HIGHLY FUNCTIONALIZED AZIRIDINES II : A FACILE SYNTHESIS OF DIETHYL AZIRIDINYLPHOSPHONATES AND 2-CHLOROAZIRIDINYLPHOSPHONATES[1]

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Dedicated to Professor Derek Barton on the occasion of his 70th birthday

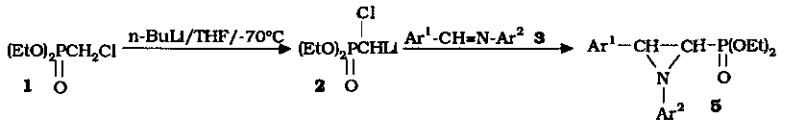
Abstract —— *The reaction of diethyl 1-lithio-1-chloromethylphosphonate with aromatic imines gave aziridinylphosphonates in good yields and with an high stereoselectivity. The resulting aziridines reacted with n-BuLi and led to the 2-lithiated anions which were trapped with carbon tetrachloride to give 2-chloroaziridinylphosphonates in excellent yields.*

The chemistry of the small ring heterocycle aziridine has known an enormous expansion in the past decade because of its mechanistic, synthetic and biological applications.[3]
For the present time there is a great request for functionally substituted aziridines which are very interesting intermediates for a lot of transformations.[4]

Previously we described briefly a novel application of the lithiated alkyl dichloroacetate anions in the preparation of the practically unknown alkyl 2-chloroaziridinylcarboxylates.[1] Now, and as a part of an ongoing program on highly functionalized aziridines directed toward the synthesis of potentially biologically important compounds,[5] we reported the reaction between the lithiated diethyl chloromethylphosphonate anion **2** and imines **3** to prepare the novel aziridinylphosphonate structures **5**.
Whereas 2-substituted ester, amide, nitrile, ketone , aldehyde, sulfone aziridines have been described,[3,4] only one example of a substituted aziridine with a 2-diethylphosphono group was mentioned. This one was obtained with moderate yield, after three steps, from diethylvinylphosphonate.[6]
Attempts to use the more direct Darzens methodology to the preparation of functionalized aziridines by the action of stabilized α-halocarbanions on imines have been limited.[7] The study reported here is also an continuation of other works in the laboratory concerned with the preparation and the Darzens type reactions of various α-halocarbanions.[8]

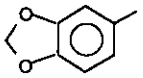
Diethyl 1-lithio-1-chloromethylphosphonate **2** was readily formed at low temperature in tetrahydrofuran/hexane from the reaction of n-butyllithium with diethylchloromethylphosphonate **1**. After addition of the imine **3**, the resultant mixture was gradually allowed to warm to - 40°C with stirring for 13 h and then to room temperature. The mixture was hydrolyzed and the expected aziridine **5** was isolated with dichloromethane in good yields.

Scheme 1



The results are summarized in Table 1.

Table 1 - Products **5** synthesized from the reaction of 1-lithio-1-chloromethylphosphonate **2** and imines **3**

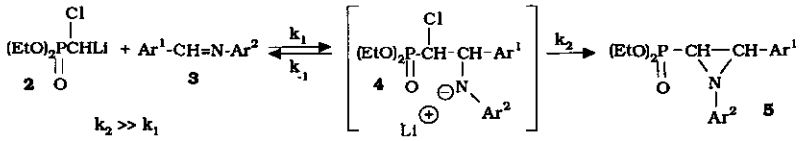
Ar^1	Ar^2	**5** Yield %	**3** Yield %
Ph	Ph	85	0
m- ClPh	Ph	30	50
p- ClPh	Ph	95	0
m- NO_2Ph	Ph	67	0
p- NO_2Ph	Ph	51	0
o- CH_3Ph	Ph	70	0
	Ph	94	0
p- CH_3OPh	Ph	53	25
Ph	p- BrPh	80	0

We observed that the carbanion **2** slowly reacted with imines, even at room temperature, and the required prolonged reaction time, to complete the reaction, led to competitive and partial decomposition of **2**, at this temperature. Thus, the better yields were obtained when a net excess of **2** was used (**2**/**3** = 3).

The excess of the carbanion **2** compensated its partial degradation and enhanced the reaction rate.

Obviously the rate determining step was the slow attack of **2** on the imine which led to the lithium amide **4**. This one, immediately, cyclized to give the aziridinylphosphonate **5** (Scheme 2); so that it was not possible to reveal the presence of **4** by quenching the reaction by hydrolysis, even at low temperature.

Scheme 2

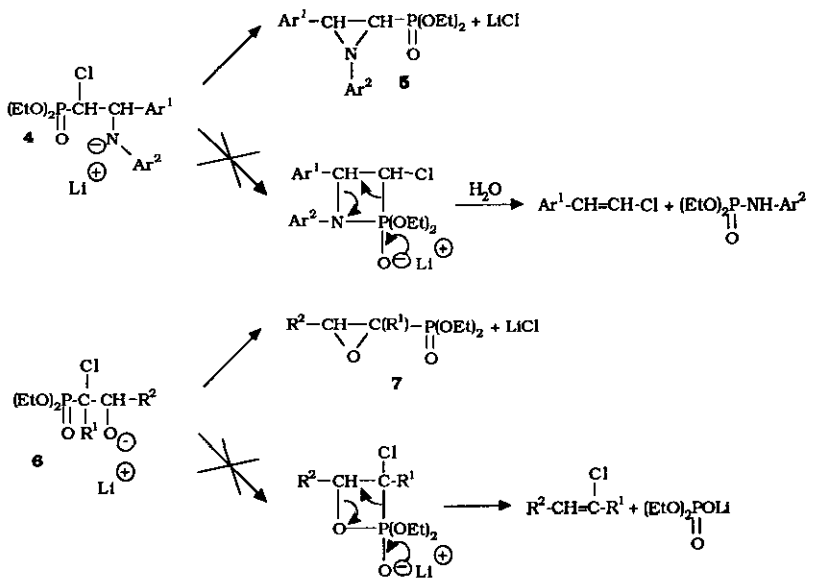


There was, here, a clear difference between the behaviour of the lithiated anion **2** with imines and its reaction with carbonyl compounds . Previously we have described the reaction of **2** with carbonyl compounds and observed that the addition of a carbonyl compound to **2** at -70°C results in the almost immediate formation of a phosphonate chlorohydrin **6** (Scheme 3). The phosphonate chlorohydrin can be isolated by hydrolysis at -70°C or can lead on warming to epoxyalkylphosphonate **7**.[9]

In the present case the high rate of the cyclisation step prevented the isolation of the phosphonate amide **4**. The anionic nitrogen of **4** was a more powerful nucleophilic center than the anionic oxygen of the phosphonate chlorohydrin **6**, and involved a more rapid cyclisation.

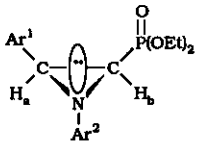
However the reactions of **2** with imines and with carbonyl compounds presented a certain analogy. In the second reaction step, the attack of the carbon bearing the chlorine atom was preferred to the attack at phosphorus atom (Wittig-Horner reaction). We supposed that the compared carbon and phosphorus atom hardness and the reactional centers proximity during the cyclisation steps (entropy factor) were more favorable to the formation of the three membered rings.

Scheme 3

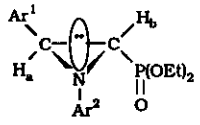


The reaction with **2** with imines was highly stereoselective and gave the broadly major "cis" stereoisomer **5a** accompanied by a small quantity of the "trans" stereoisomer **5b**.
Normally this Darzens condensation may lead, a priori, to four pairs of diastereoisomers **5a**, **5b**, **5c**, and **5d** (Scheme 4).

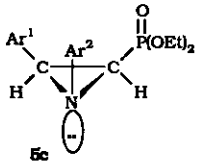
Scheme 4



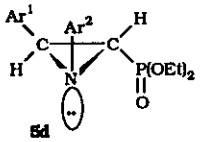
5a ("cis")



5b ("trans")



5c



5d

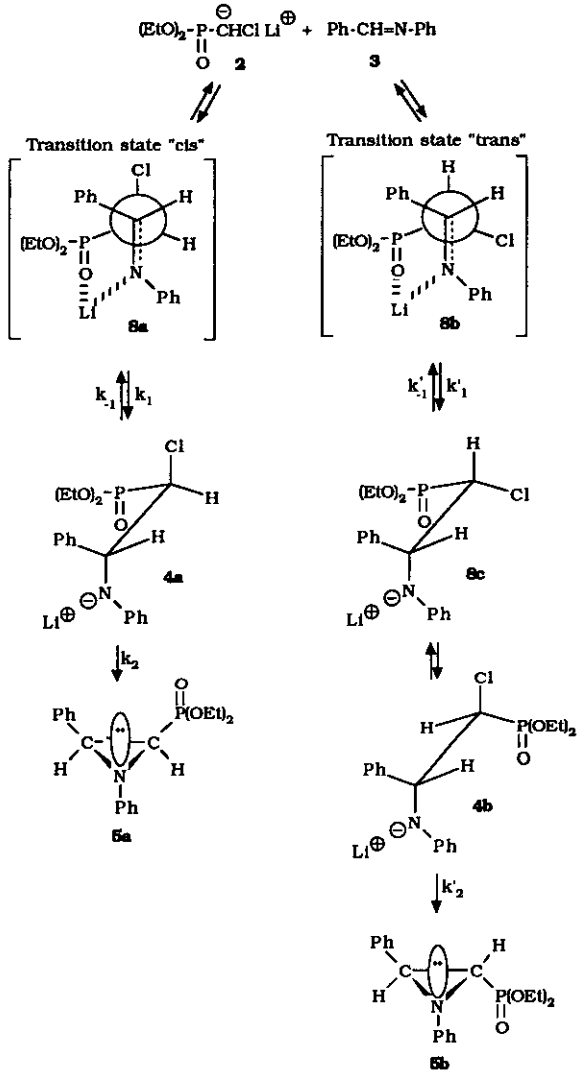
In the all studied cases of the Table 1 the ratio **5a/5b** was always superior to 95/5. The configurations of the aziridinylphosphonates **5a** and **5b** were tentatively assigned by analogy with results in closely related series. Previous studies with alkyl aziridinylsulfonates[10] and alkyl aziridinylcarboxylates[11] have demonstrated a stable relative trans configuration for the aryl groups without nitrogen inversion at room temperature. Nmr spectra of aziridines **5a** or **5b** showed an ABX system which was not modified at high temperature (boiling CCl_4, 40 h). Similarly, we supposed a trans disposition for the aryl groups into the aziridinylphosphonates **5a** and **5b** without nitrogen inversion at room temperature. Then, the stereochemical relationship of protons Ha and Hb was ascertained by an examination of the vicinal coupling constant JHa-Hb which was 7 Hz for a cis coupling (**5a**) and of 3 Hz for a trans coupling (**5b**).[10]
Furthermore the "cis" configuration for **5a** and the "trans" configuration for **5b** were supported by the chemical shifts of the proton Hb. It was known that for a low nitrogen inversion rate, the nitrogen electronic pair involved a deshielding effect on the neighbouring cis ring protons.[12] Then, the protons Hb which have chemical shifts to higher fields, at 2.4-2.6 ppm, are cis to the N-aryl substituent (**5a**). Downfield shifts at 2.6-2.8 ppm were observed for the protons Hb trans to the N-aryl substituent (**5b**).The reason for the lower chemical shifts of the protons Hb in **5b** can be thought to be due also to the deshielding effect of Ar^1.

This diastereoselective Darzens reaction in favour of the sole cis and trans isomers **5a** and **5b** deserved further comments.

The failure of the aziridines **5a** and **5b** to isomerize under the reaction conditions indicated that the product ratios **5a/5b** > 95/5 were kinetically controlled.
If we supposed the two step mechanism indicated in Scheme 2, the stereochemistry of the aziridinylphosphonates **5a** and **5b** must be determined during the slow and probably reversible

first reaction step[13](Scheme 5). To understand the stereochemical control of this first reaction step it was necessary to consider the four different transition states apt to lead to the aziridinylphosphonates **5a**, **5b**, **5c**, and **5d**. We suggested that the lithiated anion **2** approached the imine **3** so as the cation would be more or less symmetrically disposed between the developing negative charge on nitrogen and the diethylphosphono group. Two sole possible transition state arrangements **8a** and **8b** resulted which had minimal incipient eclipsing interactions, especially between the diethylphosphono group and the nitrogen phenyl group.

Scheme 5

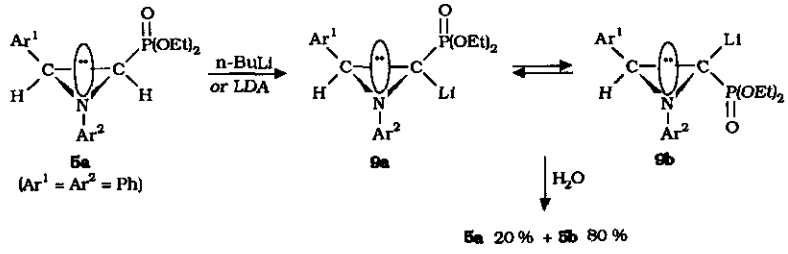


Bond formation from **8a** led to **4a** where the antiperiplanar arrangement of the nitrogen and chlorine atoms required for the cyclisation step was realized.
Bond formation from **8b** produced **8c** which did not appear to be the preferred conformer leading to **5b**. In this case the cyclisation transition state necessited the transformation of the conformer **8c** into **4b** where the nitrogen phenyl group was in strong interaction with diethylphosphono group.
Hence the rate cyclisation step was greater for **4a** than for **4b** (k2 > k'2) and, consequently, the cis isomer **5a** was the widely major product.

In view to complete the understanding of the stereochemical control in the synthesis of aziridinylphosphonates we undertook a brief examination of their thermal stability and sensitivity toward bases.

Aziridine **5a** (Ar^1 = Ar^2 = Ph) was recovered unchanged after it had been heated in boiling CCl4 under reflux for 40 h. However, after heating in boiling toluene, cis-aziridine **5a** underwent isomerization, and after 15 h, equilibrium was established between **5a** and **5b** (50:50). Similarly a mixture of **5b/5a** (Ar^1 = Ar^2 = Ph) 80/20 could be equilibrated after 15 h in boiling toluene to a 50/50 mixture of **5b** and **5a**.
These thermal isomerizations were known for aziridine esters and aziridine amides and have been explained in terms of intermediate azomethine ylid.[14]
Aziridinylphosphonates were unaffected by alkoxides at room temperature or by the anion **2** in THF, but stronger bases as butyllithium or LDA underwent isomerization of **5a** into **5b** (Ar^1 = Ar^2 = Ph), (Scheme 6 , and Table 2).

Scheme 6



The mechanism which must be considered involved a carbanion intermediate **9a** which would arise from the aziridinylphosphonate **5a** in basic medium.[15]
This carbanion **9a** would give **9b** by vibrational interconversion. The equilibrium mixture of the two carbanions would lead after hydrolysis to **5a** and **5b** with the observed ratio.
The predominance of **9b** at the equilibrium is thought to be due to the steric hindrance between Ar^1(Ph) and cis-diethylphosphono group in **9a** which was greater than the steric hindrance between Ar^2(Ph) on the nitrogen atom and the cis-diethylphosphonogroup in **9b**.

Table 2 - Isomerization of **5a** ($Ar^1 = Ar^2 = Ph$)

Base	**5a**/Base	Conditions	**5a/5b**
n-BuLi/THF	1/1	10 min , -78°C Hydrolysis , -78°C	20/80
n-BuLi/THF	1/0.1	25 h , -78 to -50°C , 48 h , 20°C	100/0
n-BuLi/THF	1/1	1 h , -78°C Hydrolysis , -78°C	20/80
LDA/THF	1/1	10 min , -78°C , Hydrolysis , -78°C	20/80
EtOK/EtOH	1/1	40 h , 20°C	100/0
t-BuOK/t-BuOH	1/1	40 h , 20°C	100/0

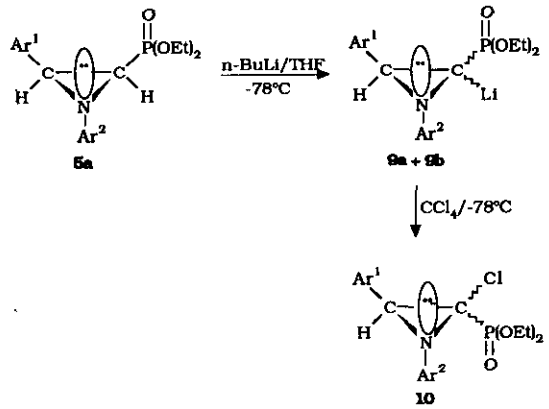
In order to confirm the existence of these carbanion species, trapping by usual alkylating reagents was attempted (CH_3I, $(CH_3)_2SO_4$, CH_2=CH-CH_2Br, $(CH_3)_2$CH-CHO). Various experiments with different conditions did not succeed.

In the all studied cases the same mixture of aziridinylphosphonates **5a/5b** = 20/80 was obtained without traces of the expected alkylation product.

There was here a clear difference between the behavior of the lithiated aziridinylphosphonate carbanions and the lithiated aziridinylsulfone carbanions which were alkylated in these conditions.[4c]

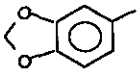
The sole positive result was observed in the reaction of the lithiated aziridinylphosphonate derived from **5a** ($Ar^1 = Ar^2 = Ph$) and the carbon tetrachloride. With this electrophilic reagent, α chlorination of the phosphonate moiety occurred and led to α chlorinated aziridinylphosphonate **10** in excellent yield (85 %) (Scheme 7).

Scheme 7



The reaction has been extended to other aziridinylphosphonates **5** and gave very good results (Table 3).

Table 3 - Preparation of (2-chloroaziridinyl)phosphonates **10** from aziridinylphosphonates **5**

Ar^1	Ar^2	**10** Yield%
Ph	Ph	85
Ph	p-BrPh	78
o-CH_3Ph	Ph	80
p-CH_3 OPh	Ph	90
	Ph	95
p-ClPh	*Ph*	83
m-ClPh	Ph	91

The reaction proved highly stereoselective and *gives one stereoisomer only of* **10**. The configurations of the 2-chloroaziridinylphosphonates **10** were difficult to assign by ^{1}H nmr. Nevertheless, by analogy with results in closely related series, the trans relationship of the Ar^1 and diethylphosphono groups, on the one hand, and of the Ar^1 and Ar^2 groups, on the other hand was supposed on the basis of the ^{13}C nmr data.[16] These conclusions can be putted together with RX data of closely related 2-chloroaziridinylcarboxylates, obtained by a Darzens type reaction, which exhibited this configuration.[17]

The α chlorinated aziridinylphosphonates were novel attractive functionally molecules. The high degree of functionality would allow a variety of chemoselective transformations, the study of which is in progress.This reaction represented also a novel case of an α chlorination of a dialkylphosphono group, a previously studied reaction in our group.[18]

EXPERIMENTAL

General Methods . Solvents were dried and distilled before use and all reactions were carried out under nitrogen. Silica gel 60 (Merck) was used for column chromatographic procedures. Ir spectra were recorded on a Perkin Elmer 580 B spectrophotometer and nmr spectra on a Perkin Elmer R12 B or on a BRUKER AM 400 (400 Mz) spectrophotometers. Microanalyses were performed by the Microanalytical Laboratory CNRS.

Typical Procedure for the Preparation of AzIridinylphosphonates 5

To a 2.4 M solution of butyllithium in hexane (12.5 ml, 30 mM) in tetrahydrofuran (30 ml) under nitrogen at -70°C, a solution of diethyl chloromethylphosphonate (1, 5.6g, 30 mM) in tetrahydrofuran (10 ml) is added dopwise at -78°C with stirring for 15 min. Stirring is continued for 50 min at -70°C whereupon a solution of the imine (3, 10 mM) in tetrahydrofuran (10 ml) is added.The mixture is gradually allowed to warm to -40°C with stirring for 13 h and then to room temperature for 1 h.Water (40ml) is added. For product isolation, the layers are separated , the aqueous layer is extracted with dichloromethane. The organic layers are combined and dried with magnesium sulfate , the solvent removed, and the residual crude product 5 analyzed by ^1H nmr before purification by silica gel column chromatography (elution hexane/ether) .

Diethyl (1,3-diphenyl-2-aziridinyl)phosphonate " cis "

Elution : hexane/ether = 3/10, yellow oil, 85% yield, n_D^{18} = 1.4625, ir 3060, 3040, 1600, 1250 cm^{-1} ; ^1H nmr (400 MHz) δ ppm 1.09 (t, J = 7 Hz, 3H), 1.20 (t, J = 7 Hz, 3H), 2.64 (dd, JH-P =19 Hz, JH-H = 7 Hz, 1H) , 3.54 (dd which appeared as a triplet, JH-P = JH-H = 7 Hz, 1H), 3.85 (m, JH-P = 3 Hz, JH-H = 7 Hz, 2H), 4.01 (m, JH-P = 3Hz, JH-H = 7 Hz, 2H), 7.0-7.7 (m, 10H). Anal. calcd for $C_{18}H_{22}NO_3P$: C, 65.25 ; H, 6.64 ; N, 4.22. Found C, 65.10 ; H, 7.14 ; N, 4.04 .

Diethyl [3-(m-chlorophenyl)-1-phenyl-2-aziridinyl]phosphonate "cis"

Elution : hexane/ether = 5/4, yellow oil, 30% yield, n_D^{18} = 1.4583, ir 3060, 1600, 1570, 1265 cm^{-1} ; ^1H nmr (60 MHz) δ ppm 1.10 (t, J = 7Hz, 6H) , 2.50 (dd, JH-P =19 Hz, JH-H =7 Hz, 1H), 3.50 (dd which appeared as a triplet, JH-P = JH-H = 7 Hz, 1H), 3.60-4.40 (m, J = 7Hz, 4H), 6.80-7.80 (m, 9H). Anal. calcd for $C_{18}H_{21}ClNO_3P$: C, 59.09 ; H, 5.74 ; Cl, 9.71 ; N, 3.83. Found C, 59.13 ; H, 5.97 ; Cl, 10.16 ; N, 3.67.

Diethyl [3-(p-chlorophenyl)-1-phenyl-2-aziridinyl]phosphonate "cis"

Elution : hexane/ether = 3/10, yellow oil, 95% yield, n_D^{18} = 1.4615 , ir 3060, 3040, 1600, 1255 cm^{-1} ; ^1H nmr (60 MHz) δ ppm 1.20 (t, J = 7Hz, 6H), 2.50 (dd, JH-P =19Hz, JH-H = 7 Hz,1H), 3.45 (dd which appeared as a triplet, JH-P = JH-H = 7 Hz, 1H), 3.70-4.50 (m, J = 7 Hz, 4H), 6.90-7.80 (m, 9H). Anal. calcd for $C_{18}H_{21}ClNO_3$ P : C, 59.09 ; H, 5.74 ; Cl, 9.71 ; N, 3.83. Found C, 59.02 ; H, 6.08 ; Cl, 9.81 ; N, 3.79.

Diethyl [3-(m-nitrophenyl)-1-phenyl-2-aziridinyl]phosphonate "cis"

Elution : ether, yellow oil, 67% yield, n_D^{18} = 1.4633 , ir 3060, 3040, 1600, 1260 cm^{-1} ; ^1H nmr (60 MHz) δ ppm 1.15 (t, J=7Hz, 6H), 2.55 (dd, JH-P =19Hz, JH-H =7 Hz, 1H), 3.50 (dd which appeared as a triplet, JH-P = JH-H = 7 Hz, 1H), 3.60-4.80 (m, J = 7 Hz, 4H), 6.80-8.50 (m, 9H). Anal. calcd for $C_{18}H_{21}N_2O_5$ P : C, 57.44 ; H, 5.58 ; N,7.44. Found C, 57.41 ; H, 5.57 ; N, 7.25.

Diethyl [3-(p-nitrophenyl)-1-phenyl-2-aziridinyl]phosphonate "cis"

Elution : ether, yellow oil, 51% yield, n_D^{18} = 1.4556 , ir 3060, 3030, 1600, 1260 cm^{-1} ; ^1H nmr (60 MHz) δ ppm 1.30 (t, J = 7 Hz , 6H), 2.60 (dd, JH-P = 19Hz, JH-H = 7 Hz, 1H), 3.20-4.60 (m, J = 7 Hz, 5H), 6.80-7.70 (m, 5H) , 7.90 (d, J = 9 Hz, 2H), 8.30 (d, J = 9 Hz, 2H). Anal. calcd for $C_{18}H_{21}N_2O_5$ P : C, 57.44 ; H, 5.58 ; N,7.44 . Found C, 57.65 ; H, 5.42 ; N, 7.38.

Diethyl [3-(o-methylphenyl)-1-phenyl-2-aziridinyl]phosphonate "cis"

Elution : hexane/ether = 5/1, yellow oil, 70% yield, n_D^{18} =1.4623, ir 3060, 3030, 1600, 1270 , 1240 cm^{-1} ; ^1H nmr (60 MHz) δ ppm 1.25 (t, J = 7 Hz, 6H), 2.60 (dd, JH-P = 19 Hz, JH-H = 7 Hz, 1H), 3.20-4.40 (m, 5H), 6.80-7.80 (m, 9H). Anal. calcd for $C_{19}H_{24}NO_3P$: C,66.08 ; H , 6.95 ; N, 4.05. Found C, 66.41 ; H, 7.25 ; N, 3.85.

Diethyl [3-(3,4-methylenedioxyphenyl)-1-phenyl-2-aziridinyl]phosphonate "cis"

Elution : hexane/ether = 1/4, yellow oil, 94% yield, n_D^{18} = 1.4595, ir 3060, 3040, 1600, 1270, 1240 cm^{-1} ; ^1H nmr (60 MHz) δ ppm 1.15 (t, J = 7 Hz, 6H), 2.40 (dd, JH-P = 19 Hz , JH-H = 7 Hz, 1H), 3.35 (dd which appeared as a triplet, J = 7 Hz, 1H), 3.60-4.30 (m, 4H), 5.85 s, 2H), 6.40-7.50 (m, 8 H). Anal. calcd for $C_{19}H_{22}NO_5$ P : C, 60.80 ; H, 5.86 ; N,3.73 . Found C, 60.77 ; H, 6.02 ; N, 3.56 .

Diethyl [3-(p-methoxyphenyl)-1-phenyl-2-aziridinyl]phosphonate "cis"

Elution : hexane/ether = 5/1, yellow oil, 53% yield, n_D^{18} =1.4583, ir 3060, 3040, 1600, 1250 cm^{-1}; ^1H nmr (60 MHz) δ ppm 1.10 (t, J = 7 Hz, 6H), 2.40 (dd, JH-P = 19Hz, JH-H=7 Hz, 1H), 3.35 (dd which appeared as a triplet, J = 7Hz, 1H), 3.50-4.50 (m, 4H) ,3.65 (s, 3H), 6.50-7.70 (m, 9 H) . Anal. calcd for C_{19} $H_{24}NO_4$ P : C, 63.15 ; H, 6.64 ; N, 3.87. Found C, 63.37 ; H, 6.42 ; N, 3.56.

Diethyl [1-(p-bromophenyl)-3-phenyl-2-aziridinyl]phosphonate "cis"

Elution : hexane/ether = 1/10, yellow oil, 80% yield, n_D^{18} =1.4556 , ir 3060, 3040,1610, 1590, 1265, 1240 cm^{-1}; ^1H nmr (60 MHz) δ ppm 1.10 (t, J = 7 Hz, 3H), 1.30 (t, J = 7 Hz, 3H), 2.45 (dd, JH-P =19 Hz, JH-H = 7 Hz, 1H), 3.20-4.60 (m, 5H), 6.50-8.00 (m, 9H). Anal. calcd for C_{18} $H_{21}BrNO_3$ P : C, 52.68 ; H, 5.12 ; Br, 19.51 ; N, 3.41. Found C, 52.92; H, 5.42; Br, 19.25; N, 3.56.

Reaction of aziridine **5a** (Ar^1 = Ar^2 = Ph) in basic medium

A 1.6 M solution of n-butyllithium (6.25 ml, 10 mmol) in hexane is added, dropwise with stirring at -78°C to pure aziridine **5a** (2.8 g, 8.5 mmol) in tetrahydrofuran (30 ml). The reaction mixture becomes dark red. After 10 min stirring at -78°C (or 1 h) water (35 ml) is added at -78°C and the product is extracted by dichloromethane (3 x 30 ml). The combined organic layer is dried with magnesium sulfate, the solvent is removed under reduced pressure.

^1H Nmr analysis of the crude residual oil showed a mixture **5b/5a** = 80/20.

Diethyl [1,3-diphenyl-2-aziridinyl]phosphonate **5b** "trans"

Yellow oil; ^1H nmr (400 MHz) δ ppm 1.22 (t, J = 7 Hz, 3 H), 1.30 (t, J = 7 Hz, 3 H), 2.83 (dd, JH-P = 20 Hz, JH-H = 3.5 Hz, 1 H), 3.86 (dd, JH-P = 8 Hz, JH-H = 3.5 Hz, 1 H), 3.96 (m, JH-P = 3 Hz, JH-H = 7 Hz, 2 H), 4.10-4.25 (m, JH-P = 3 Hz, JH-H = 7 Hz, 2 H), 6.80-7.70 (m, 10 H).

Typical procedure for the preparation of 2-chloroaziridinylphosphonates **10**

To a stirred solution of aziridinylphosphonate **5a** (Ar^1 = Ar^2 = Ph)(10 mmol) in 30 ml of tetrahydrofuran is added dropwise a 1.6 molar solution of n-butyllithium (7.5 ml, 12 mmol) in hexane at -78°C. Stirring is continued for 10 min at -78°C during which time the solution acquires a orange color indicating the formation of the lithiated anion **9**.Then tetrachloromethane (5 ml) is added. The reaction mixture becomes dark green. Stirring is continued for 1 h at -78°C and the solution is then hydrolyzed by addition of water (40 ml) at this same temperature . The aqueous layer is extracted with dichloromethane (3 x 50ml). The combined organic layer is dried with magnesium sulfate and the solvent is removed under reduced pressure. The black residue is purified by recrystallization or by column chromatography on silica gel using hexane/ether as eluent to give the product **10** as an oil .

Diethyl [2-chloro-1,3-diphenyl-2-aziridinyl]phosphonate

Elution : hexane/ether = 3/10, 85% yield, yellow oil, ir 3060, 3040, 1600, 1265 cm^{-1}; ^1H nmr (60 MHz) δ ppm 1.00 (t, J = 6.5 Hz, 3H), 1.20 (t, J = 6.5 Hz, 3H) ; 3.30-4.50 (m, 5H) , 6.50-8.00 (m, 10H). Anal. calcd for C_{18} $H_{21}ClNO_3$ P : C, 59.09 ; H, 5.74 ; Cl, 9.71 ; N, 3.83. Found C, 58.75 ; H, 5.87 ; Cl,10.14 ; N, 3.61.

Diethyl [2-chloro-1-(p-bromophenyl)-3-phenyl-2-aziridinyl]phosphonate

Elution : hexane/ether = 1/5, 78% yield, yellow oil, ir 3075, 3040, 1590, 1265 cm^{-1}; ^1H nmr (60 MHz) δ ppm 0.75-1.55 (m, 6H), 3.30-4.50 (m, 5H), 6.60-7.70 (m, 9H). Anal. calcd for C_{18} $H_{20}BrClNO_3$ P: C, 48.59 ; H, 4.72 ; Br, 17.99 ; Cl, 7.98 ; N,3.14. Found C, 48.75 ; H, 4.87 ; Br,17.65 ; Cl, 8.03 ; N, 2.98 .

Diethyl [2-chloro-3-(o-méthylphenyl)-1-phenyl-2-aziridinyl]phosphonate

Elution : hexane/ether = 2/5, 80% yield, yellow oil, ir 3070, 3040, 1600, 1260 cm^{-1}; ^1H nmr (60 MHz) δ ppm 1.05 (t, J = 6.5 Hz , 6H), 2.45 (s, 3H), 3.30-4.50 (m, 5H) , 6.50-7.90 (m, 9H). Anal. calcd for C_{19} $H_{23}ClNO_3$ P : C, 60.07 ; H, 6.06 ; Cl, 9.35 ; N, 3.68. Found C, 59.66 ; H, 6.05 ; Cl, 9.55 ; N, 3.57.

Diethyl [2-chloro-3-(p-methoxyphenyl)-1-phenyl-2-aziridinyl]phosphonate

Elution : hexane/ether = 3/10, 90% yield, yellow oil, ir 3070, 3040, 1615, 1605, 1255 cm^{-1}; ^1H nmr (60 MHz) δ ppm 1.00 (t, J=6.5Hz, 3H), 1.20 (t, J = 6.5 Hz, 3H,), 3.10-4.60 (m, 5H), 3.70 (s, 3H) , 6.30-7.90 (m, 9H). Anal. calcd for C_{19} $H_{23}ClNO_4$ P : C, 57.64 ; H, 5.81 ; Cl, 8.97 ; N,3.53. Found C, 57.73 ; H, 5.98 ; Cl, 8.85 ; N, 3.31 .

Diethyl [2-chloro-3-(3,4-methylenedioxyphenyl)-1-phenyl-2-aziridinyl]phosphonate

Recrystallization in ether, 95% yield, mp = 97°C, ir 3070, 3040, 1600, 1260 cm^{-1}; ^1H nmr (60 MHz) δ ppm 1.05 (t, J=6.5Hz, 3H), 1.25 (t, J = 6.5 Hz, 3H), 3.20-4.40 (m, 5H), 5.90 (s, 2H), 6.50-7.50 (m, 8H). Anal. calcd for C_{19} $H_{21}ClNO_5$ P : C, 55.60 ; H, 5.61 ; Cl, 8.67 ; N, 3.42 . Found C, 55.76 ; H, 5.30 ; Cl, 8.68 ; N, 3.39.

Diethyl [2-chloro-3-(p-chlorophenyl)-1-phenyl-2-aziridinyl]phosphonate

White solid, recrystallization in hexane, 83% yield, mp = 93°C, ir 3070, 3040, 1600, 1260, 1240 cm^{-1}; ^1H nmr (60 MHz) δ ppm 1.15 (t, J = 6.5 Hz, 3H), 1.20 (t, J=6.5, 3H), 3.50-4.30 (m, 5H), 6.70-7.70 (m, 9H), Anal. calcd for C_{18} $H_{20}Cl_2NO_3$ P : C, 54.00 ; H, 5.00 ; Cl, 17.75 ; N,3.50 ; Found C, 54.03 H, 5.16 ; Cl, 17.82 ; N, 3.47.

Diethyl [2-chloro-3-(m-chlorophenyl)-1-phenyl-2-aziridinyl]phosphonate

Yellow cristals, recrystallization in hexane, 91% yield, mp = 90°C, ir 3070, 3040, 1600, 1260 1240 cm^{-1}; ^1H nmr (60 MHz) δ ppm 1.15 (t, J=6.5 Hz, 3H), 1.25 (t, J= 6.5 Hz, 3H), 3.50-4.30 (m, 5H), 6.80-7.60 (m, 9H), Anal. calcd for C_{18} $H_{20}Cl_2NO_3$ P : C, 54.00 ; H, 5.00 ; Cl, 17.75 ; N, 3.50 . Found C , 54.04 ; H, 5.07 ; Cl, 17.72 ; N, 3.46.

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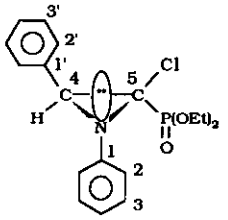

C-13 nmr data (ppm from TMS) C-1, 146.6 ; C-2, 118.7 ; C-3, 128.6 ; C-1', 132.9 ; C-2', 128.3 ; C-3', 127.5 ; C-4, 47.1 ; C-5, 65.6.

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