^{3}J_{NH}$ = 8.0 Hz, CHP), 6.65 (2H, d, J = 8.0 Hz, H_{Ar}), 6.79 (1H, t, J = 8.0 Hz, H_{Ar}), 6.92-7.58 (16H, m, H_{Ar}) ^{31}P NMR ($CDCl_3$, 161.97 MHz) δ: 14.9.

Diphenyl(2,3-dimethoxyphenyl)(phenylamino) methylphosphonate **4i**. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 3.87 and 3.97 (6H, 2s, 2× OMe), 4.86 (1H, t, $^{3}J_{NH}$ = 8.4 Hz, NH), 5.82 (1H, dd, $^{2}J_{PH}$ = 24.8, $^{3}J_{NH}$ = 10.0 Hz, CHP), 6.72–7.32 (18H, m, H_{Ar}); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ: 48.7 (d, $^{1}J_{CP}$ = 157.9 Hz, CHP),

55.7, 61.0 (2s, 2× OCH_3), 112.5 (s, C_4, C_{Ar}), 114.2 (s, $2C_{ortho}$, NHPh), 119.0 (s, C_{para}, NHPh), 120.1 (d, $^3J_{CP}$ = 4.6 Hz, C_6, C_{Ar}), 120.2 (s, C_5, C_{Ar}), 120.4 (d, $^3J_{CP}$ = 4.1 Hz, $2C_{ortho}$, OPh), 120.8 (d, $^3J_{CP}$ = 4.1 Hz, $2C_{ortho}$, OPh), 124.4 (d, $^2J_{CP}$ = 2.5 Hz, C_1, C_{Ar}), 125.2 (s, C_{para}, OPh), 125.4 (s, C_{para}, OPh), 129.2 (s, $2C_{meta}$, NHPh), 129.6 (s, $2C_{meta}$, OPh), 129.7 (s, $2C_{meta}$, OPh), 147.3 (d, $^3J_{CP}$ = 14.5 Hz, C_{ipso}, NHPh), 150.3 (d, $^2J_{CP}$ = 9.7 Hz, C_{ipso}, OPh), 150.5 (d, $^2J_{CP}$ = 9.7 Hz, C_{ipso}, OPh), 152.4 (d, $^3J_{CP}$ = 1.3 Hz, C_2, C_{Ar}), 156.04 (s, C_3, C_{Ar}).

Diphenyl(2,5-dimethoxyphenyl)(phenylamino) methylphosphonate **4j**. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 3.70 and 3.85 (6H, 2s, 2× OMe), 4.93 (1H, t, $^3J_{NH}$ = 8.8 Hz, NH), 5.77 (1H, dd, $^2J_{PH}$ = 25.2, $^3J_{NH}$ = 9.6 Hz, CHP), 6.68–7.32 (18H, m, H_{Ar}); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ: 48.9 (d, $^1J_{CP}$ = 157.8 Hz, CHP), 55.7, 56.3 (2s, 2× OCH_3), 11.9 (d, $^4J_{CP}$ = 2.1 Hz, C_5, C_{Ar}), 113.9 (s, C_4, C_{Ar}), 114.2 (d, $^3J_{CP}$ = 4.9 Hz, C_2, C_{Ar}), 114.7 (s, C_{ortho}, NHPh), 118.9 (s, C_{para}, NHPh), 120.1 (d, $^3J_{CP}$ = 4.4 Hz, $2C_{ortho}$, OPh), 120.7 (d, $^3J_{CP}$ = 4.4 Hz, $2C_{ortho}$, OPh), 120.5 (d, $^2J_{CP}$ = 5.0 Hz, C_1, C_{Ar}), 125.0 (s, C_{para}, OPh), 125.2 (s, C_{para}, OPh), 129.2 (s, $2C_{meta}$, NHPh), 129.5 (s, $2C_{meta}$, OPh), 129.6 (s, $2C_{meta}$, OPh), 146.2 (d, $^3J_{CP}$ = 15.0 Hz, C_{ipso}, NHPh), 151.6 (d, $^2J_{CP}$ = 9.7 Hz, C_{ipso}, OPh), 151.6 (d, $^2J_{CP}$ = 9.7 Hz, C_{ipso}, OPh), 154.0 (d, $^3J_{CP}$ = 3.0 Hz, C_2, C_{Ar}), 155.3 (s, C_5, C_{Ar}).

Diphenyl(phenylamino)(p-tolyl) methylphosphonate **4k**. ^{1}H NMR (400 MHz; $CDCl_3$): δ 2.35 (3H, s, CH_3), 4.79 (1H, br, NH), 5.17 (1H, d, $^2J_{HP}$ = 24.6 Hz, CHP), 6.71-7.41 (19H, m, H_{Ar}); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ: 21.4 (s, CH_3), 55.9 (d, $^1J_{CP}$ = 153.9 Hz, CHP), 114.2 (s, $2C_{ortho}$, NHPh), 118.9 (s, C_{para}, NHPh), 120.3 (d, $^3J_{CP}$ = 4.3 Hz, $2C_{ortho}$, OPh), 120.7 (d, $^3J_{CP}$ = 4.3 Hz, $2C_{ortho}$, OPh), 125.2 (s, C_{para}, OPh), 125.3 (s, C_{para}, OPh), 125.4 (s, C_4, C_{Ar}), 128.7 (d, $^3J_{CP}$ = 2.1 Hz, C_6, C_{Ar}), 128.9 (d, $^3J_{CP}$ = 6.2 Hz, C_2, C_{Ar}), 129.2 (s, C_5, C_{Ar}), 129.2 (s, $2C_{meta}$, NHPh), 129.6 (s, $2C_{meta}$, OPh), 129.7 (s, $2C_{meta}$, OPh), 134.4 (s, C_3, C_{Ar}), 138.5 (d, $^2J_{CP}$ = 2.5 Hz, C_1, C_{Ar}), 145.6 (d, $^3J_{CP}$ = 14.7 Hz, C_{ipso}, NHPh), 150.2 (d, $^2J_{CP}$ = 10.1 Hz, C_{ipso}, OPh), 150.4 (d, $^2J_{CP}$ = 10.1 Hz, C_{ipso}, OPh).

Diphenyl(phenylamino)(m-tolyl) methylphosphonate **4l**. IR (KBr) (υ_{max}, cm^{-1}): 3342 (N-H); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 2.35 (3H, s, CH_3), 4.79 (1H, bs, NH), 5.17 (1H, d, $^2J_{HP}$ = 24.6 Hz, CHP), 6.71–7.41 (19H, m, H_{Ar}); ^{13}C NMR ($CDCl_3$, 100.6 MHz) δ: 21.46 (s, CH_3), 55.96 (d, $^1J_{CP}$ = 153.9 Hz, CHP), 114.20 (s, $2C_{ortho}$, NHPh), 118.95 (s, C_{para}, NHPh), 120.36 (d, $^3J_{CP}$ = 4.3 Hz, 2 C_{ortho}, OPh), 120.75 (d, $^3J_{CP}$ = 4.3 Hz, $2C_{ortho}$, OPh), 125.24 (s, C_{para}, OPh), 125.39 (s, C_{para}, OPh), 125.41 (s, C4), 128.71 (d, $^3J_{CP}$ = 2.1 Hz, C6), 128.95 (d, $^3J_{CP}$ = 6.2 Hz, C2), 129.25 (s, C5), 129.29 (s, 2 C_{meta}, NHPh), 129.61 (s, $2C_{meta}$, OPh), 129.76 (s, $2C_{meta}$, OPh), 134.40 (s, C3), 138.51 (d, $^2J_{CP}$ = 2.5 Hz, C1),145.63 (d, $^3J_{CP}$ = 14.7 Hz, C_{ipso}, NHPh), 150.29 (d, $^2J_{CP}$ = 10.1 Hz, C_{ipso}, OPh), 150.40 (d, $^2J_{CP}$ = 10.1 Hz, C_{ipso}, OPh). ^{31}P NMR (161.97 MHz) δ: 15.51. MS *m/z* (%): 429 (17) [M+], 196 (100), 178 (15),140 (20), 104 (34), 77 (42). Anal. Calcd for $C_{26}H_{24}NO_3P$: C, 72.72; H, 5.63; N, 3.26. Found: C, 72.51; H, 5.70; N, 3.39.

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