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Graphical Abstract

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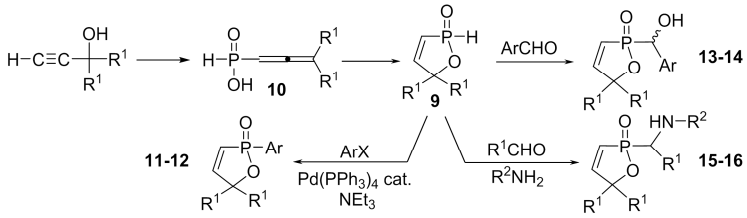

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ABSTRACT

A simple and effective preparation of 2-hydrogeno-5*H*-1,2-oxaphosphole 2-oxides **9a-b** has been developed involving direct cyclisation of *H*-phosphinic allenes. *H*-1,2-oxaphospholenes **9a-b** showed to be excellent building blocks for diversity oriented small chemical libraries. Then, reactivity of the cyclic H-phosphinates **9a-b** was investigated through Pd(0) catalyzed arylation, Pudovik and three-component Kabachnik-Fields reactions. 5*H*-1,2-oxaphospholes are excellent heterocyclic platforms offering different opportunities to modulate the substituent directly bounded to the phosphorus atom.

1. Introduction

Among FDA-approved drugs, cytotoxic phosphorus heterocycles, such as cyclophosphamide, introduced on the market in the late 1950's in USA, is still currently used as anticancer agent.[1] Since this period, the interest for the development of phosphorus-heterocycles as source of innovation and original modes of action in pharmaceutical and agrochemical fields is far from being exhausted. For example, phosphorus-containing unsaturated five-membered heterocycles such as 3-phospholene 1-oxides **1** or **2** have been claimed for their bactericide, insecticide and pesticide properties.[2] Later, benzoxaphospholes **3** and **4** were reported to have herbicidal activities,[3] and Yudelevich *et al.* described both 1,2-oxaphospholenes **5** and **6** with fungistatic activities.[4] Brandi *et al.* also described a series of tetrahydrophospholo-[2,3-d]isoxazoles **7a-d** exhibiting weak to moderate herbicide activities, and good fungicide activities against *Botrytis cinerea* on apples for **7e** and *Plasmopara viticola* on vines for **8f-g** (Figure 1).[5]

As part of our ongoing efforts in discovery and synthesis of new phosphorus heterocycles,[6] we herein report the preparation of 2-*H*-1,2-oxaphosphole-3-ene 2-oxides **9a-b** by direct cyclisation of *H*-phosphinylallenes **10a-b**. In the second part, we explored *H*-oxaphospholene potential as key building blocks for the generation of chemical libraries playing with the wide reactivity of P-H function. Thus, oxaphosphole-3-enes **9a-b** were engaged in palladium catalyzed coupling reactions with aryl halides, Pudovik additions to aldehydes and the 3-component Kabachnik-Fields reaction with amines and aldehydes leading to *P*-substituted oxaphospholenes **11-16** (Figure 1).

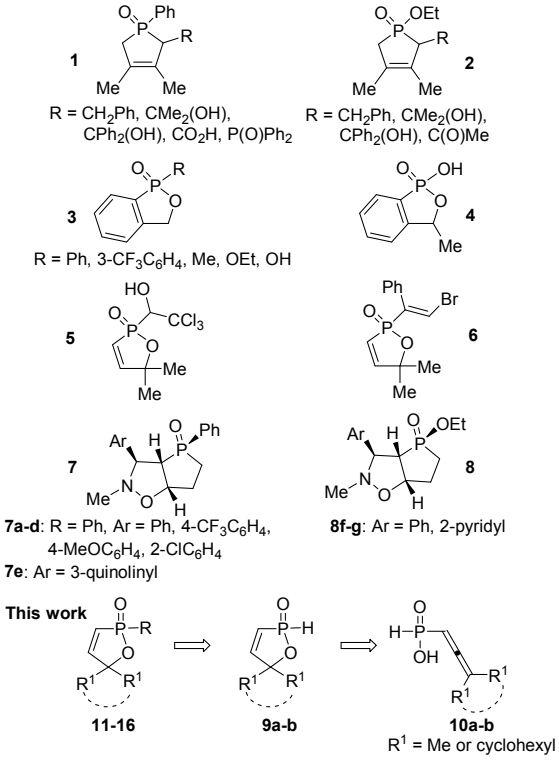


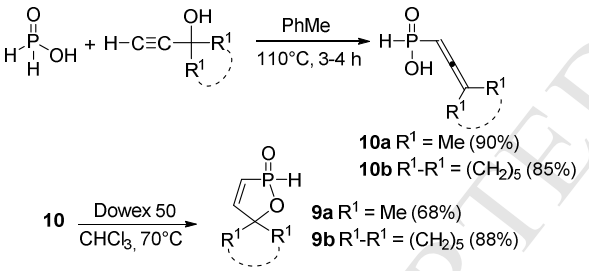
Figure 1. Biologically active five-membered phosphorus heterocycles and this work.

2. Results and Discussion

Allenylphosphonates are stable molecules that can be readily obtained by intramolecular 1,3-rearrangement (S_Ni') of 2-alkynyl phosphites,[7-11] themselves accessible either by reaction of alkyl-2-yn-1-ol derivatives with phosphorus trichloride (requiring a subsequent hydrolysis or methanolysis),[8] or by reactions with diethyl chlorophosphite[9-10] or triethyl phosphite.[11] On the other hand, trimethyl phosphite can also be used through an Arbuzov reaction (S_N2') with propargyl halides to give allenylphosphonates.[12] A larger chemical diversity of allenylphosphonates was obtained by α–functionalization of the phosphonate group using palladium-catalyzed coupling reactions.[14]

Inspired by the preparation of allenylphosphonates, allenyl *H*-phosphinate derivatives were obtained by combination of hypophosphorous acid with propargyl alcohols.[4,14,15] The *H*-allenylphosphinic acids **10a-b** were then prepared in high yields by this approach, *i.e.* by condensation/rearrangement of anhydrous hypophosphorous acid with propargyl alcohol in toluene under an inert atmosphere and removal of water (Scheme 1).[4]

Various conditions are useful for the intramolecular cyclization of allenylphosphonates into 1,2-oxaphosphol-3-enes: using Brönsted acids,[8,16-18] Lewis acids,[19-22], halogens[19,23-28], sulfuryl dichloride[29-30], sulfenyl chlorides[27,31-36], selenyl chlorides[30,31,36], *N*,*N*-diethylphenylselenylamide with pyridine-SO_3 complex[37], *m*-CPBA[38] and Pd(II)[39]. Here cyclization of allenylphosphinic acids **10a-b** has been accomplished by reaction in acidic conditions using a sulfonic acid resin, Dowex 50 as source of proton. 1,2-Oxaphospholenes **9a-b** were obtained in good yields after simple filtration of the resin and concentration to dryness (Scheme 1).



Scheme 1. Synthesis of *H*-phosphinic allenes **10a-b** and oxaphospholenes **9a-b**

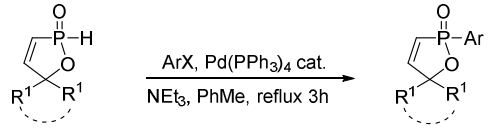
Consecutively to the synthesis of 1,2-oxaphospholenes **9a-b**, the introduction of chemical diversity at the phosphorus center has been accomplished through the reaction of the highly reactive P-H bond.

2.1 *P*-Arylation of *H*-1,2-oxaphospholenes 9a-b

Arylation takes place in the conditions usually described in the literature.[6c,40] *H*-1,2-oxaphospholenes **9a-b** were reacted with various aryl halides in presence of catalytic amounts of tetrakis (triphenylphosphine)palladium (0) (5 mol%) and triethylamine in toluene at 80°C in yields ranging from 41 to 72% (Table 1).

For all the reactions, only one compound was observed with chemical shifts in ^{31}P-NMR of the crude in the range of 40 to 50 ppm. These results established that the arylation only occurred on the phosphorus atom, and no product resulting from a competitive or a subsequent Heck or Tsuji-Trost reaction was observed.

Table 1. Arylation of *H*-oxaphospholenes **9a-9b**



9a R^1 = Me
9b R^1-R^1 = $(CH_2)_5$

11 R^1 = Me (56-72%)
12 R^1-R^1 = $(CH_2)_5$ (41-55%)

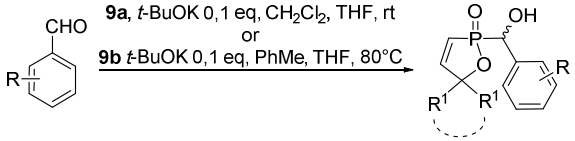
	11 R^1 = Me		
	X	Ar	Yield (%)*
11a	I	C_6H_5	70
11b	I	*p*-CH_3O-C_6H_4	72
11c	I	*p*-Cl-C_6H_4	68
11d	I	*p*-F-C_6H_4	60
11e	Br	*p*-CF_3-C_6H_4	65
11f	Br	*2*-Pyridyl	63
11g	I	*2*-Thienyl	56
	12 R^1-R^1 = $(CH_2)_5$		
	X	Ar	Yield (%)*
12a	I	C_6H_5	45
12b	I	*p*-Cl-C_6H_4	49
12c	I	*p*-F-C_6H_4	51
12d	I	*p*-CF_3-C_6H_4	55
12e	Br	*2*-Pyridyl	41

*Yield after purification by column chromatography on silica gel.

2.2 Pudovik addition of *H*-1,2-oxaphospholenes 9a-b to aromatic aldehydes

Pudovik reaction is also an excellent opportunity to introduce substituents at the phosphorus center. Using potassium *tert*-butoxide for nucleophilic activation,[41] *H*-1,2-oxaphospholenes **9a-b** reacted smoothly with aromatic aldehydes, affording the α-hydroxy adducts **13a-d** and **14a-g** in yields ranging from 35 to 91% and diastereomeric excesses up to 62% (Table 2).

Table 2. Addition of oxaphospholenes **9a-b** to aromatic aldehydes



13a-d R^1 = Me (35-59%, *de* = 4-62%)
14a-g R^1 = Cyclohexyl (63-91%, *de* = 4-61%)

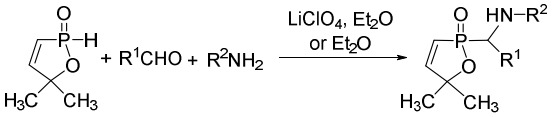
	13 R^1 = Me			
	R	Time (h)	Yield (%)*	*de* (%)**
13a	H	48	57	19
13b	*p*-F	48	59	4
13c	*p*-CH_3	48	54	16
13d	*p*-CF_3	60	35	62
	14 R^1-R^1 = $(CH_2)_5$			
	R	Time (h)	Yield (%)*	*de* (%)**
14a	H	4	80	61
14b	*p*-F	4	91	38
14c	*p*-CH_3	4	83	12
14d	*p*-CF_3	4	83	22
14e	*p*-Cl	4	75	4
14f	*p*-C_6H_5	5	75	18
14g	*o*-NO_2	3.5	63	14

*Yield after purification by column chromatography. **Determined by ^{31}P NMR of the crude.

2.3 Three-component Kabachnik-Fields reaction of *H*-1,2-oxaphospholenes 9a-b

Following the previous results obtained for aldehydes, we investigated the 3-component Kabachnik-Fields reaction of *H*-1,2-oxaphospholenes **9a-b**,[42] using a methodology developed by Heydari *et al*, with activation by $LiClO_4$ in diethyl ether.[43] The rates and the yields of the reactions appeared to be similar in presence or not of $LiClO_4$, but the purification was much easier without this salt (see compound **15a**, Table 3).

Table 3. Kabachnik-Fields reaction of oxaphospholene **9a**



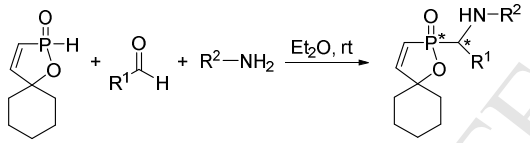
9a — **15** (37-61%, *de* = 2-11%)

	R^1	R^2	Catalyst	Yield (%)	*de* (%)*
15a	C_6H_5	C_6H_5	$LiClO_4$	53	1
15b	*p*-$CF_3C_6H_4$	C_6H_5	$LiClO_4$	59	6
15a	C_6H_5	C_6H_5	-	61	-**
15c	2-pyrrolyl	C_6H_5	-	37	11

* Determined by ^{31}P NMR of the crude.** not determined.

Afterward, we performed the Kabachnik-Fields reaction without activation using **9b**. All the results are listed in table 4. The reactions afforded the corresponding adducts in good yields (53-88%) with diastereoisomeric excesses ranging from 10 to 95% (Table 4).

Table 4. Kabachnik-Fields reaction of oxaphospholene **9b**



9b — **16a-n** (53-88%, *de* = 10-95%)

Entry	R^1	R^2	Yield (%)	*de* (%)*
16a	C_6H_5	C_6H_5	85	14
16b	*p*-ClC_6H_4	C_6H_5	76	90
16c	*p*-FC_6H_4	C_6H_5	85	11
16d	*p*-$CF_3C_6H_4$	C_6H_5	65	> 95
16e	*p*-$CH_3C_6H_4$	C_6H_5	80	> 95
16f	C_6H_5	2-C_5H_4N	75	50
16g	C_6H_5	*p*-$CF_3C_6H_4$	70	50
16h	*p*-ClC_6H_4	*p*-$CF_3C_6H_4$	65	> 95
16i	*p*-FC_6H_4	*p*-$CF_3C_6H_4$	63	> 95
16j	*p*-$CF_3C_6H_4$	*p*-$CF_3C_6H_4$	54	> 95
16k	C_6H_5	*p*-$CH_3C_6H_4$	88	14
16l	*p*-ClC_6H_4	*p*-$CH_3C_6H_4$	78	10
16m	*p*-FC_6H_4	*p*-$CH_3C_6H_4$	74	74
16n	*p*-$CF_3C_6H_4$	*p*-$CH_3C_6H_4$	53	> 95

*Determined by ^{31}P NMR of the crude, solvent Et_2O.

3. Conclusion

The synthesis of *2-H*-1,2-oxaphospholenes **9a-b**, starting from *H*-phosphinic allenes **10a-b** and consecutive cyclisation under acidic conditions using a sulfonic acid resin Dowex 50, was realized in good overall yields. *H*-1,2-oxaphospholenes **9a-b** were shown to be excellent building blocks for diversity oriented small chemical libraries. Then, the reactivity of the cyclic *H*-phosphinates **9a-b** was investigated through palladium(0) catalyzed arylation using aromatic or heteroaromatic bromides or iodides. In such conditions only P-arylation occurred and no product resulting for Heck or Tsuji-Trost coupling was observed. Furthermore, Pudovik and three-component Kabachnik-Fields reactions showed to be highly efficient to introduce functional substituents. These two reactions proceeded in good yields with surprisingly with at times surprisingly excellent diastereomeric excesses. In conclusion, we demonstrated that *H*-1,2-oxaphospholenes are excellent heterocyclic platforms offering different opportunities to modulate the substituent directly bounded to the phosphorus atom.

4. Experimental section

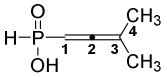
4.1 General

All reactions involving air or moisture sensitive reagents or intermediates were carried out under dry nitrogen in flame dried glassware. Reagents and solvents were distilled before use and stored under nitrogen over sodium wires (THF) or molecular sieves (dichloromethane). All reactions were monitored by ^{31}P NMR. Merck silica gel (35–70 mm) was used for column chromatography. NMR spectra were recorded on BRUKER AC-200, -250 or Avance 400 (^{1}H frequency: 200.1, 250.1 or 400.1 MHz, ^{13}C frequency: 50.3, 62.9 or 100.6 MHz, ^{31}P frequency: 81.0, 101.2, 162.0 MHz, ^{18}F frequency: 188.3 MHz, respectively). Chemical shifts are given in ppm, coupling constants are expressed in Hz. All NMR experiments performed on phosphorus were indicated uncoupling of hydrogen. All NMR led during reaction were done with a sealed capillary DMSO-D6 probe. Infrared spectra were recorded on PERKIN-ELMER 1000 spectrometer. Mass spectra were measured on JEOL JMS DX-300 spectrometer (positive FAB ionization and High Resolution using *p*-nitrobenzyl alcohol NBA).

4.2. General procedure for *H*-phosphinic allenes 10a-b

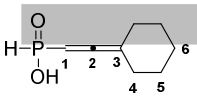
In a 500 mL three-neck round-bottom flask equipped with a condenser, a Dean-Stark apparatus under nitrogen, is placed dry hypophosphorous acid (1 eq.) in benzene (250 mL), and propargylic alcohol (2 eq.). The mixture is refluxed for 4.5 h and concentrated under vacuum.

*4.2.1. (3-Methylbuta-1,2-dien-1-yl)phosphinic acid (**10a**). Yellow oil, 45.0 g, 90% yield.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 25.3; ^{1}H NMR (250.1 MHz, $CDCl_3$) δ 1.8 (d, 6H, $^5J_{HH}$ = 3.2 Hz, 2 CH_3), 5.3 (sept, 1H, $^5J_{HH}$ = 3.2 Hz, PCH), 7.15 (d, 1H, $^1J_{PH}$ = 582 Hz, PH), 11.7 (bs, 1H, OH). ^{13}C NMR (50.3 MHz, $CDCl_3$) δ 19.0 (d, $^4J_{PC}$ = 6.7 Hz, 2 CH_3), 82.3 (d, $^1J_{PC}$ = 139.1 Hz, PCH), 98.9 (d, $^3J_{PC}$ = 17.1 Hz, C), 210.2 (s, C).



$C_5H_9O_2P$
MW 132.10, yield 90%, yellow oil.

*4.2.2. (2-Cyclohexylidenevinyl)phosphinic acid (**10b**). Yellow oil, 22.0 g, 85% yield.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 25.0; ^{1}H NMR (250.1 MHz, $CDCl_3$) δ 1.53-1.65 (m, 6H, 3 CH_2), 2.17-2.21 (m, 4H, 2 CH_2), 5.33-5.97 (m, 1H, PCH), 7.05 (dd, 1H, $^1J_{PH}$ = 580.9 Hz, $^3J_{HH}$ = 3.2 Hz, PH), 12.65 (bs, 1H, OH). ^{13}C NMR (50.3 MHz, $CDCl_3$) δ 25.6 (s, CH_2), 26.9 (d, J_{PC} = 4.2 Hz, CH_2), 29.8 (d, J_{PC} = 6.1 Hz, CH_2), 82.1 (d, $^1J_{PC}$ = 138.5 Hz, CH), 105.4 (d, $^3J_{PC}$ = 16.8 Hz, C), 207.5 (d, $^2J_{PC}$ = 1.5 Hz, C).

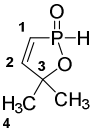


$C_8H_{13}O_2P$
MW 172.16, yield 85%, yellow oil.

4.3. General procedure for oxaphospholene 9a-b

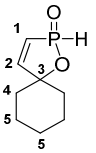
In a 100 mL three-neck round-bottom flask equipped with a condenser under nitrogen, was placed *H*-phosphinic allenes **10** (5 g), chloroform (30 mL) and sulfonic acid resin Dowex 50 (50 g). The mixture was refluxed for 48 h, and at room temperature, the mixture was filtered and concentrated to dryness under vacuum.

*4.3.1. 5,5-Dimethyl-5H-1,2-oxaphosphole 2-oxide (**9a**). Yellow oil, 3.40 g, 68% yield.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 42.3; ^{1}H NMR (250.1 MHz, $CDCl_3$) δ 1.28 (s, 3H, CH_3), 1.38 (s, 3H, CH_3), 5.98 (dd, 1H, $^{2}J_{PH}$ = 35.8 Hz, $^{3}J_{HH}$ = 8.2 Hz, PCH), 7.03 (dd, 1H, $^{3}J_{PH}$ = 40.6 Hz, $^{3}J_{HH}$ = 8.2 Hz, CH), 7.72 (d, 1H, $^{1}J_{PH}$ = 589 Hz, PH). ^{13}C NMR (50.3 MHz, $CDCl_3$) δ 28.1 (d, $^{3}J_{PC}$ = 2.9 Hz, CH_3), 28.9 (d, J_{PC} = 1.0 Hz, CH_3), 91.2 (d, $^{2}J_{PC}$ = 4.3 Hz, C), 119.0 (d, $^{1}J_{PC}$ = 102.2 Hz, PCH), 159.2 (d, $^{2}J_{PC}$ = 11.0 Hz, CH). HRMS (FAB) m/z calcd for $C_5H_{10}O_2P$ $(M+H)^+$, 133.0418; found, 133.0425. IR (NaCl): 3085, 2993, 2500, 1723, 1595, 1212, 1104, 1064, 996, 955, 922, 840, 753, 738, 622, 553, 535, 444.



$C_5H_9O_2P$
MW 132.10, yield 68%, yellow oil.

*4.3.2. 1-Oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**9b**). Yellow oil, 4.40 g, 88% yield.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 44.3; ^{1}H NMR (250.1 MHz, $CDCl_3$) δ 1.25-1.90 (m, 10H, CH_2), 6.02 (dd, 1H, $^{2}J_{PH}$ = 34.9 Hz, $^{3}J_{HH}$ = 8.3 Hz, PCH), 7.03 (dd, 1H, $^{3}J_{PH}$ = 42.3 Hz, $^{3}J_{HH}$ = 8.3 Hz, CCH), 7.72 (d, 1H, $^{1}J_{PH}$ = 592 Hz, PH). ^{13}C NMR (50.3 MHz, $CDCl_3$) δ 21.8 (s, CH_2), 21.9 (s, CH_2), 24.5 (s, CH_2), 34.5 (d, J_{PC} = 3.7 Hz, CH_2), 37.0 (s, CH_2), 90.4 (d, J_{PC} = 4.4 Hz, C), 119.3 (d, $^{1}J_{PC}$ = 101.9 Hz, PCH), 158.4 (d, J_{PC} = 12.0 Hz, CH). HRMS (FAB) m/z calcd for $C_8H_{14}O_2P$ $(M+H)^+$, 173.0730; found, 173.0735. IR (NaCl): 3085, 2993, 2500, 1723, 1595, 1212, 1104, 1064, 996, 955, 922, 840, 753, 738, 622, 553, 535, 444.

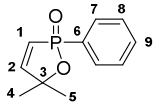


$C_8H_{13}O_2P$
MW 172.16, yield 88%, yellow oil.

4.4. General procedure for arylation of oxaphospholene 9a-b

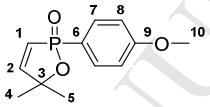
In a 25 mL three-neck round-bottom flask equipped with a condenser under nitrogen, were placed oxaphospholene **9a-b** (500 mg, 1 eq.), toluene (10 mL), palladium-tetrakis(triphenylphosphine) (5 mol%), triethylamine (3 eq.) and aryl halide (1 eq.). The reaction mixture was heated at 80°C for 3 h and precipitation of triethylammonium salt occurred. After cooling to room temperature, the reaction mixture was dissolved in ethyl acetate (30 mL) and brine solution was added. After extraction 3 times with ethyl acetate, the organic layers were dried over Na_2SO_4. The crude solution was concentrated and purified by column chromatography with as eluent a mixture of hexane/ethyl acetate.

*4.4.1. 5,5-Dimethyl-2-phenyl-5H-1,2-oxaphosphole 2-oxide (**11a**).* Brown oil, 0.55 g, 70% yield. ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 54.3; ^{1}H NMR (400.1 MHz, $CDCl_3$) δ 1.50 (s, 3H, CH_3), 1.58 (s, 3H, CH_3), 6.11 (dd, 1H, $^{2}J_{PH}$ = 33.6 Hz, $^{3}J_{HH}$ = 8.1 Hz, PCH), 7.02 (dd, 1H, $^{3}J_{PH}$ = 40.2 Hz, $^{3}J_{HH}$ = 8.1 Hz, CH), 7.38-7.43 (m, 2H, H_{ar}), 7.46-7.51 (m, 1H, H_{ar}), 7.66-7.71 (m, 2H, H_{ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 26.1 (d, $^{3}J_{PC}$ = 4.4 Hz, CH_3), 27.8 (s, CH_3), 88.4 (d, $^{2}J_{PC}$ = 4.4 Hz, C), 118.7 (d, $^{1}J_{PC}$ = 110.5 Hz, CH), 127.5 (d, $^{2}J_{PC}$ = 13.9 Hz, CH), 129.9 (d, $^{1}J_{PC}$ = 140.5 Hz, C), 130.8 (d, J_{PC} = 11.7 Hz, CH_{Ar}), 131.5 (d, $^{4}J_{PC}$ = 2.9 Hz, CH_{Ar}), 155.1 (d, J_{PC} = 11.0 Hz, CH_{Ar}). HRMS (FAB) m/z calcd for $C_{11}H_{14}O_2P$ $(M+H)^+$, 209.0731; found, 209.0725. IR (NaCl): 3042, 3000, 1590, 1212, 1202, 1108, 1070, 960, 945, 695.



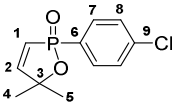
$C_{11}H_{13}O_2P$
MW 208.20, 550 mg, yield 70%, brown oil.

4.4.2. *2-(4-Methoxyphenyl)-5,5-dimethyl-5H-1,2-oxaphosphole 2-oxide (**11b**).* Brown oil, 0.648 g, 72% yield. ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 54.0; ^{1}H NMR (400.1 MHz, $CDCl_3$) δ 1.46 (s, 3H, CH_3), 1.53 (s, 3H, CH_3), 3.73 (s, 3H, OCH_3), 6.05 (dd, 1H, $^{2}J_{PH}$ = 33.6 Hz, $^{3}J_{HH}$ = 8.1 Hz, PCH), 6.86-6.89 (m, 2H, H_{ar}), 6.96 (dd, 1H, $^{3}J_{PH}$ = 40.4 Hz, $^{3}J_{HH}$ = 8.1 Hz, CH), 7.54-7.61 (m, 2H, H_{ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 27.1 (d, $^{3}J_{PC}$ = 3.7 Hz, CH_3), 28.6 (s, CH_3), 55.3 (s, OCH_3), 89.1 (d, $^{2}J_{PC}$ = 4.4 Hz, C), 114.0 (d, $^{3}J_{PC}$ = 15.4 Hz, CH), 119.8 (d, $^{1}J_{PC}$ = 111.2 Hz, PCH), 121.8 (d, $^{1}J_{PC}$ = 148.6 Hz, C), 133.8 (d, J_{PC} = 13.2 Hz, CH), 156.7 (d, J_{PC} = 10.2 Hz, CH), 163.0 (d, J_{PC} = 2.9 Hz, C_{Ar}). HRMS (FAB) m/z calcd for $C_{12}H_{16}O_3P$ $(M+H)^+$, 239.0837; found, 239.0834. IR (NaCl): 3050, 3030, 2980, 1620, 1222, 1112, 1065, 970, 945, 685.



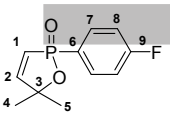
$C_{12}H_{15}O_3P$
MW 238.22, 648 mg, yield 72%, brown oil.

*4.4.3. 2-(4-Chlorophenyl)-5,5-dimethyl-5H-1,2-oxaphosphole 2-oxide (**11c**).* Brown oil, 0.623 g, 68% yield. ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 52.3; ^{1}H NMR (400.1 MHz, $CDCl_3$) δ 1.47 (s, 3H, CH_3), 1.55 (s, 3H, CH_3), 6.07 (dd, 1H, $^{2}J_{PH}$ = 33.8 Hz, $^{3}J_{HH}$ = 8.1 Hz, PCH), 7.03 (dd, 1H, $^{3}J_{PH}$ = 40.5 Hz, $^{3}J_{HH}$ = 8.1 Hz, CCH), 7.34-7.37 (m, 2H, H_{ar}), 7.56-7.61 (m, 2H, H_{ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 27.3 (d, $^{3}J_{PC}$ = 4.4 Hz, CH_3), 28.6 (s, CH_3), 89.6 (d, $^{2}J_{PC}$ = 4.4 Hz, C), 119.2 (d, $^{1}J_{PC}$ = 112.0 Hz, PCH), 128.8 (d, J_{PC} = 14.6 Hz, CH), 129.5 (d, J_{PC} = 142.0 Hz, C), 133.2 (d, J_{PC} = 12.4 Hz, CH), 139.0 (d, J_{PC} = 2.9 Hz, C), 156.7 (d, J_{PC} = 11.0 Hz, CH). HRMS (FAB) m/z calcd for $C_{11}H_{13}ClO_2P$ $(M+H)^+$, 243.0341; found, 243.0337. IR (NaCl): 3042, 3020, 3000, 2860, 1590, 1225, 1112, 1070, 965, 952, 690.



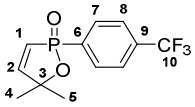
$C_{11}H_{12}ClO_2P$
MW 242.64, 623 mg, yield 68%, brown oil

*4.4.4. 2-(4-Fluorophenyl)-5,5-dimethyl-5H-1,2-oxaphosphole 2-oxide (**11d**). Brown oil, 0.512 g, 60% yield.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 51.2; ^{19}F NMR (188.3 MHz, $CDCl_3$) δ -106.3; ^{1}H NMR (400.1 MHz, $CDCl_3$) δ 1.48 (s, 3H, CH_3), 1.52 (s, 3H, CH_3), 6.06 (dd, 1H, $^{2}J_{PH}$ = 33.9 Hz, $^{3}J_{HH}$ = 8.4 Hz, PCH), 7.03 (dd, 1H, $^{3}J_{PH}$ = 40.4 Hz, $^{3}J_{HH}$ = 8.4 Hz, CH), 7.04-7.09 (m, 2H, H_{Ar}), 7.64-7.70 (m, 2H, H_{Ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 26.1 (d, $^{3}J_{PC}$ = 4.4 Hz, CH_3), 27.7 (s, CH_3), 88.5 (d, $^{2}J_{PC}$ = 4.4 Hz, C), 114.9 (dd, J_{CF} = 21.2 Hz, J_{PC} = 14.6 Hz, CH), 118.4 (d, $^{1}J_{PC}$ = 112.0 Hz, PCH), 126.0 (dd, $^{1}J_{PC}$ = 143.4 Hz, $^{4}J_{CF}$ = 2.9 Hz, C), 133.5 (dd, J_{CF} = 13.2 Hz, J_{PC} = 9.6 Hz, CH), 155.5 (d, $^{2}J_{PC}$ = 10.4 Hz, CH), 164.4 (dd, $^{1}J_{CF}$ = 253.9 Hz, $^{4}J_{PC}$ = 3.6 Hz, C). HRMS (FAB) m/z calcd for $C_{11}H_{13}FO_2P$ $(M+H)^+$, 227.0637; found, 227.0653. IR (NaCl): 3030-3000, 1610, 1535, 1332, 1199, 1108, 967, 952, 698.



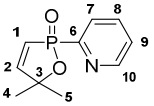
$C_{11}H_{12}FO_2P$
MW 226.19, 512 mg, yield 60%, brown oil.

*4.4.5. 5,5-Dimethyl-2-(4-(trifluoromethyl)phenyl)-5H-1,2-oxaphosphole 2-oxide (**11e**).* Brown oil, 0.68 g, 65% yield. ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 51.0; ^{19}F NMR (188.3 MHz, $CDCl_3$) δ -63.6; ^{1}H NMR (400.1 MHz, $CDCl_3$) δ 1.47 (s, 3H, CH_3), 1.56 (s, 3H, CH_3), 6.10 (dd, 1H, $^2J_{PH}$ = 34.1 Hz, $^3J_{HH}$ = 8.3 Hz, PCH), 7.08 (dd, 1H, $^3J_{PH}$ = 40.9 Hz, $^3J_{HH}$ = 8.3 Hz, CH), 7.62-7.65 (m, 2H, H_{Ar}), 7.77-7.82 (m, 2H, H_{Ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 26.9 (d, $^3J_{PC}$ = 4.4 Hz, CH_3), 28.6 (s, CH_3), 90.0 (d, $^2J_{PC}$ = 5.1 Hz, C), 118.9 (d, $^1J_{PC}$ = 112.0 Hz, PCH), 122.9 (q, $^1J_{CF}$ = 241.5 Hz, CF_3), 125.3 (qd, J_{PC} = 13.9 Hz, J_{CF} = 4.4 Hz, CH), 132.2 (d, J_{PC} = 11.7 Hz, CH), 133.8 (d, $^1J_{PC}$ = 177.1 Hz, C), 134.0 (qd, $^2J_{CF}$ = 32.9 Hz, $^4J_{PC}$ = 3.6 Hz, C), 157.3 (d, $^2J_{PC}$ = 11.0 Hz, CH). HRMS (FAB) m/z calcd for $C_{12}H_{13}F_3O_2P$ $(M+H)^+$, 277.0605; found, 277.0610. IR (NaCl): 3045, 3020, 3000, 1620, 1530, 1329, 1216, 1202, 1108, 1063, 967, 943, 715.



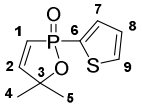
$C_{12}H_{12}F_3O_2P$
MW 276.20, 680 mg, yield 65%, brown oil.

***4.4.6.** 5,5-Dimethyl-2-(pyridin-2-yl)-5H-1,2-oxaphosphole 2-oxide (**11f**).* Brown oil, 0.50 g, 63% yield. ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 50.8; ^{1}H NMR (400.1 MHz, $CDCl_3$) δ 1.54 (s, 3H, CH_3), 1.57 (s, 3H, CH_3), 6.11 (dd, 1H, $^2J_{PH}$ = 34.1 Hz, $^3J_{HH}$ = 8.3 Hz, PCH), 7.11 (dd, 1H, $^3J_{PH}$ = 41.2 Hz, $^3J_{HH}$ = 8.3 Hz, CH), 7.32-7.36 (m, 1H, H_{ar}), 7.73-7.78 (m, 1H, H_{ar}), 8.08-8.12 (m, 1H, H_{ar}), 8.70 (d, 1 H, J = 4.8 Hz, H_{ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 26.7 (d, $^3J_{PC}$ = 3.7 Hz, CH_3), 28.5 (s, CH_3), 90.1 (d, $^2J_{PC}$ = 4.4 Hz, C), 117.9 (d, $^1J_{PC}$ = 112.7 Hz, PCH), 126.0 (d, $^4J_{PC}$ = 3.7 Hz, CH), 128.4 (d, J_{PC} = 24.1 Hz, CH), 136.2 (d, $^2J_{PC}$ = 11.0 Hz, CH), 150.5 (d, J_{PC} = 22.7 Hz, CH), 153.7 (d, $^1J_{PC}$ = 174.2 Hz, C), 157.8 (d, J_{PC} = 11.4 Hz, CH). HRMS (FAB) m/z calcd for $C_{10}H_{13}NO_2P$ $(M+H)^+$, 210.0684; found, 210.0674. IR (NaCl): 3012, 1620, 1549, 1212, 1202, 1108, 1070, 948, 932, 710.



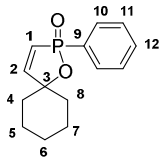
$C_{10}H_{12}NO_2P$
MW 209.18, 500 mg, yield 63%, brown oil.

*4.4.7. 5,5-Dimethyl-2-(thiophen-2-yl)-5H-1,2-oxaphosphole 2-oxide (**11g**). Brown oil, 0.453 g, 56% yield.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 44.9; ^{1}H NMR (400.1 MHz, $CDCl_3$) δ 1.51 (s, 3H, CH_3), 1.55 (s, 3H, CH_3), 6.15 (dd, 1H, $^2J_{PH}$ = 33.6 Hz, $^3J_{HH}$ = 8.1 Hz, PCH), 6.99 (dd, 1H, $^3J_{PH}$ = 42.2 Hz, $^3J_{HH}$ = 8.1 Hz, CH), 7.35-7.45 (m, 1H, H_{Ar}) 7.55-7.58 (m, 1H, H_{Ar}) 7.67-7.65 (m, 1H, H_{Ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 26.5 (d, $^3J_{PC}$ = 3.7 Hz, CH_3), 27.6 (s, CH_3), 88.5 (d, $^2J_{PC}$ = 5.9 Hz, C), 119.2 (d, $^1J_{PC}$ = 101.3 Hz, CH), 127.5 (d, J_{PC} = 16.1 Hz, CH), 130.9 (d, $^1J_{PC}$ = 157.0 Hz, C), 133.5 (d, J_{PC} = 7.3 Hz, CH), 136.0 (d, J_{PC} = 12.4 Hz, CH), 155.0 (d, $^2J_{PC}$ = 12.4 Hz, CH). HRMS (FAB) m/z calcd for $C_9H_{12}O_2PS$ $(M+H)^+$, 215.0296; found, 215.0305. IR (NaCl): 3050, 1600, 1232, 1105, 1065, 980, 939, 701.



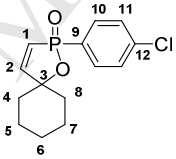
$C_9H_{11}O_2PS$
MW 214.22, 453 mg, yield 56%, brown oil.

*4.4.8. 2-Phenyl-1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**12a**). Brown oil, 0.324 g, 45% yield.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 52.8 ; ^{1}H NMR (400.1 MHz, $CDCl_3$) δ 1.17-1.91 (m, 10H, 5 CH_2), 6.13 (dd, 1H, $^2J_{PH}$ = 34.0 Hz, $^3J_{HH}$ = 8.3 Hz, PCH), 7.06 (dd, 1H, $^3J_{PH}$ = 40.1 Hz, $^3J_{HH}$ = 8.3 Hz, CH), 7.38-7.75 (m, 5H, H_{ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 21.8 (s, CH_2), 21.9 (s, CH_2), 24.6 (s, CH_2), 34.5 (d, J_{PC} = 3.7 Hz, CH_2), 37.0 (s, CH_2), 88.4 (d, $^2J_{PC}$ = 4.4 Hz, C), 118.7 (d, $^1J_{PC}$ = 110.5 Hz, PCH), 127.5 (d, J_{PC} = 13.9 Hz, CH), 130.1 (d, $^1J_{PC}$ = 141.4 Hz, C), 130.8 (d, J_{PC} = 11.7 Hz, CH), 131.5 (d, J_{PC} = 2.9 Hz, CH), 153.1 (d, $^2J_{PC}$ = 11.0 Hz, CH). HRMS (FAB) m/z calcd for $C_{14}H_{18}O_2P$ $(M+H)^+$, 249.1014; found, 249.1016. IR (NaCl): 3085, 3023, 1480, 1215, 1030, 990, 950, 690.



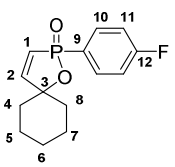
$C_{14}H_{17}O_2P$
MW 248.26, 324 mg, yield 45%, brown oil.

*4.4.9. 2-(4-Chlorophenyl)-1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**12b**). Brown oil, 0.402 g, 49% yield.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 51.5 ; ^{1}H NMR (400.1 MHz, $CDCl_3$) δ 1.33-1.91 (m, 10H, 5 CH_2), 6.13 (dd, 1H, $^2J_{PH}$ = 34.1 Hz, $^3J_{HH}$ = 8.2 Hz, PCH), 7.09 (dd, 1H, $^3J_{PH}$ = 40.4 Hz, $^3J_{HH}$ = 8.2 Hz, CH), 7.39-7.69 (m, 4H, H_{Ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 22.5 (s, CH_2), 22.9 (s, CH_2), 24.3 (s, CH_2), 36.8 (d, J_{PC} = 3.6 Hz, CH_2), 37.8 (s, CH_2), 91.4 (d, $^2J_{PC}$ = 3.6 Hz, C), 117.3 (d, $^1J_{PC}$ = 112.0 Hz, PCH), 127.5 (d, J_{PC} = 14.7 Hz, CH), 129.8 (d, $^1J_{PC}$ = 142.5 Hz, C), 132.1 (d, J_{PC} = 12.3 Hz, CH), 139.0 (d, J_{PC} = 2.9 Hz, C), 154.7, (d, $^2J_{PC}$ = 11.7 Hz, CH). HRMS (FAB) m/z calcd for $C_{14}H_{17}ClO_2P$ $(M+H)^+$, 283.0655; found, 283.0657. IR (NaCl): 3050, 3000, 1615, 1545, 1214, 1202, 1113, 1053, 965, 950, 710.



$C_{14}H_{16}ClO_2P$
MW 282.70, 402 mg, yield 49%, brown oil.

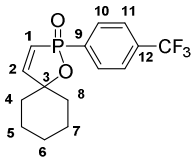
*4.4.10. 2-(4-chlorophenyl)-1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**12c**). Brown oil, 0.395 g, 51% yield.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 51.4; ^{19}F NMR (188.3 MHz, $CDCl_3$) δ -106.4; ^{1}H NMR (400.1 MHz, $CDCl_3$) δ 1.25-1.88 (m, 10H, CH_2), 6.10 (dd, 1H, $^2J_{PH}$ = 34.1 Hz, $^3J_{HH}$ = 8.3 Hz, PCH), 7.04 (dd, 1H, $^3J_{PH}$ = 40.4 Hz, $^3J_{HH}$ = 8.3 Hz, CH), 7.47-7.54 (m, 2H, H_{Ar}), 7.62-7.91 (m, 2H, H_{Ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 22.0 (s, CH_2), 22.1 (s, CH_2), 24.7 (s, CH_2), 35.8 (d, J_{PC} = 3.6 Hz, CH_2), 37.3 (s, CH_2), 91.4 (d, $^2J_{PC}$ = 3.6 Hz, C), 115.9 (dd, J_{CF} = 22.0 Hz, J_{PC} = 15.4 Hz, CH), 119.9 (d, $^1J_{PC}$ = 112.7 Hz, CH), 134.6 (dd, J_{CF} = 12.4 Hz, J_{PC} = 8.8 Hz, CH), 126.3 (dd, $^1J_{PC}$ = 143.4 Hz, $^4J_{CF}$ = 2.9 Hz, C), 154.7 (d, J_{PC} = 11.7 Hz, CH), 165.4 (dd, $^1J_{CF}$ = 256.9 Hz, $^4J_{PC}$ = 3.7 Hz, C). HRMS (FAB) m/z calcd for $C_{14}H_{17}FO_2P$ $(M+H)^+$, 267.0950; found, 267.0953. IR (NaCl): 3000, 1620, 1545, 1343, 1219, 1202, 1111, 1054, 960, 945, 695.



$C_{14}H_{16}FO_2P$
MW 266.25, 395 mg, yield 51%, brown oil.

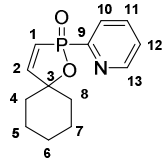
*4.4.11. 2-(4-(trifluoromethyl)phenyl)-1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**12d**). Brown oil, 0.505 g, 55% yield.* ^{31}P NMR (81.0 MHz, $CDCl_3$): δ 50.6 ; ^{19}F NMR (188.3 MHz, $CDCl_3$) δ - 64.6; ^{1}H NMR (400.1 MHz, $CDCl_3$) δ 1.25-1.96 (m, 10H, CH_2), 6.19 (dd, 1H,

$^2J_{PH}$ = 34.4 Hz, $^3J_{HH}$ = 8.3 Hz, PCH), 7.08 (dd, 1H, $^3J_{PH}$ = 40.6 Hz, $^3J_{HH}$ = 8.3 Hz, CH), 7.47-7.54 (m, 2H, H_{Ar}), 7.62-7.91 (m, 2H, H_{Ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 21.6 (s, CH_2), 21.9 (s, CH_2), 25.4 (s, CH_2), 34.3 (d, J_{PC} = 3.7 Hz, CH_2), 36.6 (s, CH_2), 92.8 (d, $^3J_{PC}$ = 5.1 Hz, C), 118.5 (d, $^1J_{PC}$ = 114.4 Hz, PCH), 122.9 (q, $^1J_{CF}$ = 245.6 Hz, CF_3), 125.3 (qd, J_{PC} = 13.9 Hz, J_{CF} = 4.4 Hz, CH), 132.20 (d, J_{PC} = 11.7 Hz, CH), 133.8 (d, $^1J_{PC}$ = 177.1 Hz, C), 134.0 (qd, J_{CF} = 32.9 Hz, J_{PC} = 3.6 Hz, C), 157.3 (d, $^2J_{PC}$ = 11.0 Hz, CH). HRMS (FAB) m/z calcd for $C_{15}H_{17}F_3O_2P$ $(M+H)^+$, 317.0918; found, 317.0915. IR (NaCl): 3045, 3012, 1617, 1549, 1331, 1229, 1202, 1108, 1065, 950, 940, 690.



$C_{15}H_{16}F_3O_2P$
MW 316.26, 505 mg, yield 55%, brown oil.

*4.4.12. 2-(pyridin-2-yl)-1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**12e**). Brown oil, 0.296 g, 41% yield.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 49.3 ; ^{1}H NMR (400.1 MHz, $CDCl_3$) δ 1.20-1.91 (m, 10H, CH_2), 6.13 (dd, 1H, $^2J_{PH}$ = 34.1 Hz, $^3J_{HH}$ = 8.3 Hz, PCH), 7.06 (dd, 1H, $^3J_{PH}$ = 40.1 Hz, $^3J_{HH}$ = 8.3 Hz, CH), 7.31-7.36 (m, 1H, H_{Ar}), 7.74-7.78 (m, 1H, H_{Ar}), 8.05-8.10 (m, 1H, H_{Ar}), 8.70 (d, 1H, *J* = 4.8 Hz, H_{Ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 21.8 (s, CH_2), 21.8 (s, CH_2), 24.6 (s, CH_2), 34.5 (d, J_{PC} = 3.7 Hz, CH_2), 37.0 (s, CH_2), 89.4 (d, $^2J_{PC}$ = 4.4 Hz, C), 117.9 (d, $^1J_{PC}$ = 110.6 Hz, PCH), 126.0 (d, J_{PC} = 3.7 Hz, CH), 128.5 (d, J_{PC} = 24.3 Hz, CH), 136.3 (d, J_{PC} = 11.2 Hz, CH), 150.7 (d, J_{PC} = 23.1 Hz, CH), 154.2 (d, $^1J_{PC}$ = 174.2 Hz, C), 157.8 (d, J_{PC} = 11.2 Hz, CH). HRMS (FAB) m/z calcd for $C_{13}H_{17}NO_2P$ $(M+H)^+$, 250.0997; found, 250.0997. IR (NaCl): 3085, 3023, 1450, 1230, 1030, 990, 950, 690.

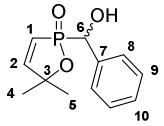


$C_{13}H_{16}NO_2P$
MW 249.25, 296 mg, yield 41%, brown oil.

4.5. General procedure for addition of oxaphospholene 9a to aromatic aldehydes (Pudovik reaction)

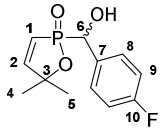
In a 25 mL three-neck round-bottom flask equipped with a condenser under nitrogen, was placed, oxaphospholene **9a** (3.03 mmol, 1 eq.), dichloromethane (5 mL), aldehyde (6.06 mmol, 2 eq.) and a mixture of potassium *tert*-butoxide (0.30 mmol, 0.1 eq.) in tetrahydrofuran (3 mL). After 2 to 2.5 days of stirring (see table 2), water was added. The mixture was extracted with chloroform (3 × 20 mL), the organic layers were dried over sodium sulfate and evaporated. The white solid was purified by column chromatography with as eluent a mixture of CH_2Cl_2/MeOH to afford a mixture of two diastereoisomers.

*4.5.1. 2-(Hydroxy(phenyl)methyl)-5,5-dimethyl-5H-1,2-oxaphosphole 2-oxide (**13a**). Colorless oil, 0.410 g, 57% yield, de = 19%.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 63.8 (41%, *dia 1*), 64.5 (59%, *dia 2*). ^{1}H NMR (250.1 MHz, $CDCl_3$) δ *dia 1:* 1.19 (s, 3H, CH_3), 1.41 (s, 3H, CH_3), 5.04 (d, 1H, $^2J_{PH}$ = 9.5 Hz, CHOH), 5.18 (s, 1H, OH), 5.80 (dd, 1H, $^2J_{PH}$ = 33.5 Hz, $^3J_{HH}$ = 8.2 Hz, PCH), 6.85 (dd, 1H, $^3J_{PH}$ = 39.5 Hz, $^3J_{HH}$ = 8.2 Hz, CH), 7.15-7.30 (m, 5H_{Ar}). *dia 2:* 0.88 (s, 3H, CH_3), 1.35 (s, 3H, CH_3), 5.18 (d, 1H, $^2J_{PH}$ = 11.5 Hz, CHOH), 5.24 (s, 1H, OH), 5.98 (dd, 1H, $^2J_{PH}$ = 33.1 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.75 (dd, 1H, $^3J_{PH}$ = 39.9 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.15-7.30 (m, 5H_{Ar}). ^{13}C NMR (50.3 MHz, $CDCl_3$) δ *dia 1:* 26.3 (d, J_{PC} = 4.3 Hz, CH_3), 28.5 (s, CH_3), 71.9 (d, $^1J_{PC}$ = 112.1 Hz, CHOH), 90.4 (d, $^2J_{PC}$ = 2.0 Hz, C), 115.9 (d, $^1J_{PC}$ = 99.3 Hz, PCH), 136.9 (d, $^2J_{PC}$ = 1.4 Hz, C), 158.0 (d, $^2J_{PC}$ = 11.0 Hz, CH). *dia 2:* 25.8 (d, J_{PC} = 4.3 Hz, CH_3), 28.6 (s, CH_3), 72.5 (d, $^1J_{PC}$ = 114.6 Hz, CH), 90.4 (d, J_{PC} = 2.0 Hz, C), 116.0 (d, $^1J_{PC}$ = 100.5 Hz, CH), 136.7 (s, C), 157.3 (d, $^2J_{PC}$ = 10.4 Hz, CH). δ *other signals* 126.9, 127.0, 127.4, 127.5, 127.8, 127.8, 127.9, 128.2. HRMS (FAB) m/z calcd for $C_{12}H_{16}O_3P$ $(M+H)^+$, 239.0837; found, 239.0845. IR (NaCl): 3252, 2990, 2940, 1620, 1456, 1410, 1220, 1164, 1111, 1061, 1015, 961, 929, 873, 854, 840, 832, 765, 715, 653, 603, 559.



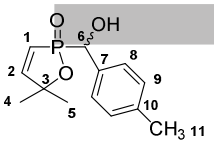
$C_{12}H_{15}O_3P$
MW 238.22, 410 mg, yield 57%, colorless oil. *de* = 19%.

*4.5.2. 2-((4-Fluorophenyl)(hydroxy)methyl)-5,5-dimethyl-5H-1,2-oxaphosphole 2-oxide (**13b**). Colorless oil, 0.574 g, 59% yield, de = 4%.* ^{31}P NMR (162.0 MHz, $CDCl_3$): δ 62.9 (48%, *dia 1*), 64.2 (52%, *dia 2*). ^{19}F NMR (188.3 MHz, $CDCl_3$) δ - 109; ^{1}H NMR (400.1 MHz, $CDCl_3$) δ 0.90 (s, 3H, CH_3), 1.20 (s, 3H, CH_3), 1.45 (s, 3H, CH_3), 1.50 (s, 3H, CH_3), 5.11 (d, 1H, $^2J_{PH}$ = 8.0 Hz, CHOH), 5.20 (d, 1H, $^2J_{PH}$ = 11.2 Hz, CHOH), 5.94 (dd, 1H, $^2J_{PH}$ = 33.3 Hz, $^3J_{HH}$ = 8.2 Hz, PCH), 6.08 (dd, 1H, $^2J_{PH}$ = 32.7 Hz, $^3J_{HH}$ = 8.2 Hz, PCH), 6.78 (dd, 1H, $^3J_{PH}$ = 39.9 Hz, $^3J_{HH}$ = 8.2 Hz, CH), 6.92 (dd, 1H, $^3J_{PH}$ = 39.5 Hz, $^3J_{HH}$ = 8.2 Hz, CH),7.24-7.49 (m, 4 H_{Ar}). ^{13}C NMR (50.3 MHz, $CDCl_3$) δ *dia 1:* 26.9 (d, J_{PC} = 4.3 Hz, CH_3), 28.9 (s, CH_3), 72.4 (d, $^1J_{PC}$ = 117.8 Hz, CHOH), 94.5 (d, $^2J_{PC}$ = 2.2 Hz, C), 116.0 (dd, J_{CF} = 22.0 Hz, J_{PC} = 2.2 Hz, CH), 116.5 (d, $^1J_{PC}$ = 101.0 Hz, PCH), 130.2 (dd, J_{CF} = 8.0 Hz, J_{PC} = 5.1 Hz, CH), 134.8 (d, J_{PC} = 2.9 Hz, C), 160.4 (d, $^2J_{PC}$ = 10.2 Hz, CH), 164.2 (dd, $^1J_{CF}$ = 245.2 Hz, J_{PC} = 3.7 Hz, C). *dia 2:* 26.4 (d, J_{PC} = 4.2 Hz, CH_3), 29.0 (s, CH_3), 71.9 (d, $^1J_{PC}$ = 117.9 Hz, CHOH), 94.3 (d, $^2J_{PC}$ = 2.2 Hz, C), 116.0 (dd, J_{CF} = 22.0 Hz, J_{PC} = 2.2 Hz, CH), 117.0 (d, $^1J_{PC}$ = 101.7 Hz, PCH), 130.6 (dd, J_{CF} = 8.0 Hz, J_{PC} = 4.4 Hz, CH), 134.6 (dd, J_{PC} = 2.3 Hz, J_{CF} = 2.3 Hz, C), 159.9 (d, J_{PC} = 9.5 Hz, CH), 164.1 (dd, $^1J_{CF}$ = 245.2 Hz, J_{PC} = 3.7 Hz, C). HRMS (FAB) m/z calcd for $C_{12}H_{15}FO_3P$ $(M+H)^+$, 257.0742; found, 257.0742. IR (NaCl): 3260, 2995, 2950, 1635, 1452, 1336, 1224, 1162, 1100, 1054, 872, 855, 765, 656, 565.



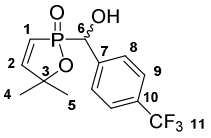
$C_{12}H_{14}FO_3P$
MW 256.21, 574 mg, yield 59%, colorless oil. *de* = 4 %.

*4.5.3. 2-(Hydroxy(p-tolyl)methyl)-5,5-dimethyl-5H-1,2-oxaphosphole 2-oxide (**13c**). Colorless oil, 0.520 g, 54% yield, de = 16%.* ^{31}P NMR (162.0 MHz, $CDCl_3$): δ 64.7 (42%, *dia 1*), 65.4 (58%, *dia 2*). ^{1}H NMR (400.1 MHz, $CDCl_3$) δ *dia 1:* 1.25 (s, 3H, CH_3), 1.47 (s, 3H, CH_3), 2.31 (d, 3H, *J* = 1.8 Hz, 3H, CH_3), 5.09 (d, 1H, $^2J_{PH}$ = 9.7 Hz, CHOH), 5.27 (s, 1H, OH), 6.04 (dd, 1H, $^2J_{PH}$ = 32.9 Hz, $^3J_{HH}$ = 8.3 Hz, PCH), 6.94 (dd, 1H, $^3J_{PH}$ = 39.4 Hz, $^3J_{HH}$ = 8.3 Hz, CH), 7.10-7.33 (m, 4 H_{Ar}). *dia 2:* 0.95 (s, 3H, CH_3), 1.41 (s, 3H, CH_3), 2.30 (d, 3H, *J* = 1.7 Hz, 3H, CH_3), 5.00 (d, 1H, $^2J_{PH}$ = 8.8 Hz, CHOH), 5.30 (s, 1H, OH), 5.90 (dd, 1H, $^2J_{PH}$ = 33.4 Hz, $^3J_{HH}$ = 8.3 Hz, PCH), 6.81 (dd, 1H, $^3J_{PH}$ = 39.8 Hz, $^3J_{HH}$ = 8.3 Hz, CH), 7.10-7.33 (m, 4 H_{Ar}). ^{13}C NMR (50.32 MHz, $CDCl_3$) δ *dia 1:* 21.6 (s, CH_3), 26.9 (d, $^3J_{PC}$ = 4.3 Hz, CH_3), 28.9 (s, CH_3), 72.5 (d, $^1J_{PC}$ = 113.9 Hz, CHOH), 90.7 (s, C), 116.6 (d, $^1J_{PC}$ = 100.1 Hz, PCH), 127.7 (d, J_{PC} = 5.4 Hz, CH), 129.1 (d, J_{PC} = 2.7 Hz, CH), 134.0 (s, C), 138.0 (s, C), 158.3 (d, $^2J_{PC}$ = 10.7 Hz, CH). *dia 2:* 21.6 (s, CH_3), 26.4 (d, $^3J_{PC}$ = 4.2 Hz, CH_3), 29.0 (s, CH_3), 72.3 (d, $^1J_{PC}$ = 112.0 Hz, CHOH), 90.7 (s, C), 116.7 (d, $^1J_{PC}$ = 100.5 Hz, PCH), 127.2 (d, J_{PC} = 5.4 Hz, CH), 129.4 (d, J_{PC} = 3.1 Hz, CH), 133.9 (s, C), 137.9 (s, C), 157.5 (d, $^2J_{PC}$ = 10.4 Hz, CH). HRMS (FAB) m/z calcd for $C_{13}H_{18}O_3P$ $(M+H)^+$, 253.0993; found, 253.0997. IR (NaCl): 3260, 2995, 1645, 1214, 1167, 1124, 1065, 1013, 965, 930, 875, 853, 834, 770, 720, 612, 550.



$C_{13}H_{17}O_3P$
MW 252.25, 520 mg, yield 54%, colorless oil. *de* = 16 %.

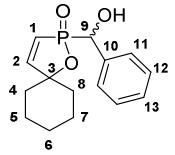
*4.5.4. 2-(Hydroxy(4-(trifluoromethyl)phenyl)methyl)-5,5-dimethyl-5H-1,2-oxaphosphole 2-oxide (**13d**).* **13d** was prepared according to the Pudovik procedure. The residue was triturated in diethyl ether, and filtered. The major diastereomer was obtained as white crystals (250 mg, 27%). The filtrate was purified by column chromatography with as eluent a mixture of CH_2Cl_2/MeOH giving a colorless oil (75 mg) containing both diastereomers (de = 62 %). Overall mass 325 mg, 35% yield. Dia 1 (major): M.P.: 202°C; ^{31}P NMR (101.25 MHz, $CDCl_3$): δ *67*%. ^{19}F NMR (188.3 MHz, $CDCl_3$) δ - 62.3; ^{1}H NMR (250.1 MHz, $CDCl_3$) δ 1.49 (s, 3H, CH_3), 1.60 (s, 3H, CH_3), 4.92 (s, 1H, OH), 5.17 (d, 1H, $^2J_{PH}$ = 11.5 Hz, CHOH), 6.01 (dd, 1H, $^2J_{PH}$ = 34.8 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 7.32 (dd, 1H, $^3J_{PH}$ = 40.4 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.46-7.89 (m, 4H, 4 H_{Ar}). ^{13}C NMR (50.3 MHz, $CDCl_3$) δ 25.3 (d, J_{PC} = 3.7 Hz, CH_3), 27.4 (s, CH_3), 71.0 (d, $^1J_{PC}$ = 116.0 Hz, CHOH), 91.4 (d, $^2J_{PC}$ = 2.6 Hz, C), 114.0 (d, $^1J_{PC}$ = 101.4 Hz, PCH), 125.0 (q, $^1J_{CF}$ = 272 Hz, CF_3), 124.7 (qd, J_{CF} = 3.3 Hz, J_{PC} = 3.3 Hz, CH), 127.3 (d, J_{PC} = 4.7 Hz, CH), 129.2 (qd, J_{CF} = 31.8 Hz, J_{PC} = 3.3 Hz, C), 142.0 (s, C), 159.8 (d, $^2J_{PC}$ = 10.2 Hz, CH). HRMS (FAB) m/z calcd for $C_{13}H_{15}F_3O_3P$ $(M+H)^+$, 307.0710; found, 307.0694. IR (NaCl): 3252, 3088, 2990, 2940, 2879, 1618, 1592, 1464, 1412, 1331, 1213, 1164, 1111, 1061, 1015, 959, 928, 876, 855, 844, 825, 764, 705, 653, 616, 598, 559, 463, 414.
Dia 2 (minor): ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 64.4; ^{19}F NMR (188.3 MHz, $CDCl_3$) δ -62.4; ^{1}H NMR (250.1 MHz, $CDCl_3$) δ 1.22 (s, 6H, CH_3), 4.92 (s, 1H, OH), 5.27 (d, 1H, $^2J_{PH}$ = 11.5 Hz, CHOH), 6.06 (dd, 1H, $^2J_{PH}$ = 33.2 Hz, $^3J_{HH}$ = 8.2 Hz, PCH), 6.76 (dd, 1H, $^3J_{PH}$ = 40.2 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.46-7.89 (m, 4H, 4 H_{Ar}). ^{13}C NMR (50.3 MHz, $CDCl_3$) δ 25.3 (d, J_{PC} = 3.7 Hz, CH_3), 27.4 (s, CH_3), 71.0 (d, $^1J_{PC}$ = 116 Hz, CH), 91.4 (d, $^2J_{PC}$ = 2.6 Hz, C), 114.0 (d, $^1J_{PC}$ = 101.4 Hz, CH), 125.0 (q, $^1J_{CF}$ = 272 Hz, CF_3), 124.7 (qd, J_{CF} 3.3 Hz, J_{PC} = 3.3 Hz, CH), 127.3 (d, J_{PC} = 4.7 Hz, CH), 129.2 (qd, J_{CF} = 31.8 Hz, J_{PC} = 3.3 Hz, C), 142.0 (s, C), 159.8 (d, $^2J_{PC}$ = 10.2 Hz, CH). HRMS (FAB) m/z calcd for $C_{13}H_{15}F_3O_3P$ $(M+H)^+$, 307.0710; found, 307.0714. IR (NaCl): 3269, 1625, 1336, 1218, 1144, 1111, 1061, 928, 876, 764.



$C_{13}H_{14}F_3O_3P$
MW 306.22, 325 mg, yield 35%, white cristals (major diastereomer), melting point: 202°C. *de* = 62 %.

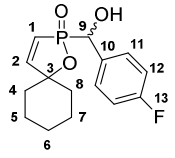
4.6. General procedure for addition of oxaphospholene 9b to aromatic aldehydes (Pudovik reaction)
In a 25 mL three-neck round-bottom flask equipped with a condenser under nitrogen containing, was placed oxaphospholene **9b** (2.90 mmol, 1 eq.), toluene (10 mL), aldehyde (1 eq.) and a mixture of potassium *tert*-butoxide (0.29 mmol, 0.1 eq.) in toluene (1 mL). The reaction mixture was heated at 80°C for 3.5 to 5 h (see table 2). After cooling to room temperature, addition of 5 mL of water, extraction with diethyl acetate (3 × 10 mL), the organic layers were dried over sodium sulfate and evaporated under vacuum. Upon addition of diethyl ether (10 mL), a white solid **14** was obtained after filtration and drying.

*4.6.1. 2-(Hydroxy(phenyl)methyl)-1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**14a**). White solid, 0.645 g, 80% yield, de = 61%.* ^{31}P NMR (101.2 MHz, DMSO-D_6): δ 63.2 (81%, *dia 1*), 62.4 (19%, *dia 2*). ^{1}H NMR (400.1 MHz, DMSO-D_6) δ *dia 1:* 1.12-1.70 (m, 10H, CH_2), 5.01 (d, 1H, $^2J_{PH}$ = 8.4 Hz, CHOH), 5.01 (d, 1H, $^2J_{PH}$ = 8.4 Hz, CHOH), 6.20 (dd, 1H, $^2J_{PH}$ = 34.2 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 7.15 (dd, 1H, $^3J_{PH}$ = 39.5 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.26-7.38 (m, 5H, H_{Ar}). *dia 2:* 1.12-1.70 (m, 10H, CH_2), 4.90 (d, 1H, $^2J_{PH}$ = 11.7 Hz, CHOH), 6.09 (dd, 1H, $^2J_{PH}$ = 34.2 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 7.26-7.38 (m, 6H, H_{Ar} + CH) . ^{13}C NMR (50.3 MHz, DMSO-D_6) δ *dia 1:* 22.1 (s, 2 CH_2), 24.7 (s, CH_2), 34.2 (d, J_{PC} = 2.2 Hz, CH_2), 36.8 (s, CH_2), 71.2 (d, $^1J_{PC}$ = 114.9 Hz, CHOH), 91.1 (d, $^2J_{PC}$ = 1.9 Hz, C), 117.7 (d, $^1J_{PC}$ = 98.8 Hz, PCH), 127.8 (d, J_{PC} = 2.9 Hz, CH), 127.8 (d, J_{PC} = 5.1 Hz, CH), 128.1 (d, J_{PC} = 2.2 Hz, CH), 138.8 (d, $^2J_{PC}$ = 2.9 Hz, C), 157.2 (d, $^2J_{PC}$ = 9.5 Hz, CH). *dia 2:* 22.1 (s, CH_2), 22.2 (s, CH_2), 24.8 (s, CH_2), 34.7 (d, J_{PC} = 2.2 Hz, CH_2), 37.0 (s, CH_2), 72.1 (d, $^1J_{PC}$ = 114.9 Hz, CHOH), 91.3 (d, $^2J_{PC}$ = 1.5 Hz, C), 117.4 (d, $^1J_{PC}$ = 98.8 Hz, PCH), 127.6 (d, J_{PC} = 5.1 Hz, CH), 128.3 (d, J_{PC} = 2.9 Hz, CH), 138.8 (s, C), 157.6 (d, $^2J_{PC}$ = 9.5 Hz, CH), 1 CH_{Ar} is overlapping with the major stereoisomer. HRMS (FAB) m/z calcd for $C_{15}H_{20}O_3P$ $(M+H)^+$, 279.1150; found, 279.1166. IR (NaCl): 3190, 2950, 1565, 1465, 1326, 1276, 1211, 1165, 1093, 1063, 1012, 950, 875, 840, 820, 750, 570.



$C_{15}H_{19}O_3P$
MW 278.29, 645 mg, yield 80%, white solid, melting point: 207°C. *de* = 61 %.

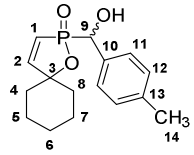
*4.6.2. 2-(Hydroxy(phenyl)methyl)-1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**14b**). White solid, 0.770 g, 91% yield, de = 38%.* ^{31}P NMR (101.2 MHz, CD_3OD): δ 66.4 (d, 31%, $^6J_{PF}$ = 4.6 Hz, *dia 1*), 66.7 (d, 69%, $^6J_{PF}$ = 4.6 Hz, *dia 2*). ^{19}F NMR (188.3 MHz, CD_3OD) δ -110.0; ^{1}H NMR (400.1 MHz, CD_3OD) δ *dia 1:* 1.39-1.87 (m, 10H, CH_2), 5.14 (d, 1H, $^2J_{PH}$ = 11.8 Hz, CHOH), 6.16 (dd, 1H, $^2J_{PH}$ = 34.6 Hz, $^3J_{HH}$ = 8.5 Hz, PCH), 7.18-7.26 (m, 2H, H_{Ar}), 7.39 (dd, 1H, $^3J_{PH}$ = 39.9 Hz, $^3J_{HH}$ = 8.5 Hz, CH), 7.54-7.60 (m, 2H, H_{Ar}). *dia 2:* 1.39-1.87 (m, 10H, CH_2), 5.24 (d, 1H, $^2J_{PH}$ = 7.2 Hz, CHOH), 6.31 (dd, 1H, $^2J_{PH}$ = 34.8 Hz, $^3J_{HH}$ = 8.5 Hz, PCH), 7.18-7.26 (m, 2H, H_{Ar}), 7.31 (dd, 1H, $^3J_{PH}$ = 40.1 Hz, $^3J_{HH}$ = 8.5 Hz, CH), 7.54-7.60 (m, 2H, H_{Ar}). ^{13}C NMR (100.6 MHz, CD_3OD) δ *dia 1:* 23.1 (s, CH_2), 23.2 (s, CH_2), 25.9 (s, CH_2), 35.9 (d, J_{PC} = 3.66 Hz, CH_2), 38.2 (s, CH_2), 72.4 (d, $^1J_{PC}$ = 117.8 Hz, CHOH), 94.5 (d, $^2J_{PC}$ = 2.2 Hz, C), 116 (dd, J_{CF} = 22.0 Hz, J_{PC} = 2.2 Hz, CH), 116.5 (d, $^1J_{PC}$ = 101.0 Hz, PCH), 130.2 (dd, J_{CF} = 8.0 Hz, J_{PC} = 5.1 Hz, CH), 134.8 (d, J_{PC} = 2.9 Hz, C), 160.4 (d, $^2J_{PC}$ = 10.2 Hz, CH), 164.1 (dd, $^1J_{CF}$ = 245.2 Hz, J_{PC} = 3.7 Hz, C). *dia 2:* 23.2 (s, CH_2), 23.3 (s, CH_2), 25.9 (s, CH_2), 35.4 (d, J_{PC} = 2,9 Hz, CH_2), 38.0 (s, CH_2), 71.9 (d, $^1J_{PC}$ = 117.8 Hz, CHOH), 94.3 (d, $^2J_{PC}$ = 2.2 Hz, C), 116.0 (dd, J_{CF} = 22.0 Hz, J_{PC} = 2.2 Hz, CH), 117.0 (d, $^1J_{PC}$ = 101.7 Hz, PCH), 130.6 (dd, J_{CF} = 8.0 Hz, J_{PC} = 4.4 Hz, CH), 134.6 (dd, J_{PC} = 2.3 Hz, J_{CF} = 2.3 Hz, C), 159.9 (d, $^2J_{PC}$ = 9.5 Hz, CH), 164.1 (dd, $^1J_{CF}$ = 245.2 Hz, J_{PC} = 3.7 Hz, C). HRMS (FAB) m/z calcd for $C_{15}H_{18}FO_3P$ $(M+H)^+$, 297.1056; found, 297.1067. IR (NaCl): 3231, 2936, 2411, 1601, 1505, 1448, 1320, 1215, 1202, 1179, 1151, 1064, 950, 906, 855, 836, 791, 732, 722, 578, 558, 520.



$C_{15}H_{17}FO_3P$
MW 296.28, 770 mg, yield 91%, white solid, melting point: 198°C. *de* = 38 %.

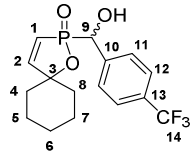
*4.6.3. 2-(Hydroxy(p-tolyl)methyl)-1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**14c**). White solid, 0.700 g, 83% yield, de = 12%.* ^{31}P NMR (162.0 MHz, DMSO-D_6): δ 61.5 (44%, *dia 1*), 66.7 (56%, *dia 2*). ^{1}H NMR (400.1 MHz, DMSO-D_6) δ *dia 1:* 1.16-1.70 (m, 10H, CH_2), 2.29 (d, 3H, $^7J_{PH}$ = 1.8 Hz, CH_3), 4.84 (dd, 1H, $^2J_{PH}$ = 11.1 Hz, J_{HH} = 5.3 Hz, CHOH), 6.07 (dd, 1H, $^2J_{PH}$ = 34.1 Hz, $^3J_{HH}$ = 8.4 Hz,

PCH), 6.10-6.15 (m, 2H, H_{Ar}), 7.05 (dd, 1H, $^3J_{PH}$ = 40.3 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.22-7.30 (m, 2H, H_{Ar}). *dia 2:* 1.16-1.70 (m, 10H, CH_2), 2.28 (d, 1H, $^7J_{PH}$ = 1.8 Hz, CH_3), 5.15 (dd, 1H, $^2J_{PH}$ = 7.3 Hz, J_{HH} = 5.1 Hz, CHOH), 6.18 (dd, 1H, $^2J_{PH}$ = 34.1 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.10-6.15 (m, 2H, H_{Ar}), 7.15 (dd, 1H, $^3J_{PH}$ = 40.1 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.22-7.30 (m, 2H, H_{Ar}). ^{13}C NMR (100.6 MHz, DMSO-D_6) δ *dia 1:* 20.7 (s, CH_3), 21.7 (s, CH_2), 21.7 (s, CH_2), 24.3 (s, CH_2), 34.2 (d, J_{PC} = 2.9 Hz, CH_2), 36.5 (s, CH_2), 71.5 (d, $^1J_{PC}$ = 115.6 Hz, CHOH), 90.7 (d, $^2J_{PC}$ = 2.2 Hz, C), 117.2 (d, $^1J_{PC}$ = 98.1 Hz, PCH), 127.0 (d, J_{PC} = 5.1 Hz, CH), 128.4 (d, J_{PC} = 2.2 Hz, CH), 135.1 (d, J_{PC} = 2.2 Hz, C), 136.4 (d, J_{PC} = 4.3 Hz, C), 160.0 (d, $^2J_{PC}$ = 10.2 Hz, CH). d*ia 2:* 20.7 (s, CH_3), 21.6 (s, CH_2), 21.6 (s, CH_2), 24.2 (s, CH_2), 33.8 (d, J_{PC} = 2.2 Hz, CH_2), 36.3 (s, CH_2), 70.5 (d, $^1J_{PC}$ = 114.9 Hz, CHOH), 90.5 (d, $^2J_{PC}$ = 2.2 Hz, C), 117.3 (d, $^1J_{PC}$ = 98.8 Hz, PCH), 127.2 (d, J_{PC} = 5.1 Hz, CH), 128.2 (d, J_{PC} = 2.2 Hz, CH), 135.4 (s, C), 136.4 (d, $^2J_{PC}$ = 3.7 Hz, C), 156.4 (d, $^2J_{PC}$ = 9.5 Hz, CH). HRMS (FAB) m/z calcd for $C_{16}H_{22}O_3P$ $(M+H)^+$, 293.1306; found, 293.1303. IR (NaCl): 3418, 1651, 1203, 1106, 1064, 942, 904, 813, 740, 631, 552.



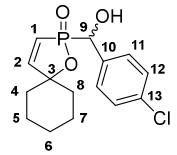
$C_{16}H_{21}O_3P$
MW 292.31, 700 mg, yield 83%, white solid, melting point: 170°C. *de* = 12%.

*4.6.4. 2-(Hydroxy(4-(trifluoromethyl)phenyl)methyl)-1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**14d**). White solid, 0.830g, 83% yield, de = 22%.* ^{31}P NMR (101.2 MHz, CD_3OD): δ 61.9 (39%, *dia 1*), 64.1 (61%, *dia 2*). ^{19}F NMR (188.3 MHz, CD_3OD) δ -61.3; ^{1}H NMR (400.13 MHz, DMSO-d_6) δ *dia 1:* 1.39-1.87 (m, 10H, CH_2), 5.14 (d, 1H, $^2J_{PH}$ = 11.8 Hz, CHOH), 6.16 (dd, 1H, $^2J_{PH}$ = 34.6 Hz, $^3J_{HH}$ = 8.5 Hz, PCH), 7.18-7.26 (m, 2H, H_{Ar}), 7.39 (dd, 1H, $^3J_{PH}$ = 39.9 Hz, $^3J_{HH}$ = 8.5 Hz, CH), 7.54-7.60 (m, 2H, H_{Ar}). *dia 2:* 1.39-1.87 (m, 10H, CH_2), 5.24 (d, 1H, $^2J_{PH}$ = 7.2 Hz, CHOH), 6.31 (dd, 1H, $^2J_{PH}$ = 34.8 Hz, $^3J_{HH}$ = 8.5 Hz, PCH), 7.18-7.26 (m, 2H, H_{Ar}), 7.31 (dd, 1H, $^3J_{PH}$ = 40.1 Hz, $^3J_{HH}$ = 8.5 Hz, CH), 7.54-7.60 (m, 2H, H_{Ar}). ^{13}C NMR (100.6 MHz, CD_3OD) δ *dia 1:* 21.8 (s, CH_2), 21.9 (s, CH_2), 24.6 (s, CH_2), 34.7 (d, J_{PC} = 2.9 Hz, CH_2), 37.0 (s, CH_2), 72.2 (d, $^1J_{PC}$ = 109.8 Hz, CHOH), 92.7 (d, $^2J_{PC}$ = 2.2 Hz, C), 116.1 (d, $^1J_{PC}$ = 101.0 Hz, PCH), 124.4 (d, $^1J_{CF}$ = 272.2 Hz, CF_3), 125.1 (qd, J_{CF} = 8.0 Hz, J_{PC} = 5.1 Hz, CH), 127.2 (d, J_{PC} = 5.1 Hz, CH), 140.8 (s, C), 158.3 (d, $^2J_{PC}$ = 11.7 Hz, CH). *dia 2:* 22.0 (s, CH_2), 22.0 (s, CH_2), 24.5 (s, CH_2), 34.1 (d, J_{PC} = 3.6 Hz, CH_2) 36.8 (s, CH_2), 72.2 (d, $^1J_{PC}$ = 112.7 Hz, CHOH), 93.0 (d, $^2J_{PC}$ = 1.5 Hz, C), 115.7 (d, $^1J_{PC}$ = 102.5 Hz, PCH), 124.4 (d, $^1J_{CF}$ = 272.2 Hz, CF_3), 124.9 (qd, J_{CF} = 8.3 Hz, J_{PC} = 5.2 Hz, CH), 127.5 (d, J_{PC} = 5.1 Hz, CH), 141.0 (d, $^2J_{PC}$ = 1.5 Hz, C), 157.6 (d, $^2J_{PC}$ = 11.0 Hz, CH). HRMS (FAB) m/z calcd for $C_{16}H_{19}F_3O_3P$ $(M+H)^+$, 347.1024; found, 347.1020. IR (NaCl): 3211, 2936, 2862, 1620, 1583, 1455, 1416, 1325, 1227, 1204, 1163, 1126, 1120, 1067, 1016, 940, 907, 837, 814, 737, 606, 555.



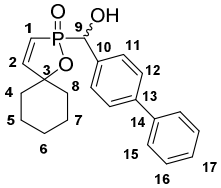
$C_{16}H_{18}F_3O_3P$
MW 346.29, 830 mg, yield 83%, white solid, melting point: 158°C. *de* = 22 %.

*4.6.5. 2-((4-Chlorophenyl)(hydroxy)methyl)-1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**14e**). White solid, 0.680g, 75% yield, de = 4%.* ^{31}P NMR (101.2 MHz, CD_3OD): δ 66.2 (48%, *dia 1*), 66.6 (52%, *dia 2*). ^{1}H NMR (400.1 MHz, CD_3OD) δ *dia 1:* 1.32-1.80 (m, 10H, CH_2), 5.05 (d, 1H, $^2J_{PH}$ = 12.3 Hz, CHOH), 6.06 (dd, 1H, $^2J_{PH}$ = 34.8 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 7.31 (dd, 1H, $^3J_{PH}$ = 40.1 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.36-7.47 (m, 4H, H_{Ar}). *dia 2:* 1.32-1.80 (m, 10H, CH_2), 5.15 (d, 1H, $^2J_{PH}$ = 7.6 Hz, CHOH), 6.2 (dd, 1H, $^2J_{PH}$ = 34.8 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 7.21 (dd, 1H, $^3J_{PH}$ = 40.3 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.36-7.47 (m, 4H, H_{Ar}). ^{13}C NMR (100.6 MHz, CD_3OD) δ *dia 1:* 22.0 (s, CH_2), 22.1 (s, CH_2), 24.8 (s, CH_2), 34.8 (d, J_{PC} = 3.1 Hz, CH_2), 37.1 (s, CH_2), 71.3 (d, $^1J_{PC}$ = 116.9 Hz, CHOH), 93.2 (d, $^2J_{PC}$ = 2.7 Hz, C), 115.3 (d, $^1J_{PC}$ = 101.0 Hz, PCH), 128.4 (d, J_{PC} = 3.1 Hz, CH), 128.8 (d, J_{PC} = 5.4 Hz, CH), 133.9 (d, J_{PC} = 3.5 Hz, C), 136.6 (s, C), 159.4 (d, $^2J_{PC}$ = 10.3 Hz, CH). *dia 2:* 22.1 (s, CH_2), 22.1 (s, CH_2), 24.7 (s, CH_2), 34.3 (d, J_{PC} = 3.1 Hz, CH_2), 36.9 (s, CH_2), 70.8 (d, $^1J_{PC}$ = 117.3 Hz, CHOH), 93.5 (d, $^2J_{PC}$ = 1.9 Hz, C), 117.7 (d, $^1J_{PC}$ = 101.6 Hz, CH), 128.2 (d, J_{PC} = 2.7 Hz, CH), 129.2 (d, J_{PC} = 5.0 Hz, CH), 136.4 (d, J_{PC} = 3.1 Hz, C), 136.6 (s, C), 158.9 (d, $^2J_{PC}$ = 10.0 Hz, CH). HRMS (FAB) m/z calcd for $C_{15}H_{19}ClO_3P$ $(M+H)^+$, 313.0760; found, 313.0764. IR (NaCl): 3184, 2947, 2850, 2386, 1577, 1493, 1448, 1406, 1322, 1259, 1208, 1158, 1091, 1064, 1013, 943, 873, 831, 812, 738, 643, 563, 540.



$C_{15}H_{18}ClO_3P$
MW 312.73, 680 mg, yield 75%, white solid, melting point: 183°C. *de* = 4 %.

*4.6.6. 2-([1,1'-biphenyl]-4-yl(hydroxy)methyl)-1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**14f**). White solid, 0.770g, 75% yield, de = 18%.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 64.6 (59%, *dia 1*), 62.5 (41%, *dia 2*). one diastereomer was separated ^{1}H NMR (400.1 MHz, $CDCl_3$) δ *dia 1:* 1.33-1.88 (m, 10H, CH_2), 5.10 (d, $^2J_{PH}$ = 5.8 Hz, CHOH), 5.98 (dd, $^2J_{PH}$ = 33.8 Hz, $^3J_{HH}$ = 8.5 Hz, PCH), 6.89 (dd, $^3J_{PH}$ = 39.6 Hz, $^3J_{HH}$ = 8.5 Hz, CH), 7.24-7.49 (m, 9H, H_{Ar}). *dia 2:* 1.33-1.88 (m, 10H, CH_2), 5.10 (d, $^2J_{PH}$ = 11.9 Hz, CHOH), 6.09 (dd, $^2J_{PH}$ = 32.8 Hz, $^3J_{HH}$ = 8.5 Hz, PCH), 6.73 (dd, $^3J_{PH}$ = 39.4 Hz, $^3J_{HH}$ = 8.53 Hz, CH), 7.24-7.49 (m, 9H, H_{Ar}). ^{13}C NMR (101 MHz, $CDCl_3$) δ 21.9 (s, CH_2), 21.9 (s, CH_2), 24.7 (s, CH_2), 34.3 (d, J = 3.4 Hz, CH_2), 36.9 (s, CH_2), 72.7 (d, ^1J = 113.5 Hz, CHO), 92.7 (d, ^2J = 1.4 Hz, C), 116.2 (d, ^1J = 101.7 Hz, PCH), 126.8 (d, J = 2.8 Hz, CH_{Ar}), 127.1 (s, CH_{Ar}), 127.4 (s, CH_{Ar}), 127.8 (d, J = 5.3 Hz, CH_{Ar}), 128.9 (s, CH_{Ar}), 135.8 (s, C_{Ar}), 140.8 (s, J = 1.4 Hz, C_{Ar}), 140.8 (d, J = 3.7 Hz, C_{Ar}), 157.3 (d, ^2J = 10.9 Hz, CH). HRMS (FAB) m/z calcd for $C_{21}H_{24}O_3P$ $(M+H)^+$, 355.1463; found, 355.1463. IR (NaCl): 3410, 2959, 1661, 1605, 1433, 1261, 1102, 1051, 949, 749, 694.

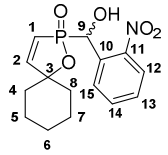


$C_{21}H_{23}O_3P$
MW 354.39, 770 mg, yield 75%, white solid, melting point: 150°C. *de* = 4 %.

4.6.7. 2-(hydroxy(2-nitrophenyl)methyl)-1-oxa-2-phosphaspiro[4.5]-dec-3-ene 2-oxide (**14g**). The two diastereomers were separated by chromatography on silica-gel. White solid, 0.770g, 63%, de = 14%. *Dia 1*: 254 mg. ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 64.3; ^{1}H NMR (250.1 MHz, $CDCl_3$) δ 0.85-1.69 (m, 10H, CH_2), 6.33 (dd, 1H, $^2J_{PH}$ = 30.3 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.53 (d, 1H, $^2J_{PH}$ = 18.0 Hz, CHOH), 6.82 (dd, 1H, $^3J_{PH}$ = 41.0 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.42-7.46 (m, 1H, CH_{Ar}), 7.63-7.69 (m, 1H, CH_{Ar}), 7.90-7.92 (m, 1H, CH_{Ar}), 8.22 (d, 1H, $^3J_{HH}$ = 8.2 Hz, CH_{Ar}). ^{13}C NMR (50.3 MHz, $CDCl_3$) δ 21.7 (s, CH_2), 21.8 (s, CH_2), 24.6 (s, CH_2), 34.5 (d, J_{PC} = 3.7 Hz, CH_2), 37.0 (s, CH_2), 70.3 (d, $^1J_{PC}$ = 117.6 Hz, CHOH), 92.8 (d, $^2J_{PC}$ = 1.5 Hz, C), 116.4 (d, $^1J_{PC}$ = 108.3 Hz, PCH), 124.9 (d, J_{PC} = 2.2 Hz, CH), 128.1 (d, J_{PC} = 3.7 Hz, CH), 128.7 (d, J_{PC} = 5.1 Hz, CH), 133.9 (d, J_{PC} = 2.9 Hz, CH), 135.2 (s, C), 146.5 (d, J_{PC} = 5.1 Hz, C), 156.7 (d, $^2J_{PC}$ = 13.2 Hz, CH). HRMS (FAB) m/z calcd for $C_{15}H_{19}NO_5P$ $(M+H)^+$, 324.1001; found, 324.1008. IR (NaCl): 3172, 2939, 1525, 1340, 1222, 1192, 1156, 937, 856, 735, 555.

Dia 2: 336 mg. ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 65.5; ^{1}H NMR (250.1 MHz, $CDCl_3$) δ 0.90-1.80 (m, 10H, CH_2), 6.23 (dd, 1H, $^2J_{PH}$ = 31.5 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.45 (d, 1H, $^2J_{PH}$ = 15.4 Hz, CHOH), 7.04 (dd, 1H, $^3J_{PH}$ = 43.2 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.44-7.45

(m, 1H, CH), 7.66-7.70 (m, 1H, CH), 7.91-7.98 (m, 1H, CH), 8.24 (d, 1H, $^3J_{HH}$ = 8.2 Hz, CH). ^{13}C NMR (50.3 MHz, CD_3OD) δ 21.7 (s, CH_2), 21.8 (s, CH_2), 24.5 (s, CH_2), 34.5 (d, J_{PC} = 3.7 Hz, CH_2), 36.9 (s, CH_2), 71.4 (d, $^1J_{PC}$ = 120.3 Hz, CHOH), 92.8 (d, $^2J_{PC}$ = 1.5 Hz, C), 116.5 (d, $^1J_{PC}$ = 109.3 Hz, PCH), 124.9 (d, J_{PC} = 2.2 Hz, CH), 128.2 (d, J_{PC} = 3.7 Hz, CH), 128.9 (d, J_{PC} = 5.1 Hz, CH), 134.9 (d, J_{PC} = 2.9 Hz, CH), 136.3 (s, C), 146.9 (d, J_{PC} = 5.1 Hz, C), 157.0 (d, $^2J_{PC}$ = 14.2 Hz, CH).

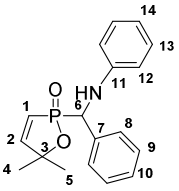


$C_{15}H_{18}NO_3P$
MW 323.28, 770 mg, yield 63%, *de* = 14 %.

4.7. General procedure for addition of xaphospholene 9a to imines (Kabachnik Fields reaction activated by $LiClO_4$)

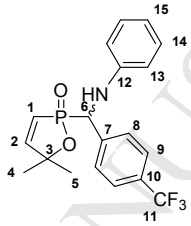
In a 25 mL Schlenk tube and under nitrogen, were placed a solution of lithium perchlorate (4.17 mmol) in diethyl ether (2.1 mL), aldehyde (1 eq.) and amine (1 eq.) in diethyl ether (10 mL). After 15 minutes of stirring at room temperature, a solution of oxaphospholene **9a** (3.79 mmol, 1 eq.) in diethyl ether (2 mL) is added and the resulting mixture was stirred for 30 minutes. Then water (20 mL) was added and the reaction mixture was directly extracted with ethyl acetate. The organic layers were dried over sodium sulfate, filtered and evaporated under vacuum.

*4.7.1. 5,5-dimethyl-2-(phenyl(phenylamino)methyl)-5**H**-1,2-oxaphosphole 2-oxide **(15a). 15a was purified by** trituration of the solid in ethyl acetate afforded 630 mg of white crystals, 59% yield, de = 1% (The low de did not allow to attribute NMR signals to the respective diastereomers).* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 59.1 (49%, *dia 1*), 62.1 (51%, *dia 2*). ^{1}H NMR (250.1 MHz, $CDCl_3$) δ 1.21 (s, 3H, CH_3), 1.33 (s, 3H, CH_3) 1.53 (s, 3H, CH_3), 1.56 (s, 3H, CH_3), 4.72 (d, 1H, $^2J_{PH}$ = 14.1 Hz, CHN), 4.78 (d, 1H, $^2J_{PH}$ = 17.0 Hz, CHN), 5.85 (dd, 1H, $^2J_{PH}$ = 32.7 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.20 (dd, 1H, $^2J_{PH}$ = 33.1 Hz, $^3J_{HH}$ = 8.2 Hz, PCH), 6.61-6.75 (m, 3H, H_{Ar}), 6.86 (dd, 1H, $^3J_{PH}$ = 40.6 Hz, $^3J_{HH}$ = 8.2 Hz, CH), 6.90 (dd, 1H, $^3J_{PH}$ = 40.6 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.08-7.50 (m, 7H, H_{Ar}). ^{13}C NMR (100.6 MHz, CD_3OD) δ 24.4 (d, J_{PC} = 3.7 Hz, CH_3), 26.7 (d, J_{PC} = 3.7 Hz, CH_3), 28.5 (s, CH_3), 28.6 (s, CH_3), 59.5 (d, $^1J_{PC}$ = 104.2 Hz, CHN), 59.6 (d, $^1J_{PC}$ = 102.9 Hz, CHN), 90.3 (d, $^2J_{PC}$ = 3.1 Hz, C), 90.4 (d, $^2J_{PC}$ = 3.1 Hz, C), 114.2 (s, CH), 114.2 (s, CH), 117.5 (d, $^1J_{PC}$ = 107.4 Hz, PCH), 117.6 (d, $^1J_{PC}$ = 104.8 Hz, PCH), 118.5 (s, CH), 118.7 (s, CH), 127.8 (d, J_{PC} = 4.9 Hz, CH), 127.9 (d, J_{PC} = 2.8 Hz, CH), 128.0 (d, J_{PC} = 3.0 Hz, CH), 128.1 (d, J_{PC} = 3.7 Hz, CH), 128.7 (d, J_{PC} = 2.9 Hz, CH), 128.9 (d, J_{PC} = 2.9 Hz, CH), 129.1 (s, CH), 129.2 (s, CH), 135.4 (d, J_{PC} = 4.9 Hz, C), 136.0 (d, J_{PC} = 2.5 Hz, C), 146.5 (d, J_{PC} = 13.5 Hz, C), 146.5 (d, J_{PC} = 13.5 Hz, C), 157.3 (d, $^2J_{PC}$ = 11.0 Hz, CH), 157.4 (d, $^2J_{PC}$ = 11.0 Hz, CH). MS (FAB) m/z for $C_{18}H_{20}NO_2P$ $(M+H)^+$, 314 (100%). IR (NaCl): 3295, 3309, 1609, 1537, 1502, 1452, 1311, 1223, 1193, 1165, 976, 945, 863, 760, 702, 691, 555, 464.



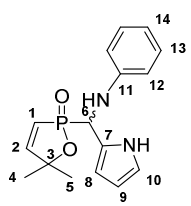
$C_{18}H_{20}NO_2P$
MW 313.34, 630 mg, yield 59%, *de* = 1 %.

*4.7.2. 5,5-Dimethyl-2-((phenylamino)(4-(trifluoromethyl)phenyl) methyl)-5H-1,2-oxaphosphole 2-oxide **(15b)**. **15b** was purified by column chromatography (dichloromethane/methanol 99:1) affording 855 mg of a mixture of two diastereomers as a white solid, 59% yield, de = 6% (The low de did not allow to attribute NMR signals to the respective diastereomers).* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 58.3 (47%, *dia 1*), 61.1 (53%, *dia 2*). ^{19}F NMR (188.3 MHz, $CDCl_3$) δ -65.2; ^{1}H NMR (400.1 MHz, $CDCl_3$) δ 1.30 (s, 3H, CH_3), 1.36 (s, 3H, CH_3), 1.55 (s, 3H, CH_3), 1.58 (s, 3H, CH_3), 4.78 (d, 1H, $^2J_{PH}$ = 16.8 Hz, CHN), 4.87 (d, 1H, $^2J_{PH}$ = 19.6 Hz, CHN), 5.90 (dd, 1H, $^2J_{PH}$ = 33.4 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.20 (dd, 1H, $^2J_{PH}$ = 33.6 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.55-6.80 (m, 3 H_{Ar}), 6.95 (dd, 1H, $^3J_{PH}$ = 41.0 Hz, $^3J_{HH}$ = 8.2 Hz, CH), 7.05 (dd, 1H, $^3J_{PH}$ = 41.1 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.11-7.74 (m, 7H_{Ar} + NH). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 26.5 (d, $^3J_{PC}$ = 3.7 Hz, CH_3), 26.6 (d, $^3J_{PC}$ = 4.3 Hz, CH_3), 28.5 (s, CH_3), 28.5 (s, CH_3), 59.1 (d, $^1J_{PC}$ = 101.1 Hz, CHN), 59.3 (d, $^1J_{PC}$ = 103.6 Hz, CHN), 91.2 (d, $^2J_{PC}$ = 3.7 Hz, C), 91.3 (d, $^2J_{PC}$ = 3.7 Hz, C), 114.1 (s, CH), 114.2 (s, CH), 117.1 (d, $^1J_{PC}$ = 107.3 Hz, PCH), 117.3 (d, $^1J_{PC}$ = 104.5 Hz, PCH), 118.9 (s, CH), 119.0 (s, CH), 124.1 (qd, $^1J_{CF}$ = 272 Hz, J_{PC} = 1.2 Hz, CF_3), 124.2 (qd, $^1J_{CF}$ = 272 Hz, J_{PC} = 1.2 Hz, CF_3), 125.3-125.7 (m, CH), 125.8-125.9 (m, CH), 128.2-128.3 (m, CH), 129.24 (s, CH), 129.28 (s, CH), 130.2 (qd, J_{CF} = 32.5 Hz, J_{PC} = 3.1 Hz, C), 130.3 (qd, J_{CF} = 32.5 Hz, J_{PC} = 3.7 Hz, C), 131.6 (d, J_{PC} = 2.9 Hz, C), 146.5 (d, J_{PC} = 4.8 Hz, C), 146.5 (d, J_{PC} = 3.7 Hz, C), 158.1 (d, $^2J_{PC}$ = 11.0 Hz, CH), 159.3 (d, $^2J_{PC}$ = 11.0 Hz, CH). IR (NaCl): 3300, 2982, 1603, 1500, 1463, 1325, 1298, 1164, 1123, 1067, 1017, 955, 924, 845, 749. Elementary analysis: calcd for $C_{19}H_{19}F_3NO_2P$, 59.85%C, 5.02%H; found, 59.82%C, 4.91%H.



$C_{19}H_{19}F_3NO_2P$
MW 381.33, 855 mg, yield 59%, white solid, melting point: 112°C. *de* = 6 %.

*4.7.3. 5,5-Dimethyl-2-((phenylamino)(4-(trifluoromethyl)phenyl) methyl)-5H-1,2-oxaphosphole 2-oxide **(15c)**. **15c** was purified by recrystallization in diethyl ether affording 420 mg of a mixture of two diastereomers as a red solid, 37% yield, de = 12%.* ^{31}P NMR (162.0 MHz, $CDCl_3$): δ 60.8 (44%, *dia 1*), 61.9 (56%, *dia 2*). ^{1}H NMR (400.1 MHz, $CDCl_3$) δ *dia 1:* 1.26 (s, 3H, CH_3), 1.54 (s, 3H, CH_3), 4.92 (d, 1H, $^2J_{PH}$ = 15.2 Hz, CHN), , 6.12-6.14 (m, 2H, H_{Ar}), 6.14 (dd, 1H, $^2J_{PH}$ = 33.3 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.69-6.77 (m, 4H, H_{Ar}), 7.02 (dd, 1H, $^3J_{PH}$ = 41.1 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.11-7.17 (m, 2H, H_{Ar}), 9.64 (s, 1H, NH). *dia 2:* 1.46 (s, 3H, CH_3), 1.56 (s, 3H, CH_3), 4.94 (d, 1H, $^2J_{PH}$ = 15.7 Hz, CHN), 5.95 (dd, 1H, $^3J_{PH}$ = 32.9 Hz, $^3J_{HH}$ = 8.2 Hz, PCH), 6.12-6.14 (m, 2H, H_{Ar}), 6.69-6.77 (m, 4H, H_{Ar}), 6.92 (dd, 1H, $^2J_{PH}$ = 40.4 Hz, $^3J_{HH}$ = 8.2 Hz, CH), 7.11-7.17 (m, 2H, H_{Ar}), 9.69 (s 1H, NH). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ *dia 1:* 26.6 (d, $^3J_{PC}$ = 3.7 Hz, CH_3), 28.5 (s, CH_3), 53.4 (d, $^1J_{PC}$ = 110.0 Hz, CHN), 90.3 (d, $^2J_{PC}$ = 2.4 Hz, C), 107.9 (d, J_{PC} = 7.3 Hz, CH), 108.2 (d, J_{PC} = 1.8 Hz, CH), 114.3 (s, CH), 116.8 (d, $^1J_{PC}$ = 103.0 Hz, PCH), 119.0-119.1 (m, CH), 119.0 (s, CH), 124.9 (d, J_{PC} = 3.1 Hz, C), 129.3 (s, CH), 146.8 (d, J_{PC} = 9.2 Hz, C), 158.2 (d, $^2J_{PC}$ = 11.0 Hz, CH). *dia 2:* 26.5 (d, J_{PC} = 3.7 Hz, CH_3), 28.6 (s, CH_3), 53.6 (d, $^1J_{PC}$ = 111.5 Hz, CHN), 90.6 (d, $^2J_{PC}$ = 2.5 Hz, C), 107.5 (d, J_{PC} = 6.7 Hz, CH), 108.2 (d, J_{PC} = 3.1 Hz, CH), 114.1 (s, CH), 117.6 (d, $^1J_{PC}$ = 104.8 Hz, PCH), 119.0-119.1 (m, CH), 119.0 (s, CH), 125.1 (d, J_{PC} = 3.1 Hz, C), 129.2 (s, CH), 146.5 (d, J_{PC} = 9.2 Hz, C), 157.2 (d, $^2J_{PC}$ = 11.0 Hz, CH). IR (NaCl): 3291, 3115, 2991, 1603, 1498, 1458, 1319, 1211, 1160, 956, 934, 814, 748, 691, 691. HRMS (FAB) m/z calcd for $C_{16}H_{20}N_2O_2P$ $(M+H)^+$, 303.1262; found, 303.1278.

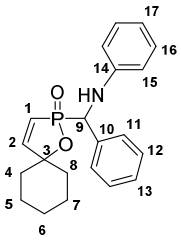


$C_{16}H_{19}N_2O_2P$
MW 302.31, 420 mg, yield 37%, red solid, melting point: 138°C. *de* = 12 %.

4.8. General procedure for addition of oxaphospholene 9b to imines (Kabachnik Fields reaction)

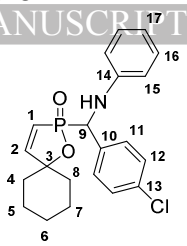
In a 25 mL Schlenk tube and under nitrogen, were placed a solution of aldehyde (1 eq.) and amine (1 eq.) in diethyl ether (10 mL). After stirring at room temperature, a solution of oxaphospholene **9b** (1.45 mmol, 1 eq.) in diethyl ether (2 mL) was added. After 12 h of stirring, the precipitate was filtered, washed with cold diethyl ether and dried under vacuum.

4.8.1. 2-(Phenyl(phenylamino)methyl)-1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**16a**). *White solid*, 0.430 g, 85% yield, de = 14%. ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 59.5 (43%, *dia 1*), 62.5 (57%, *dia 2*). ^{1}H NMR (400.13 MHz, $CDCl_3$) δ *dia 1:* 1.14-1.85 (m, 10H, CH_2), 4.71 (d, 1H, $^{2}J_{PH}$ = 15.6 Hz, CHN), 6.19 (dd, 1H, $^{2}J_{PH}$ = 33.6 Hz, $^{3}J_{HH}$ = 8.4 Hz, PCH), 6.50-6.63, (m, 2H, H_{Ar}), 6.99 (dd, 1H, $^{3}J_{PH}$ = 40.5 Hz, $^{3}J_{HH}$ = 8.4 Hz, CH), 7.09-7.14 (m, 2H, H_{Ar}), 7.27-7.29 (m, 1H, H_{Ar}), 7.31-7.35 (m, 2H, H_{Ar}), 7.41-7.43, (m, 3H, H_{Ar}); *dia 2:* 1.14-1.85 (m, 10H, CH_2), 4.78 (d, 1H, $^{2}J_{PH}$ = 19.3 Hz, CHN), 5.87 (dd, 1H, $^{2}J_{PH}$ = 33.6 Hz, $^{3}J_{HH}$ = 8.3 Hz, PCH), 6.50-6.63, (m, 2H, H_{Ar}), 6.90 (dd, 1H, $^{3}J_{PH}$ = 40.5 Hz, $^{3}J_{HH}$ = 8.4 Hz, CH), 7.09-7.14 (m, 2H, H_{Ar}), 7.27-7.29 (m, 1H, H_{Ar}), 7.31-7.35 (m, 2H, H_{Ar}), 7.41-7.43 (m, 3H, H_{Ar}); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ *dia 1:* 21.8 (s, CH_2), 22.0 (s, CH_2), 24.6 (s, CH_2), 35.1 (d, J_{PC} = 2.9 Hz, CH_2), 36.9 (s, CH_2), 59.7 (d, $^{1}J_{PC}$ = 103.9 Hz, CHN), 92.3 (d, $^{2}J_{PC}$ = 2.9 Hz, C), 114.2 (s, CH), 117.8 (d, $^{1}J_{PC}$ = 105.4 Hz, PCH), 118.6 (s, CH), 127.91 (s, CH), 128.1 (d, J_{PC} = 3.6 Hz, CH), 128.7 (d, J_{PC} = 2.9 Hz, CH), 129.1 (s, CH), 135.5 (d, J_{PC} = 5.1 Hz, C), 146.6 (d, J_{PC} = 13.2 Hz, C), 157.4 (d, $^{2}J_{PC}$ = 11.7 Hz, CH), *dia 2:* 21.9 (s, CH_2), 22.0 (s, CH_2), 24.7 (s, CH_2), 35.3 (d, J_{PC} = 3.7 Hz, CH_2), 37.0 (s, CH_2), 59.8 (d, $^{1}J_{PC}$ = 102.5 Hz, CHN), 92.2 (d, $^{2}J_{PC}$ = 2.9 Hz, C), 114.2 (s, CH), 117.7 (d, $^{1}J_{PC}$ = 107.6 Hz, PCH), 118.4 (s, CH), 127.8 (s, CH), 127.91 (d, J_{PC} = 5.1 Hz, CH), 128.8 (d, J_{PC} = 2.9 Hz, CH), 129.1 (s, CH), 136.1 (d, J_{PC} = 2.2 Hz, C), 146.6 (d, J_{PC} = 13.2 Hz, C), 156.4 (d, $^{2}J_{PC}$ = 11.0 Hz, CH). HRMS (FAB) m/z calcd for $C_{21}H_{25}NO_2P$ $(M+H)^+$, 354.1623; found, 354.1634. IR (NaCl): 3402, 3295, 2940, 1600, 1499, 1450, 1323, 1230, 957, 941, 898, 881, 743, 695, 596, 553.



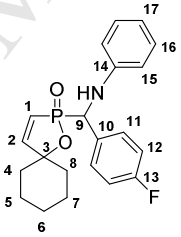
$C_{21}H_{24}NO_2P$
MW 353.40, 430 mg, yield 85%, white solid, melting point: 173°C, *de* = 14 %.

*4.8.2. 2-((4-Chlorophenyl)(phenylamino)methyl)-1-oxa-2-phosphaspiro[4.5]-dec-3-ene 2-oxide (**16b**). White solid, 0.426g, 76% yield, de = 90%.* ^{31}P NMR NMR (162.0 MHz, $CDCl_3$): δ 57.5 (5%, *dia 1*), 61.1 (95%, *dia 2*). ^{1}H NMR (400.1 MHz, $CDCl_3$) δ (ppm): 1.14-1.77 (m, 10H, CH_2), 4.66 (d, 1H, $^{2}J_{PH}$ = 18.8 Hz, CHN), 5.79 (dd, 1H, $^{2}J_{PH}$ = 33.1 Hz, $^{3}J_{HH}$ = 8.4 Hz, PCH), 6.47-6.49, (m, 2H, H_{Ar}), 6.65-6,68, (m, 1H, H_{Ar}), 6.87 (dd, 1H, $^{3}J_{PH}$ = 40.9 Hz, $^{3}J_{HH}$ = 8.4 Hz, CH), 7.01-7.05 (m, 2H, H_{Ar}), 7.20-7.27 (m, 4H, H_{Ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 22.0 (s, CH_2), 24.1 (s, CH_2), 24.6 (s, CH_2), 34.4 (d, J_{PC} = 3.7 Hz, CH_2), 37.05 (s, CH_2), 59.1 (d, $^{1}J_{PC}$ = 101.7 Hz, CHN), 92.3 (d, $^{2}J_{PC}$ = 2.2 Hz, C), 114.2 (s, CH), 117.5 (d, $^{1}J_{PC}$ = 107.6 Hz, PCH), 118.8 (s, CH), 129.0 (d, J_{PC} = 2.9 Hz, CH), 129.1 (s, CH), 129.1 (d, J_{PC} = 5.1 Hz, CH), 133.0 (d, J_{PC} = 2.9 Hz, C), 134.8 (d, J_{PC} = 2.2 Hz, C), 146.3 (d, J_{PC} = 13.2 Hz, C), 156.8 (d, $^{2}J_{PC}$ = 11.0 Hz, CH). HRMS (FAB) m/z calcd for $C_{21}H_{24}ClNO_2P$ $(M+H)^+$, 388.1233; found, 388.1200; IR (NaCl): 3306, 2932, 2852, 1605, 1533, 1499, 1485, 1440, 1406, 1316, 1264, 1231, 1189, 1084, 1015, 953, 936, 907, 891, 835, 746, 692, 597.



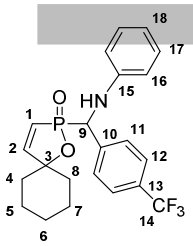
$C_{21}H_{23}ClNO_2P$
MW 387.84, 426 mg, yield 76%, white solid, melting point: 189°C, *de* = 90 %.

*4.8.3. 2-((4-Fluorophenyl)(phenylamino)methyl)-1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**16c**). White solid, 0.460g, 85% yield, de = 11%.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 57.8 (53%, *dia 1*), 60.9 (47%, *dia 2*). ^{19}F NMR (188.3 MHz, $CDCl_3$) δ (ppm)*:* -114.3 (53%, *dia 1*), -114.7 (47%, *dia 2*). ^{1}H (400.1 MHz, $CDCl_3$) δ (ppm): *dia 1:* 1.14-1.77 (m, 10H, CH_2), 4.67 (d, 1H, $^{2}J_{PH}$ = 19.0 Hz, CHN), 6.11 (dd, 1H, $^{2}J_{PH}$ = 33.6 Hz, $^{3}J_{HH}$ = 8.4 Hz, PCH), 6.95 (dd, 1H, $^{3}J_{PH}$ = 40.5 Hz, $^{3}J_{HH}$ = 8.4 Hz, CH), 7.01-7.06 (m, 4H, H_{Ar}), 7.27-7.29 (m, 5H, H_{Ar}); *dia 2:* 1.14-1.77 (m, 10H, CH_2), 4.58 (d, 1H, $^{2}J_{PH}$ = 15.6 Hz, CHN), 5.78 (dd, 1H, $^{2}J_{PH}$ = 33.2 Hz, $^{3}J_{HH}$ = 8.4 Hz, PCH), 7.01-7.06 (m, 4H, H_{Ar}), 7.27-7.29 (m, 5H, H_{Ar}); ^{13}C NMR (100.6 MHz, $CDCl_3$) δ *dia 1:* 21.8 (s, CH_2), 22.0 (s, CH_2), 24.6 (s, CH_2), 35.4 (s, CH_2), 36.9 (s, CH_2), 59.0 (d, $^{1}J_{PC}$ = 104.6 Hz, CHN), 92.4 (d, $^{2}J_{PC}$ = 2.9 Hz, C), 114.3 (s, C), 115.7 (dd, J_{PC} = 2.0 Hz, J_{CF} = 17.6 Hz, C), 117.5 (d, $^{1}J_{PC}$ = 107.5 Hz, PCH), 118.8 (s, CH), 129.2 (s, CH), 129.4-129.5 (m, CH), 146.3 (s, C), 157.5 (d, $^{2}J_{PC}$ = 12.0 Hz, CH). *dia 2:* 21.9 (s, CH_2), 22.0 (s, CH_2), 24.7 (s, CH_2), 35.4 (s, CH_2), 37.0 (s, CH_2), 58.9 (d, $^{1}J_{PC}$ = 103.2 Hz, CHN), 92.1 (d, $^{2}J_{PC}$ = 4.4 Hz, C), 114.2 (s, ^{5}C), 115.9 (dd, J_{CF} = 17.6 Hz, J_{PC} = 2.9 Hz, C), 117.8 (d, $^{1}J_{PC}$ = 105.4 Hz, PCH), 118.7 (s, CH), 129.1 (s, CH), 129.4-129.5 (m, CH), 146.4 (s, CH), 156.7 (d, $^{2}J_{PC}$ = 11.7 Hz, CH). HRMS (FAB) m/z calcd for $C_{21}H_{24}FNO_2P$ $(M+H)^+$, 372.1529; found, 372.1535. IR (NaCl): 3313, 3055, 2936, 1603, 1535, 1507, 1490, 1439, 1318, 1277, 1224, 955, 902, 893, 842, 812, 745, 691, 564.

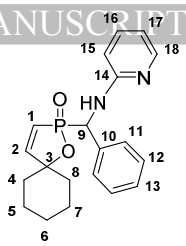


$C_{21}H_{23}FNO_2P$
MW 371.89, 460 mg, yield 85%, white solid, melting point: 160°C, *de* = 11 %.

*4.8.4. 2-((Phenylamino)(4-(trifluoromethyl)phenyl)methyl)-1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**16d**). White solid, 0.395g, 65% yield, de > 95%.* ^{31}P NMR (101.2 MHz, DMSO-D_6): δ 59.9; ^{19}F NMR (188.3 MHz, $CDCl_3$) δ (ppm)*:* -61.8; ^{1}H NMR (250.1 MHz, DMSO-D_6) δ (ppm): 1.31-1.81 (m, 10H, CH_2), 4.89 (d, 1H, $^{2}J_{PH}$ = 19.7 Hz, CHN), 5.95 (dd, 1H, $^{2}J_{PH}$ = 33.7 Hz, $^{3}J_{HH}$ = 8.4 Hz, PCH), 6.60-6.63 (m, 2H, H_{Ar}), 6.75-6.89 (m, 2H, H_{Ar}), 6.97 (dd, 1H, $^{3}J_{PH}$ = 40.8 Hz, $^{3}J_{HH}$ = 8.4 Hz, CH), 7.11-7.14 (m, 2H, H_{Ar}), 7.60-7.64 (m, 2H, H_{Ar}). ^{13}C NMR (100.6 MHz, DMSO-D_6) δ 22.0 (s, 2 CH_2), 24.6 (s, CH_2), 35.3 (d, J_{PC} = 2.9 Hz, CH_2), 37.0 (s, CH_2), 59.3 (d, $^{1}J_{PC}$ = 101.0 Hz, CHN), 91.5 (d, $^{2}J_{PC}$ = 2.9 Hz, C), 114.2 (s, CH), 117.2 (d, $^{1}J_{PC}$ = 107.6 Hz, PCH), 118.9 (s, CH), 124.3 (q, $^{1}J_{CF}$ = 255.1 Hz, CF_3), 125.9 (m, CH), 128.2 (d, J_{PC} = 5.2 Hz, CH), 129.2 (s, CH), 130.7 (q, J_{CF} = 29.9 Hz, C), 131.6 (d, J_{PC} = 2.9 Hz, C), 150.7 (d, J_{PC} = 13.2 Hz, C), 157.2 (d, $^{2}J_{PC}$ = 11.0 Hz, CH). HRMS (FAB) m/z calcd for $C_{22}H_{24}F_3NO_2P$ $(M+H)^+$, 422.1497; found, 422.1497. IR (NaCl): 3304, 2941, 1602, 1542, 1499, 1415, 1330, 1276, 1232, 1157, 1119, 1067, 1016, 939, 909, 886, 842, 743, 687.

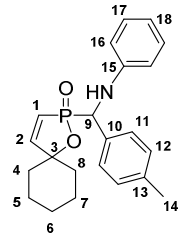


$C_{22}H_{23}F_3NO_2P$
MW 421.40, 395 mg, yield 65%, white solid, melting point: 206°C, *de* > 95 %.



$C_{20}H_{23}N_2O_2P$
MW 354.39, 355 mg, yield 75%, white solid, melting point: 181°C, *de* = 50%.

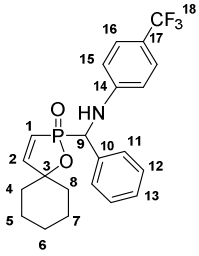
*4.8.5. 2-((Phenylamino)(p-tolyl)methyl)-1-oxa-2-phosphaspiro[4.5] dec-3-ene 2-oxide (**16e**). White solid, 0.425g, 80% yield, de > 95%.* ^{31}P NMR (101.2 MHz, DMSO-D_6): δ 60.2; ^{1}H NMR (400.1 MHz, DMSO-D_6) δ 0.77-1.6 (m, 10H, 5 CH_2), 2.17 (s, 3H, CH_3), 4.88 (dd, *J* = 9.0 Hz, $^2J_{PH}$ = 21 Hz, 1H, CHN), 6.05 (dd, $^2J_{PH}$ = 34.0 Hz, $^3J_{HH}$ = 8.4 Hz, 1H, PCH), 6.44-6.47 (m, 1H, H_{Ar}), 6.62-6.64 (m, 2H, H_{Ar}), 6.91-6.95 (m, 2H, H_{Ar}), 7.01-7.03 (m, 2H, H_{Ar}), 7.05 (dd, $^3J_{PH}$ = 40.1 Hz, $^3J_{HH}$ = 8.4 Hz, 1H, CH), 7.23-7.21 (m, 2H, H_{Ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 20.6 (s, CH_3), 21.6 (s, CH_2), 21.6 (s, CH_2), 24.2 (s, CH_2), 33.7 (s, CH_2), 36.5 (s, CH_2), 57.8 (d, $^1J_{PC}$ = 103.9 Hz, CHN), 91.2 (d, $^2J_{PC}$ = 2.9 Hz, C), 113.3 (s, C), 116.7 (s, CH), 117. 5 (d, $^1J_{PC}$ = 101.0 Hz, PCH), 128.2 (d, J_{PC} = 5.1 Hz, CH), 128.6 (d, J_{PC} = 2.9 Hz, CH), 134.0 (s, C), 136.5 (d, J_{PC} = 2.9 Hz, C), 139.7 (s CH), 147.2 (d, $^2J_{PC}$ = 12.4 Hz, C), 156.5 (d, $^2J_{PC}$ = 10.2 Hz, CH). HRMS (FAB) m/z calcd for $C_{22}H_{26}NO_2P$ $(M+H)^+$, 368.1779; found, 368.1765. IR (NaCl): 3301, 3052, 2934, 2859, 1603, 1541, 1499, 1445, 1318, 1276, 1265, 1232, 1202, 1191, 948, 938, 909, 892, 758, 742, 689, 596, 550.



$C_{22}H_{25}NO_2P$
MW 367.43, 425 mg, yield 80%, white solid, melting point: 216°C, *de* > 95%.

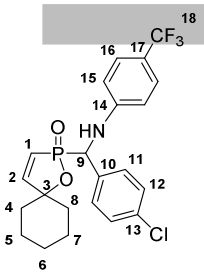
*4.8.6. 2-(Phenyl(pyridin-2-ylamino)methyl)-1-oxa-2-phospha-spiro[4.5]dec-3-ene 2-oxide (**16f**). White solid, 0.355g, 75% yield, de = 50%.* ^{31}P NMR (101.2 MHz, DMSO-D_6): δ 60.6 (75%, *dia 1*), 61.8 (25%, *dia 2*). ^{1}H NMR (400.1 MHz, DMSO-D_6) δ (ppm): *dia 1:* 0.77-1.6 (m, 10H, CH_2), 5.73 (d, 1H, $^2J_{PH}$ = 17.0 Hz, CHN), 6.23 (dd, 1H, $^2J_{PH}$ = 34.2 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 7.15 (dd, 1H, $^3J_{PH}$ = 39.5 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.2-7.6 (m, 8H, H_{Ar}), 8.05 (m, 1H, ^{18}CH). *dia 2:* 0.77-1.6 (m, 10H, CH_2), 5.70 (d, 1H, $^2J_{PH}$ = 16.8 Hz, CHN), 6.07 (dd, 1H, $^2J_{PH}$ = 34.2 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 7.2-7.6 (m, 8H, H_{Ar}), 7.10 (dd, 1H, $^3J_{PH}$ = 40.1 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 8.05 (m, 1H, CH). ^{13}C NMR (100.6 MHz, DMSO-D_6) δ *dia 1:* 21.4 (s, 2 CH_2), 24.1 (s, CH_2), 33.7 (s, CH_2), 36.5 (s, CH_2), 55.1 (d, $^1J_{PC}$ = 105.4 Hz, CH), 91.2 (d, J_{PC} = 2.9 Hz, C), 109.2 (s, CH), 116.7 (s, CH), 118.2 (d, $^1J_{PC}$ = 100.3 Hz, PCH), 127.2 (d, J_{PC} = 2.9 Hz, CH), 128.0 (d, J_{PC} = 2.2 Hz, CH), 128.1 (d, J_{PC} = 4.4 Hz, CH), 136.7 (s, CH), 134.0 (s, CH), 136.5 (d, J_{PC} = 2.9 Hz, C), 129.7 (CH), 146.9 (s, CH), 156.8 (d, $^2J_{PC}$ = 11.0 Hz, CH), 157.3 (d, J_{PC} = 7.3 Hz, C). *dia 2:* 21.5 (s, 2 CH_2), 24.2 (s, CH_2), 33.8 (s, CH_2), 36.7 (s, CH_2), 55.2 (d, $^1J_{PC}$ = 106.2 Hz, CHN), 91.2 (d, $^2J_{PC}$ = 2.9 Hz, C), 109.2 (s, CH), 116.9 (s, CH), 118.1 (d, $^1J_{PC}$ = 101.1 Hz, PCH), 127.3 (d, J_{PC} = 2.9 Hz, CH), 127.8 (d, J_{PC} = 2.2 Hz, CH), 128.2 (d, J_{PC} = 4.4 Hz, CH), 136.7 (s, CH), 134.0 (s, CH), 136.6 (d, J_{PC} = 2.9 Hz, C), 129.7 (s, CH), 146.9 (s, CH), 156.8 (d, $^2J_{PC}$ = 10.7 Hz, CH), 157.2 (d, J_{PC} = 7.3 Hz, C). HRMS (FAB) m/z calcd for $C_{20}H_{24}N_2O_2P$ $(M+H)^+$, 355.1575; found, 355.1576. IR (NaCl): 3277, 3200, 2933, 1609, 1524, 1482, 1448, 1419, 1320, 1199, 1152, 1024, 943, 906, 741, 698, 559.

*4.8.7. 2-(Phenyl((4-(trifluoromethyl)phenyl)amino)methyl)-1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**16g**). White solid, 0.430g, 70% yield, de = 50%.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 58.9 (25%, *dia 1*), 60.7 (75%, *dia 2*). ^{19}F NMR (188.3 MHz, $CDCl_3$) δ (ppm)*:* -61.8; ^{1}H NMR (250.1 MHz, $CDCl_3$) δ (ppm): *dia 1:* 0.67-1.64 (m, 10H, CH_2), 5.11 (d, 1H, $^2J_{PH}$ = 21.6 Hz, CHN), 6.33 (dd, 1H, $^2J_{PH}$ = 36.3 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.99 (dd, 1H, $^3J_{PH}$ = 35.3 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 6.87-6.93, (m, 2H, H_{Ar}), 7.20-7.46 (m, 8H, H_{Ar}); *dia 2:* 0.67-1.64 (m, 10H, CH_2), 5.20 (d, $^2J_{PH}$ = 20.1 Hz, 1H, CHN), 6.19 (dd, 1H, $^2J_{PH}$ = 34.8 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.87-6.93, (m, 2H, H_{Ar}), 7.20-7.46 (m, 8H, H_{Ar} + CH). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ *dia 1:* 21.4 (s, CH_2), 21.5 (s, CH_2), 24.1 (s, CH_2), 34.1 (s, CH_2), 36.4 (s, CH_2), 57.5 (d, $^1J_{PC}$ = 103.9 Hz, CHN), 91.5 (d, $^2J_{PC}$ = 2.9 Hz, C), 112.9 (s, CH), 116.5 (q, J_{CF} = 31.5 Hz, C), 117.9 (d, $^1J_{PC}$ = 102.4 Hz, PCH), 125.9 (m, CH), 127.3 (q, $^1J_{CF}$ = 270.1 Hz, CF_3), 127.4 (d, J_{PC} = 2.2 Hz, CH), 128.1-128.2 (m, CH), 128.2 (d, J_{PC} = 4.4 Hz, CH), 130.3 (q, J_{CF} = 5.1 Hz, CH), 131.6 (d, J_{PC} = 2.9 Hz, C), 150.7 (dd, J_{PC} = 11.0 Hz, J_{CF} = 2.2 Hz, C), 157.3 (d, $^2J_{PC}$ = 10.2 Hz, CH), *dia 2:* 21.5 (s, CH_2), 21.6 (s, CH_2), 24.1 (s, CH_2), 33.4 (s, CH_2), 36.4 (s, CH_2), 57.7 (d, $^1J_{PC}$ = 103.2 Hz, CHN), 91.5 (d, $^2J_{PC}$ = 2.9 Hz, C), 112.6 (s, CH), 116.5 (q, J_{CF} = 31.5 Hz, C), 117.2 (d, $^1J_{PC}$ = 101.0 Hz, PCH), 125.90 (m, CH), 127.3 (q, $^1J_{CF}$ = 270.1 Hz, CF_3), 128.0 (d, J_{PC} = 3.7 Hz, CH), 128.1-128.2 (m, CH), 128.4 (d, J_{PC} = 5.1 Hz, CH), 130.3 (q, $^4J_{CF}$ = 5.1 Hz, CH), 131.7 (d, J_{PC} = 2.9 Hz, C), 132.8 (d, J_{PC} = 2.9 Hz, C), 150.5 (d, J_{PC} = 11.0 Hz, C), 156.9 (d, $^2J_{PC}$ = 10.2 Hz, CH). HRMS (FAB) m/z calcd for $C_{22}H_{24}F_3NO_2P$ $(M+H)^+$, 422.1497; found, 422.1502. IR (NaCl): 3280, 3191, 3059, 2941, 1617, 1549, 1452, 1331, 1229, 1202, 1160, 1108, 1063, 950, 940, 831, 808, 757, 695, 565.

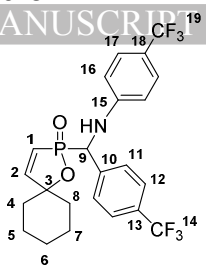


$C_{22}H_{23}F_3NO_2P$
MW 421.40, 430 mg, yield 70%, white solid, melting point: 216°C, *de* = 50%.

*4.8.8. 2-((4-Chlorophenyl)((4-(trifluoromethyl)phenyl)amino)-methyl)-1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**16h**). White solid, 0.430g, 65% yield, de = 95%.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 61.0; ^{19}F NMR (188.3 MHz, $CDCl_3$) δ (ppm)*:* -61.7; ^{1}H NMR (250.1 MHz, $CDCl_3$) δ 1.20-1.84 (m, 10H, CH_2), 4.75, (d, 1H, $^2J_{PH}$ = 19.7 Hz, CHN), 5.86 (dd, 1H, $^2J_{PH}$ = 33.3 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.57-6.60, (m, 2H, H_{Ar}) 6.97 (dd, 1H, $^3J_{PH}$ = 41.1 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.28-7.33 (m, 6H, H_{Ar}). ^{13}C NMR (62.9 MHz, $CDCl_3$) δ 22.4 (s, CH_2), 24.1 (s, CH_2), 25.0 (s, CH_2), 34.4 (s, CH_2), 37.4 (s, CH_2), 54.7 (d, $^1J_{PC}$ = 103.2 Hz, CH), 92.5 (s, C), 113.6 (s, CH), 117.2 (d, $^1J_{PC}$ = 100.3 Hz, PCH), 126.9 (m, CH), 127.9 (q, $^2J_{CF}$ = 28.3 Hz, C), 128.2 (q, $^1J_{CF}$ = 215.9 Hz, CF_3), 130.0-130.1 (m, 2 × CH), 131.0 (d, $^3J_{PC}$ = 4.8 Hz, CH), 133.0 (d, $^2J_{PC}$ = 2.9 Hz, C), 136.6 (s, C), 151.2 (d, $^2J_{PC}$ = 9.6 Hz, C), 158.1 (d, $^2J_{PC}$ = 10.1 Hz, CH). HRMS (FAB) m/z calcd for $C_{22}H_{23}ClF_3NO_2P$ $(M+H)^+$, 456.1107; found, 456.1112. IR (NaCl): 3288, 2932, 1618, 1548, 1419, 1332, 1229, 1107, 1064, 936, 908, 887, 827, 758, 628.

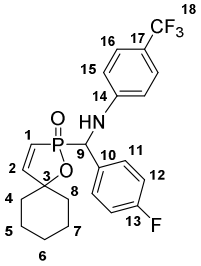


$C_{22}H_{22}ClF_3NO_2P$
MW 455.85, 430 mg, yield 65%, white solid, melting point: 210°C, *de* > 95%.



$C_{23}H_{22}F_6NO_2P$
MW 489.40, 383 mg, yield 54%, white solid, melting point: 172°C, *de* > 95%.

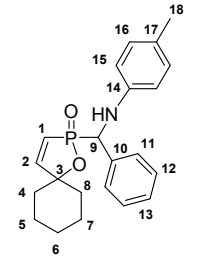
*4.8.9. 2-((4-Fluorophenyl)((4-(trifluoromethyl)phenyl)amino)methyl) -1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**16i**). Yellow solid, 0.400g, 63% yield, de > 95%.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 61.4 (d, $^6J_{PF}$ = 5.5 Hz). ^{19}F NMR (188.3 MHz, $CDCl_3$) δ (ppm)*:* -113.7 (d, $^6J_{PF}$ = 5.5 Hz, 1F, CF). -61.7 (s, 3F, CF_3). ^{1}H (250.1 MHz, $CDCl_3$) δ 0.99-1.84 (m, 10H, 5 CH_2), 4.76, (d, 1H, $^2J_{PH}$ = 19.4 Hz, CHN), 5.86 (dd, 1H, $^2J_{PH}$ = 33.1 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.58-6.60 (m, 2H, H_{Ar}), 6.96 (dd, 1H, $^3J_{PH}$ = 40.6 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.05-7.08 (m, 2H, H_{Ar}), 7.29-7.40 (m, 4H, H_{Ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 21.5 (s, CH_2), 21.6 (s, CH_2), 24.1 (s, CH_2), 33.5 (d, J_{PC} = 2.9 Hz, CH_2), 36.5 (s, CH_2), 56.7 (d, $^1J_{PC}$ = 103.9 Hz, CHN), 91.5 (d, $^2J_{PC}$ = 2.2 Hz, C), 112.6 (s, CH), 114.9 (dd, J_{CF} = 21.2 Hz, J_{PC} = 2.2 Hz, CH), 116.5 (q, J_{CF} = 37.3 Hz, C), 117.2 (d, $^1J_{PC}$ = 101.0 Hz, CH), 125.1 (q, $^1J_{CF}$ = 270.0 Hz, CF_3), 125.9 (m, CH), 130.3 (q, J_{CF} = 5.1 Hz, CH), 132.8 (d, J_{PC} = 2.9 Hz, C), 150.4 (d, J_{PC} = 13.9 Hz, C), 157.9 (d, $^2J_{PC}$ = 10.2 Hz, CH), 161.6 (m, C). HRMS (FAB) m/z calcd for $C_{22}H_{23}F_4NO_2P$ $(M+H)^+$, 440.1402; found, 440.1400. IR (NaCl): 3288, 2933, 1616, 1548, 1510, 1332, 1229, 1158, 1103, 1063, 936, 907, 886, 827, 809, 564.



$C_{22}H_{22}F_4NO_2P$
MW 439.39, 400 mg, yield 63%, yellow solid, melting point: 212°C, *de* > 95%.

*4.8.10. 2-((4-(Trifluoromethyl)phenyl)((4-(trifluoromethyl)phenyl) amino)methyl)-1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**16j**). White solid, 0.383g, 54% yield, de > 95%.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 61.0; ^{19}F NMR (188.3 MHz, $CDCl_3$) δ (ppm)*:* -61.8 (3F, CF_3), -63.0 (3F, CF_3). ^{1}H NMR (250.13 MHz, $CDCl_3$) δ 1.20-1.84 (m, 10H, CH_2), 4.86, (d, 1H, $^2J_{PH}$ = 19.9 Hz, CHN), 5.87 (dd, 1H, $^2J_{PH}$ = 33.7 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.57-6.60 (m, 2H, H_{Ar}), 7.00 (dd, 1H, $^3J_{PH}$ = 41.0 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.28-7.64 (m, 6H, H_{Ar}). ^{13}C NMR (62.9 MHz, $CDCl_3$) δ 21.5 (s, CH_2), 21.6 (s, CH_2), 24.1 (s, CH_2), 33.5 (d, J_{PC} = 2.9 Hz, CH_2), 36.5 (s, CH_2), 57.6 (d, $^1J_{PC}$ = 101.7 Hz, CHN), 91.8 (d, $^2J_{PC}$ = 2.9 Hz, C), 112.6 (s, CH), 116.8 (d, $^1J_{PC}$ = 101.7 Hz, PCH), 117.3 (q, J_{CF} = 32.2 Hz, 2 × C), 123.9 (q, $^1J_{CF}$ = 272.2 Hz, CF_3), 124.8 (q, $^1J_{CF}$ = 270.0 Hz, CF_3), 124.8 (m, CH), 125.8 (m, CH), 128.4 (d, J_{PC} = 2.9 Hz, C), 128.8 (d, J_{CF} = 5.1 Hz, CH), 149.6 (d, J_{PC} = 10.2 Hz, C), 157.1 (d, $^2J_{PC}$ = 11.0 Hz, CH). HRMS (FAB) m/z calcd for $C_{23}H_{23}F_6NO_2P$ $(M+H)^+$, 490.1370; found, 490.1396. IR (NaCl): 3289, 2934, 1618, 1332, 1230, 1158, 1105, 1066, 935, 909, 888, 828, 808, 750.

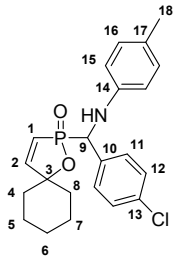
*4.8.11. 2-(Phenyl(p-tolylamino)methyl)-1-oxa-2-phosphaspiro[4.5]-dec-3-ene 2-oxide (**16k**). White solid, 0.470 g, 88% yield, de = 14%.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 59.1 (43%, *dia 1*), 57.0 (57%, *dia 2*). ^{1}H NMR (400.1 MHz, $CDCl_3$) δ *dia 1*: 1.18-1.75 (m, 10H, CH_2), 2.10 (s, 3H, CH_3), 4.58 (d, 1H, $^2J_{PH}$ = 15.6 Hz, CHN), 6.11 (dd, 1H, $^2J_{PH}$ = 33.6 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.41-6.44, (m, 2H, H_{Ar}), 6.91 (dd, 1H, $^3J_{PH}$ = 40.5 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 6.80-6.83 (m, 2H, H_{Ar}), 7.16-7.25 (m, 3H, H_{Ar}), 7.30-7.32 (m, 2H, H_{Ar}), *dia 2:* 1.18-1.75 (m, 10H, CH_2), 2.1 (s, 3H, CH_3), 4.66 (d, 1H, $^2J_{PH}$ = 19.2 Hz, CHN), 5.78 (dd, 1H, $^2J_{PH}$ = 33.3 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.41-6.44, (m, 2H, H_{Ar}) 6.79 (dd, 1H, $^3J_{PH}$ = 40.3 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 6.80-6.83 (m, 2H, H_{Ar}), 7.16-7.25 (m, 3H, H_{Ar}), 7.30-7.32 (m, 2H, H_{Ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ *dia 1:* 20.4 (s, CH_3), 21.8 (s, CH_2), 21.9 (s, CH_2), 24.6 (s, CH_2), 35.2 (s, CH_2), 36.9 (s, CH_2), 60.0 (d, $^1J_{PC}$ = 104.7 Hz, CHN), 92.2 (d, $^2J_{PC}$ = 2.9 Hz, C), 114.3 (s, CH), 117.8 (d, $^1J_{PC}$ = 105.4 Hz, CH), 127.8 (s, C), 127.9 (s, CH), 128.0 (d, J_{PC} = 2.9 Hz, CH), 128.6 (d, J_{PC} = 5.8 Hz, CH), 135.6 (d, J_{PC} = 5.1 Hz, C), 144.1 (d, $^3J_{PC}$ = 13.9 Hz, C), 157.2 (d, $^2J_{PC}$ = 11.7 Hz, CH), *dia 2:* 20.4 (s, CH_3), 22.0 (s) 22.1 (s, CH_2), 24.7 (s, CH_2), 35.2 (s, CH_2), 37.0 (s, CH_2), 60.0 (d, $^1J_{PC}$ = 102.3 Hz, CH), 92.2 (d, J_{PC} = 2.2 Hz, C), 114.4 (s, CH), 117.6 (d, $^1J_{PC}$ = 106.8 Hz, CH), 127.7 (s, C), 127.8 (s, CH), 127.9 (d, J_{PC} = 5.8 Hz, CH), 128.8 (d, J_{PC} = 1.9 Hz, CH), 136.2 (d, J_{PC} = 2.9 Hz, C), 144.3 (d, J_{PC} = 5.1 Hz, C), 156.3 (d, $^2J_{PC}$ = 11.0 Hz, CH). HRMS (FAB) m/z calcd for $C_{22}H_{27}NO_2P$ $(M+H)^+$, 368.1779; found, 368.1784. IR (NaCl): 3394, 3309, 2934, 2856, 1616, 1523, 1448, 1319, 1262, 1216, 1106, 955, 940, 900, 805, 695, 587.



$C_{22}H_{26}NO_2P$
MW 367.43, 470 mg, yield 88%, white solid, melting point: 240°C, *de* = 14%.

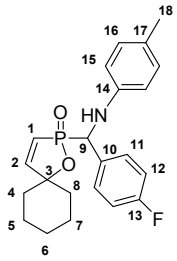
*4.8.12. 2-((4-Chlorophenyl)(p-tolylamino)methyl)-1-oxa-2-phospha-spiro[4.5]dec-3-ene 2-oxide (**16l**). White solid, 0.450g, 78% yield, de = 10%.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 58.7 (45%, *dia 1*), 61.8 (55%, *dia 2*). ^{1}H NMR (400.1 MHz, $CDCl_3$) δ *dia 1*: 1.14-1.77 (m, 10H, CH_2), 2.2 (s, CH_3), 4.63 (d, 1H, $^2J_{PH}$ = 16.0 Hz, CHN), 6.11 (dd, 1H, $^2J_{PH}$ = 33.8 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.47-6.50 (m, 2H, H_{Ar}), 6.90-6.93 (m, 2H, H_{Ar}), 7.04 (dd, 1H, $^3J_{PH}$ = 40.7 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.28-7.37 (m, 4H, H_{Ar}). *dia 2:* 1.14-1.77 (m, 10H, CH_2), 2.20 (s, CH_3), 4.74 (d, 1H, $^2J_{PH}$ = 19.2 Hz, CHN), 5.90 (dd, 1H, $^2J_{PH}$ = 33.4 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.47-6.50 (m, 2H, H_{Ar}), 6.90-6.93 (m, 2H, H_{Ar}), 6.94 (dd, 1H, $^3J_{PH}$ = 40.5 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.28-7.37 (m, 4H, H_{Ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ *dia 1:* 20.4 (s, CH_3), 21.8 (s, CH_2), 21.9 (s, CH_2), 24.6 (s, CH_2), 35.4 (d, J_{PC} = 2.9 Hz, CH_2), 36.9 (s, CH_2), 59.4 (d, $^1J_{PC}$ = 104.6 Hz, CHN), 92.4 (d, $^2J_{PC}$ = 2.9 Hz, C), 114.3 (s, C), 117.8 (d, $^1J_{PC}$ = 106.1 Hz, PCH), 128.1 (s, C), 128.8 (d, J_{PC} = 2.9 Hz, CH), 129.2 (s, CH), 129.7 (s, CH), 133.7 (d, J_{PC} = 3.7 Hz, C), 134.2 (d, J_{PC} = 5.1 Hz, C), 144.0 (s, C), 157.5 (d, $^2J_{PC}$ = 11.0 Hz, CH), *dia 2:* 20.4 (s, CH_3), 21.9 (s, CH_2), 22.0 (s, CH_2), 24.6 (s, CH_2), 35.2 (d, J_{PC} = 3.7 Hz, CH_2), 37.0 (s,

CH_2), 59.2 (d, $^1J_{PC}$ = 102.5 Hz, CHN), 92.4 (d, J_{PC} = 2.9 Hz, C), 114.4 (s, C), 117.4 (d, $^1J_{PC}$ = 106.8 Hz, PCH), 128.0 (s, C), 129.0 (d, J_{PC} = 2.9 Hz, CH), 129.2 (d, J_{PC} = 1.4 Hz, CH), 129.6 (s, CH), 133.8 (d, J_{PC} = 4.4 Hz, C), 134.9 (d, J_{PC} = 2.2 Hz, C), 143.8 (s, C), 156.8 (d, $^2J_{PC}$ = 11.4 Hz, CH). HRMS (FAB) m/z calcd for $C_{22}H_{26}ClNO_2P$ $(M+H)^+$, 402,1389; found, 402,1392. IR (NaCl): 3400, 3313, 3055, 2934, 2810, 1619, 1523, 1487, 1446, 1318, 1261, 1212, 1089, 1015, 950, 907, 806, 593, 508.



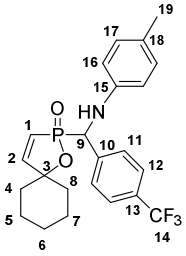
$C_{22}H_{25}ClNO_2P$
MW 401.87, 450 mg, yield 78%, white solid, melting point: 240°C, *de* = 10%.

*4.8.13. 2-((4-Fluorophenyl)(p-tolylamino)methyl)-1-oxa-2-phospha-spiro[4.5]dec-3-ene 2-oxide (**16m**). White solid, 0.413g, 74% yield, de = 74%.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 59.1 (13%, dia 1), 62.2 (87%, dia 2). ^{19}F NMR (188.3 MHz, $CDCl_3$) δ (ppm): -114.49 (13%), -114.46 (87%). ^1H NMR (400.1 MHz, $CDCl_3$) δ dia 1: 1.24-1.75 (m, 10H, CH_2), 2.10 (s, 3H, CH_3), 4.55 (d, 1H, $^2J_{PH}$ = 15.6 Hz, CHN), 6.11 (dd, 1H, $^2J_{PH}$ = 33.4 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.34-6.45 (m, 2H, H_{Ar}), 6.83-6.87 (m, 4H, H_{Ar}), 7.20-7.32 (m, 3H, H_{Ar} and CH). dia 2: 1.24-1.75 (m, 10H, CH_2), 2.1 (s, 3H, CH_3), 4.66 (d, 1H, $^2J_{PH}$ = 18.8 Hz, CHN), 5.81 (dd, 1H, $^2J_{PH}$ = 33.3 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.40-6.67 (m, 2H, H_{Ar}), 6.84 (dd, $^3J_{PH}$ = 40.3 Hz, $^3J_{HH}$ = 8.4 Hz, 1H, CH), 6.86-6.87 (m, 4H, H_{Ar}), 7.24-7.32 (m, 2H, H_{Ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 20.4 (s, CH_3), 22.0 (s, CH_2), 24.6 (s, CH_2), 35.3 (s, CH_2), 35.4 (s, CH_2), 37.0 (s, CH_2), 59.1 (d, $^1J_{PC}$ = 103.2 Hz, CHN), 92.3 (s, C), 114.4 (s, C), 115.8 (dd, J_{CF} = 21.9 Hz, J_{PC} = 2.9 Hz, C), 117.5 (d, $^1J_{PC}$ = 106.8 Hz, PCH), 127.9 (s, C), 129.4-129.7, (m, CH), 129.6 (s, C), 131.9 (m, C), 144.0 (d, J_{PC} = 8 Hz, C), 156.7 (d, $^2J_{PC}$ = 11.0 Hz, CH), 162.5 (d, J_{CF} = 273 Hz, C). HRMS (FAB) m/z calcd for $C_{22}H_{26}FNO_2P$ $(M+H)^+$, 386.1685; found, 386.1682. IR (NaCl): 3453, 3315, 2934, 1621, 1506, 1487, 1440, 1318, 1262, 1220, 1218, 1200, 946, 907, 845, 804, 750, 581.



$C_{22}H_{25}FNO_2P$
MW 385.22, 413 mg, yield 74%, white solid, melting point: 200°C, *de* = 74%.

*4.8.14. 2-((p-Tolylamino)(4-(trifluoromethyl)phenyl)methyl)-1-oxa-2-phosphaspiro[4.5]dec-3-ene 2-oxide (**16n**). White solid, 0.335g, 53% yield, de > 95%.* ^{31}P NMR (101.2 MHz, $CDCl_3$): δ 58.4; ^{19}F NMR (188.3 MHz, $CDCl_3$) δ (ppm): -63.4; ^1H NMR (400.1 MHz, $CDCl_3$) δ 1.38-1.67 (m, 10H, 5 CH_2), 2.11 (s, 3H, CH_3), 4.63 (d, 1H, $^2J_{PH}$ = 16.2 Hz, CHN), 6.13 (dd, 1H, $^2J_{PH}$ = 33.8 Hz, $^3J_{HH}$ = 8.4 Hz, PCH), 6.39-6.41, (m, 2H, H_{Ar}), 6.83 (d, 2H, J_{HH} = 8.0 Hz, H_{Ar}), 6.97 (dd, 1H, $^3J_{PH}$ = 41.1 Hz, $^3J_{HH}$ = 8.4 Hz, CH), 7.45-7.51 (m, 4H, H_{Ar}). ^{13}C NMR (100.6 MHz, $CDCl_3$) δ 20.4 (s, CH_3), 21.8 (s, CH_2), 21.9 (s, CH_2), 24.5 (s, CH_2), 35.2 (d, J_{PC} = 2.9 Hz, CH_2), 36.9 (s, CH_2), 59.7 (d, $^1J_{PC}$ = 102.5 Hz, CHN), 92.6 (d, $^2J_{PC}$ = 3.7 Hz, C), 114.2 (s, C), 117.5 (d, $^1J_{PC}$ = 106.1 Hz, PCH), 125.6 (q, J_{CF} = 3.7 Hz, CH), 128.2 (s, CH), 128.2 (s, CH), 128.3 (s, C), 129.7 (s, CH), 131.0 (q, J_{FC} = 28.0 Hz, C), 137.5 (q, $^1J_{FC}$ = 227 Hz, CF_3), 140.1 (m, C), 143.6 (s, C), 157.8 (d, $^2J_{PC}$ = 11.7 Hz, CH). HRMS (FAB) m/z calcd for $C_{23}H_{26}F_3NO_2P$ $(M+H)^+$, 436.1653; found, 436.1655. IR (NaCl): 3403, 3057, 2948, 1616, 1522, 1448, 1422, 1328, 1258, 1213, 1158, 1114, 1068, 1018, 947, 905, 850, 807, 604.



$C_{23}H_{25}F_3NO_2P$
MW 435.42, 335 mg, yield 53%, white solid, melting point: 206°C, *de* > 95%.

Acknowledgments

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