

CYCLIZATION OF  $\beta$ -ALKENYL-SUBSTITUTED PHOSPHONIUM  
SALTS USING 115% POLYPHOSPHORIC ACID — A NEW  
ROUTE TO CARBON-PHOSPHORUS HETEROCYCLES

By

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CYCLIZATION OF CHALAZINON-SUBSTITUTED N-HOBERNOLKINNY PHOSPHONIUM  
SALTS USING 15% TRIOXOPHOSPHORIC ACID IN DIMETHYL PHOSPHORIC ACID \*\* A NEW  
ROUTE TO CARBOROPHOSPHORASBOROPHOSPHORAS ONE-THROXPHORUS HETEROCYCLES

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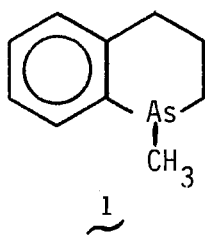
## CHAPTER I

### HISTORICAL

#### Syntheses and Chemistry of Selected Six-Membered C-P Heterocyclic Systems

##### A. Derivatives of Phosphinoline

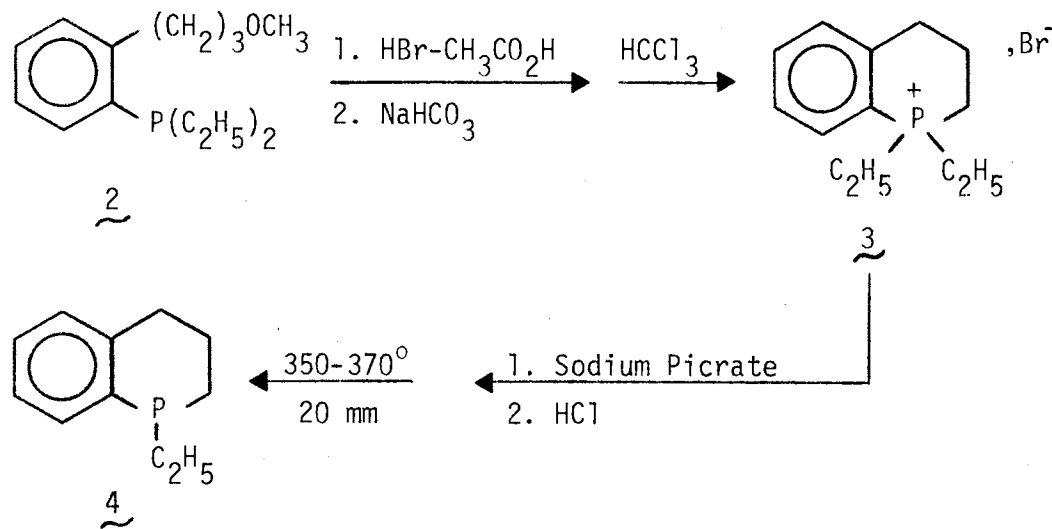
A considerable amount of the early synthetic work in the area of the phosphinoline and isophosphinoline ring systems was pioneered by Frederick Mann while much of the recent research has been done by Gottfried Märkl and co-workers. It is of interest to note that the arsenic derivative,<sup>18</sup> 1,2,3,4-tetrahydro-1-methylarsinoline (1), was



prepared some 30 years before the initial phosphinoline compound was made.

The first derivative to be synthesized was 1-ethyl-1,2,3,4-tetrahydrophosphinoline (4).<sup>9</sup> The method involved a very long reaction sequence starting with *o*-bromobenzyl bromide which was successfully converted to diethyl-(*o*-(3-methoxypropyl)phenyl)phosphine (2). The methoxy group was replaced by bromine when 2 was boiled in hydrobromic acid-acetic acid, giving the hydrobromide derivative. Basification gave the

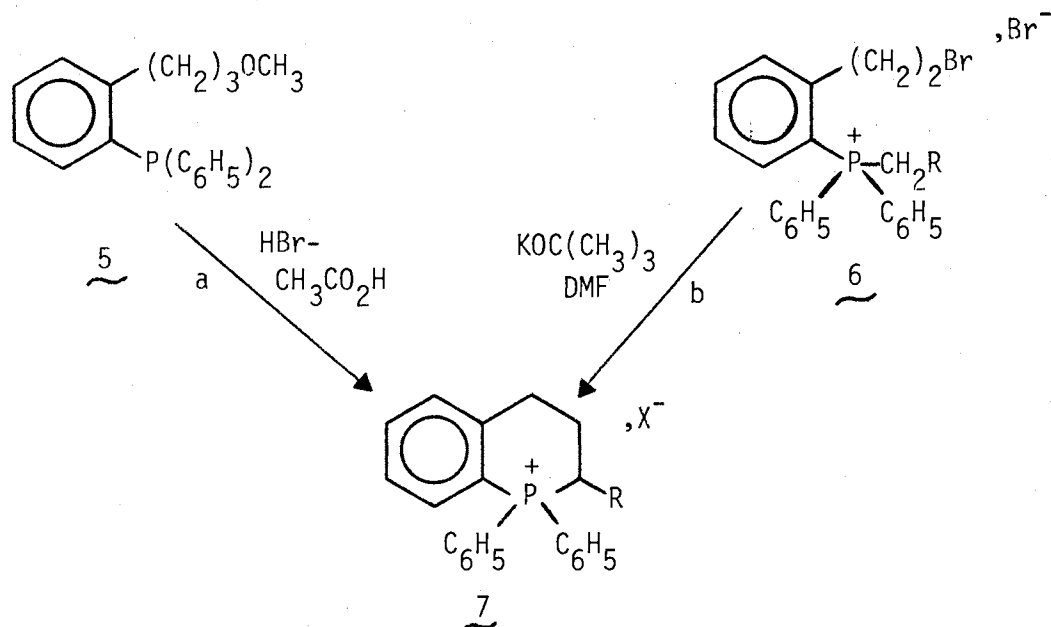
phosphine, which in chloroform cyclized to 1,1-diethyl-1,2,3,4-tetra-



hydrophosphinolinium bromide (**3**). This compound was converted, via the picrate, into the pure chloride, which at 350-370°/20 mm decomposed smoothly to give 1-ethyl-1,2,3,4-tetrahydrophosphinoline (**4**), b.p. 141-143°/18 mm (78%).<sup>9</sup> It was further characterized by its methiodide and methopicrate derivatives.

Märkl, working along a similar synthetic route,<sup>74</sup> showed that [o-(3-methoxypropyl)phenyl]diphenylphosphine (**5**), treated as with **2** above, reacted by direct intramolecular quaternization during cleavage of the ether, giving 1,2,3,4-tetrahydro-1,1-diphenylphosphinolinium tetrafluoroborate (**7a**), m.p. 193-195° (74%). Again starting materials are very difficultly accessible. Similarly, benzyl-[o-(2-bromoethyl)phenyl]-diphenylphosphinolinium bromide (**6**) undergoes intramolecular C-alkylation<sup>77</sup> to give 1,2,3,4-tetrahydro-1,1,2-triphenylphosphinolinium tetrafluoroborate (**7b**).

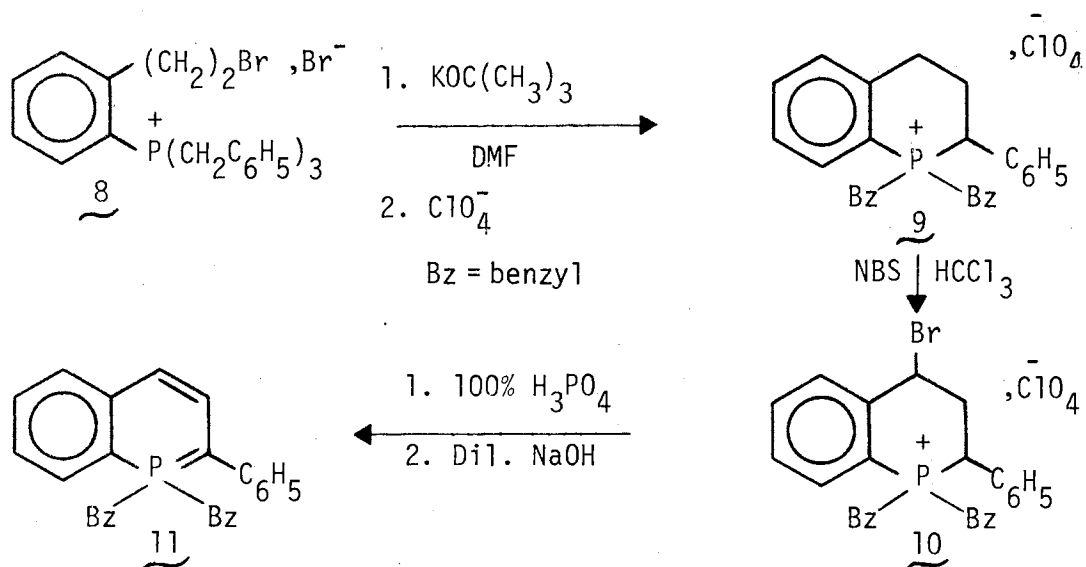
In the preparation of a 1,1-disubstituted phosphanaphthalene derivative, Märkl and Heier<sup>81</sup> once again used intramolecular C-alkylation to obtain an intermediate phosphinoline. When **8** was treated with potassium tert.-butoxide in DMF, **9** was isolated, and this underwent



	R	X <sup>-</sup>	m.p., °C	%
a	H	BF <sub>4</sub>	193-195	74
b	C <sub>6</sub> H <sub>5</sub>	BF <sub>4</sub>	248-250	68

bromination in the 4-position when treated with NBS in chloroform.

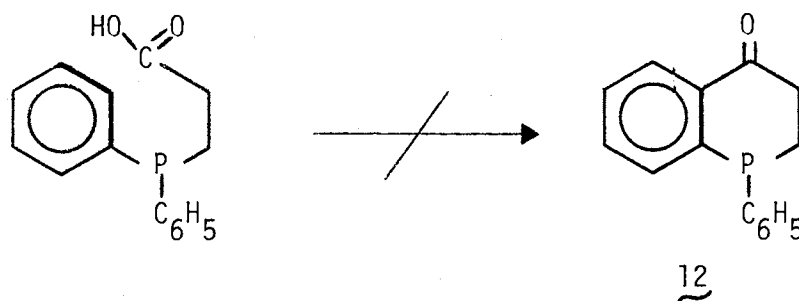
Treatment of **10** with 100%  $\text{H}_3\text{PO}_4$  caused debromination followed by isomer-



ization and, upon addition of  $\text{NaOH}$ , deprotonation resulted in the formation of 1,1-dibenzyl-2-phenyl-1-phosphaphthalene (**11**).

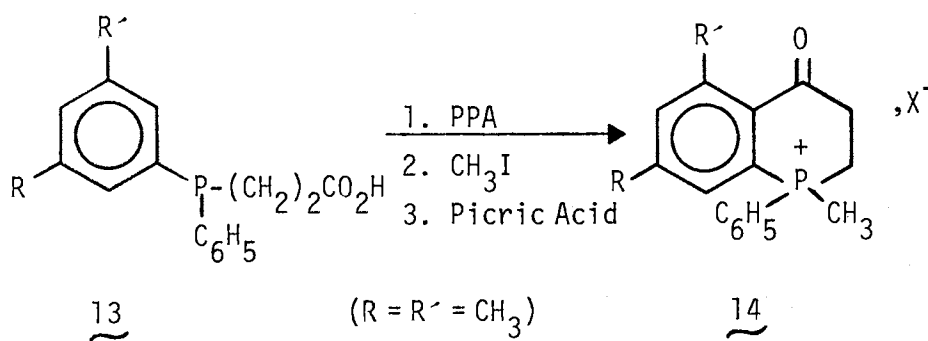
Very few derivatives of 1,2,3,4-tetrahydrophosphinoline containing substituents in positions other than 1 or 2 have been prepared. An

early attempt to synthesize the ketophosphine 12 by the cyclization of 3-(diphenylphosphino)propionic acid failed,<sup>72</sup> but the corresponding



(diphenylamino)propionic acid readily gave the 1,2,3,4-tetrahydro-1-phenyl-4-quinolinone.<sup>27</sup>

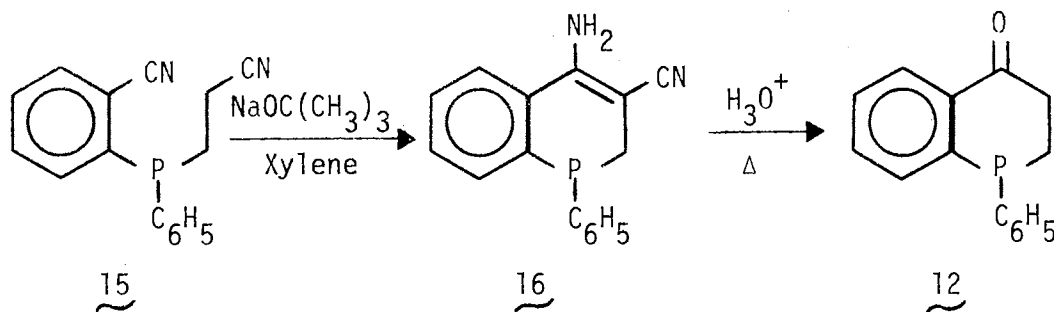
Gallagher, Kirby, and Mann<sup>40</sup> later investigated the preparation of several ketophosphines using different reaction routes. The first approach involved the open-chain propionic acid 13. Several reagents were employed to induce cyclization, but only polyphosphoric acid



(percent was not stated) proved useful. The product was isolated as the methopicrate, i.e., 1,2,3,4-tetrahydro-1,5,7-trimethyl-4-oxo-1-phenylphosphinolinium picrate (14) [ $X = C_6H_2N_3O_7$ , m.p. 170-171°]. The low yield obtained by this route made the practical value very questionable.

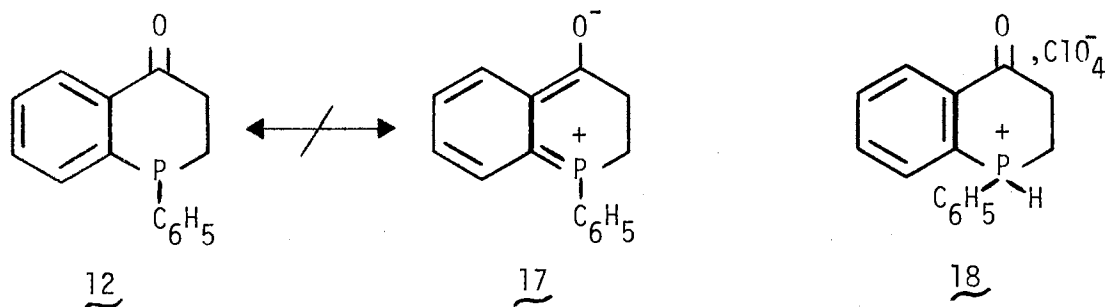
The second method involved the use of standard reactions to prepare the 4-oxo derivative. o-Bromoaniline was converted through a long

series of reactions to 2-cyanoethyl-(*o*-cyanophenyl)phenylphosphine (15),<sup>40</sup> which, under basic conditions, underwent an internal cyclization to 16. Vigorous acidic hydrolysis gave the colorless 1,2,3,4-tetra-



hydro-1-phenyl-4-phosphinolone (12), b.p. 143-145°/0.05 mm, m.p. 46-47°.

The properties of 12 were studied in some detail. Its reactions included the formation of a methopicate, a 1-oxide derivative, a semi-carbazone of the carbonyl group, and the perchlorate using aqueous perchloric acid.<sup>40</sup> The infrared spectrum of phosphine 12 shows a strong

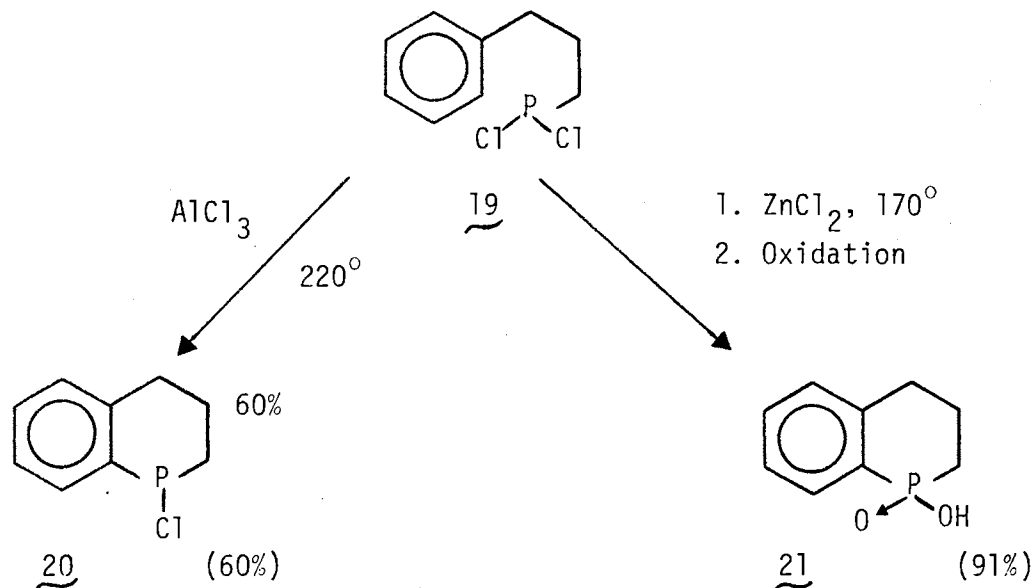


C=O band at 1680  $\text{cm}^{-1}$  while the oxide shows a band at 1700  $\text{cm}^{-1}$ , the change apparently being due to the inductive effect of the P=O group, which has a strong absorption at 1190  $\text{cm}^{-1}$ . The spectrum of the perchlorate 18 showed a C=O band at 1687  $\text{cm}^{-1}$ , but no OH absorption was found. With the shift in the carbonyl function and the absence of the OH group, the implication is that the electronic interaction between

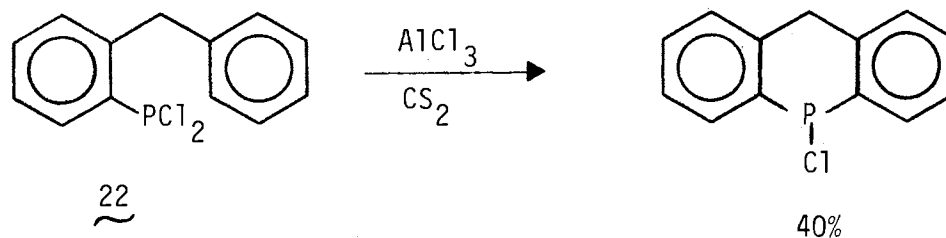


the nonbonded electron pair on the phosphorus in 12 and the  $\pi$  system is small. Also, the UV spectrum of the phosphine (and its 1-oxide) in ethanol was unaffected by the addition of hydrochloric acid. This supports the point that 17 does not contribute much to the hybrid and protonation principally occurs at phosphorus to give 18.

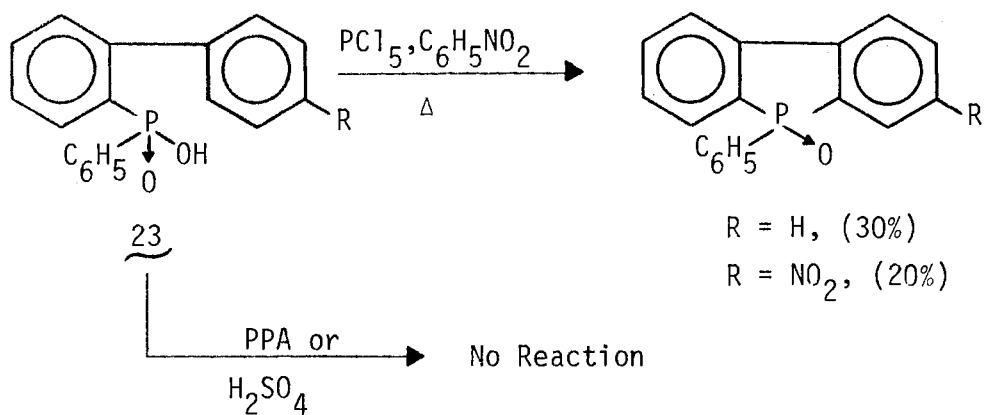
In several recent developments, the phosphinoline system has been prepared from compounds that undergo cyclization at phosphorus. It was shown that 19 could be treated with several cyclizing agents to yield different 1,2,3,4-tetrahydrophosphinolines.<sup>103</sup>



The key to success for this cyclization may be the choice of an appropriate Lewis acid with the absence of solvent. It was demonstrated in a very similar reaction that 22 could be used to prepare the

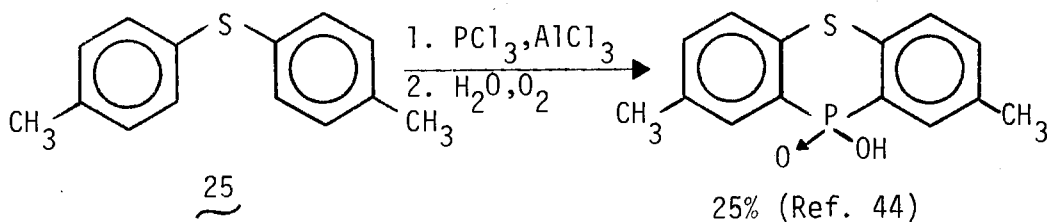
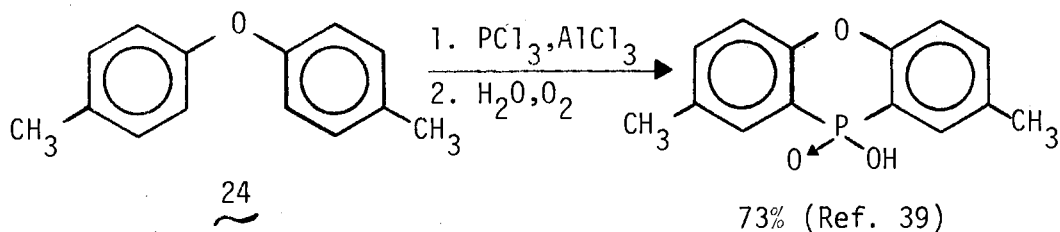


tricyclic C-P heterocycle but only in low yield.<sup>61</sup> Lewis acids are sometimes superior to very strong protonic acids as shown by the fact that 23 is unaffected by polyphosphoric acid or  $H_2SO_4$ , but cyclized

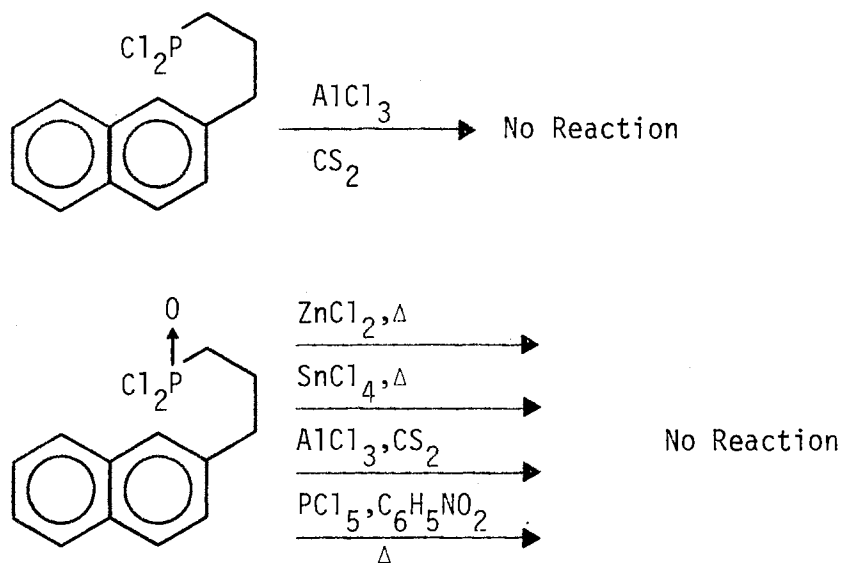


upon treatment with  $\text{PCl}_5$ .<sup>19</sup> Again yields were only modest.

Other systems have shown that the cyclization is dependent upon substituents on the phosphorus-containing compounds. When 24 and 25



were treated in almost exactly the same manner as previously cited, the increase in yield was dramatic. Later, it was pointed out by Chen<sup>24</sup> that the following reactions failed to give the desired cyclized product. This is a very surprising result because the C-1 position in

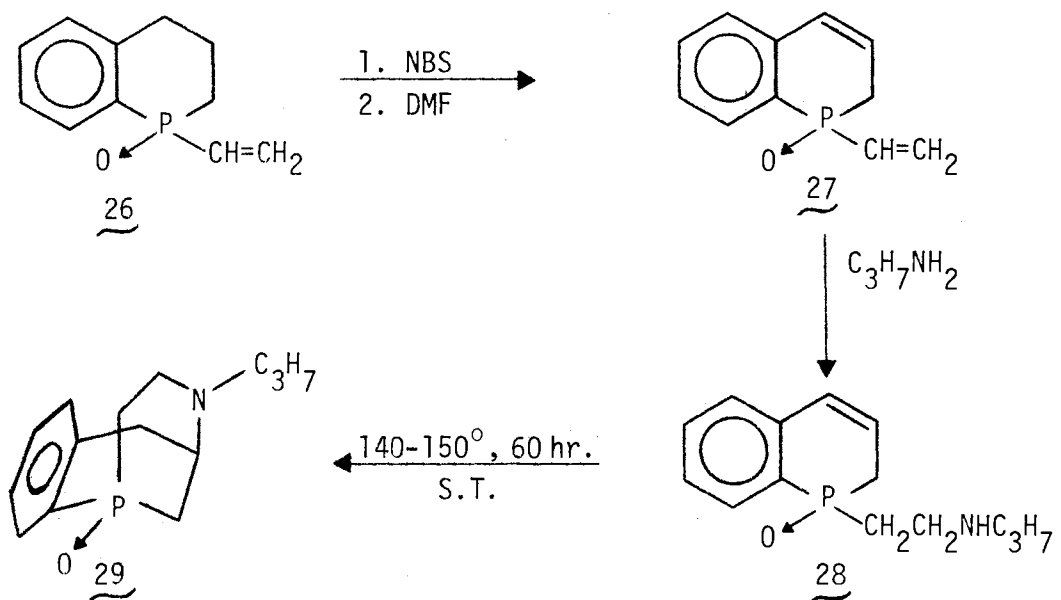


naphthalene is usually very reactive toward electrophilic substitution.<sup>68</sup> A steric factor could not be eliminated from consideration.

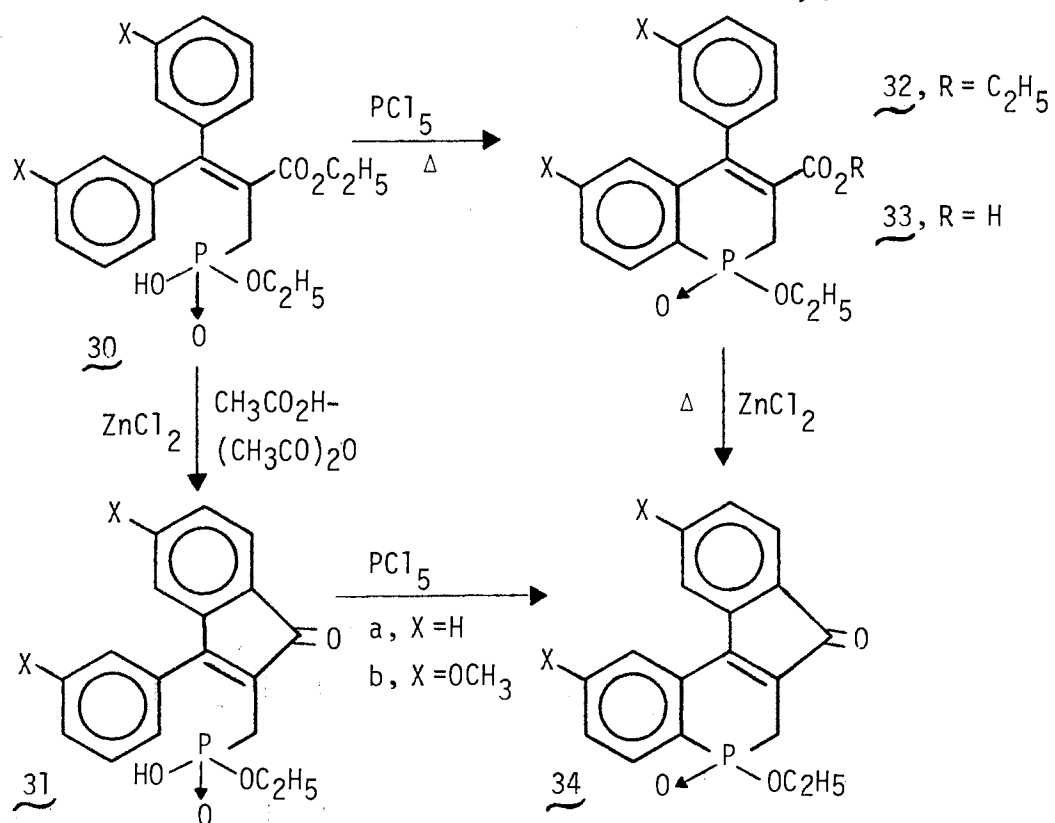
Treatment of 21 with  $\text{SOCl}_2$  gave the 1-chloro derivative which, on reaction with the appropriate Grignard reagent, gave the 1-ethyl- or 1-phenyl-1,2,3,4-tetrahydrophosphinoline 1-oxide. When the 1-ethyl derivative was reduced with trichlorosilane followed by treatment with sulfur, there resulted a phosphine sulfide derivative.

Acid 21 was converted via the corresponding acid chloride into the substituted 1-vinylphosphine oxide 26.<sup>25</sup> The reaction of 26 with NBS<sup>74</sup>, followed by treatment with DMF gave 27, which underwent a Michael-type addition with propylamine to give 1-[2-(propylamino)ethyl]-1,2-dihydrophosphinoline 1-oxide (28). Upon heating 60 hr. in a sealed tube at 140-150°, the amine was converted to 4-propyl-1,2,3,4,5,6-hexahydro-1,5-methano-4,1-benzazaphosphocine 1-oxide (29).<sup>25</sup>

In similar fashion, Griffin and Bryant<sup>47</sup> utilized the Stobbe condensation<sup>90</sup> to prepare half esters of  $\gamma$ -substituted allylphosphonic



acids, e.g., ethyl hydrogen  $\beta$ -carbethoxy- $\gamma,\gamma$ -diphenylallylphosphonate (**30**). Compounds of this structure possess the correct functionality for cyclizations at phosphorus to form 1,2-dihydrophosphinolines **32** or **33**, or at carbon to form oxoindenonylmethylphosphonates **31**.

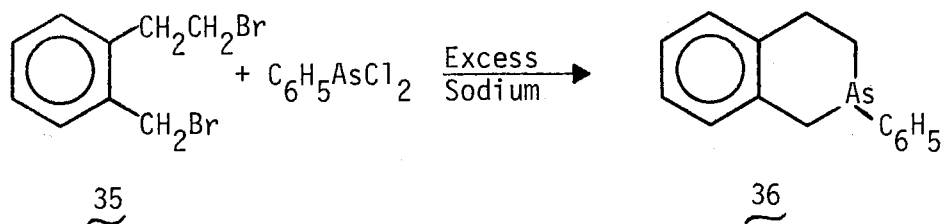


Treatment of 30a with phosphorus pentachloride yields 33a which, on esterification followed by treatment with zinc chloride, yields the tetracyclic oxoindenonodihydrophosphinoline, 3-ethoxy-3-phospha-1,2-benzo-3,4-dihydrofluorenone 3-oxide (34a).<sup>47</sup> When 30a was treated with zinc chloride in acetic acid-acetic anhydride, 31a was produced; this was also transformed to 34a by the use of phosphorus pentachloride. Similar cyclizations were achieved with 30b. Although the yields of 33a and 33b were extremely low (7% and 11%, respectively), other cyclizing reagents (phosphorus pentachloride and stannic chloride, phosphorus pentoxide, aluminum chloride in benzene, or phosphorus pentachloride in nitrobenzene<sup>19</sup>), were even less effective.

#### B. Derivatives of Isophosphinoline

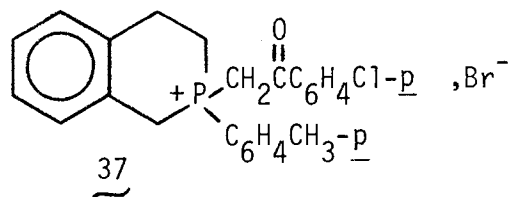
Although derivatives of this class were successfully prepared before the corresponding phosphinolines, very few synthetic methods have been developed to make the isophosphinoline a relatively simple system to obtain. Many of the older techniques closely parallel those used to prepare and isolate the phosphinolines.

The first successful synthesis of an isoarsinoline system<sup>52</sup> used

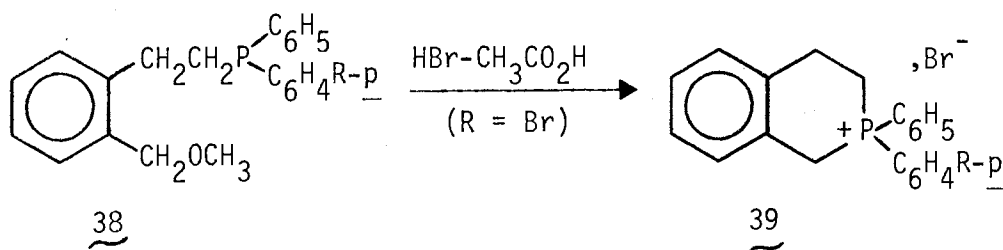


an equimolecular mixture of 35 and phenylarsonous dichloride in boiling ether with an excess of sodium wire to give 36 in 31% yield upon distillation. Phenylphosponous dichloride similarly treated with 35

gave no useful results; p-tolylphosphonous dichloride<sup>53</sup> gave the isophosphinoline in very small yield, identified only by quaternization with p-chlorophenacyl bromide to form 2-(p-chlorophenacyl)-1,2,3,4-tetrahydro-2-p-tolylisophosphinolinium bromide (37), m.p. 227-230°.

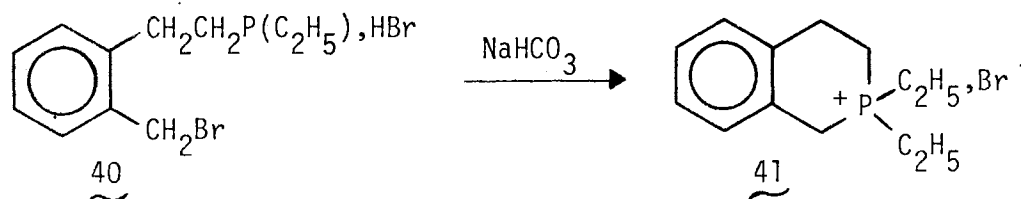


In a preparation very similar to that of 7, the phosphine 38 in hydrobromic acid-acetic acid was heated to produce the bromomethyl phosphine which then underwent an internal cyclization to form 2-(p-bromophenyl)-1,2,3,4-tetrahydro-2-phenylisophosphinolinium bromide (39), m.p. 218-221° (picrate, m.p. 186-187°).<sup>53</sup> The 2-(p-hydroxyphenyl)



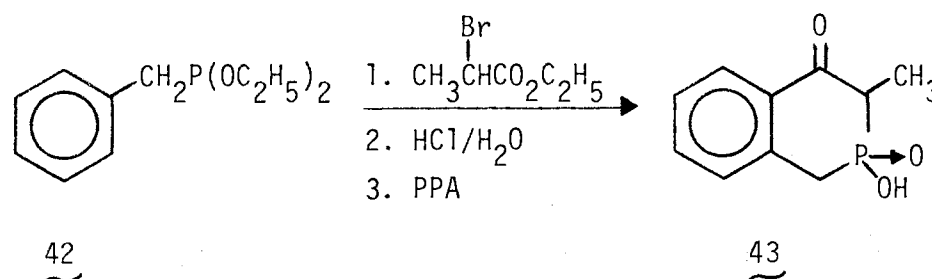
derivative was also produced in 75% yield.

Similarly, an isomer<sup>9</sup> of 4 was prepared in essentially the same fashion. The hydrobromide 40, obtained from the ether cleavage, upon treatment with sodium bicarbonate, liberated the phosphine which cyclized to 41. Treatment of 41, exactly like 3, gave pure 2-ethyl-1,2,3,4-tetrahydroisophosphinoline, b.p. 129-132°/15 mm (78%), which



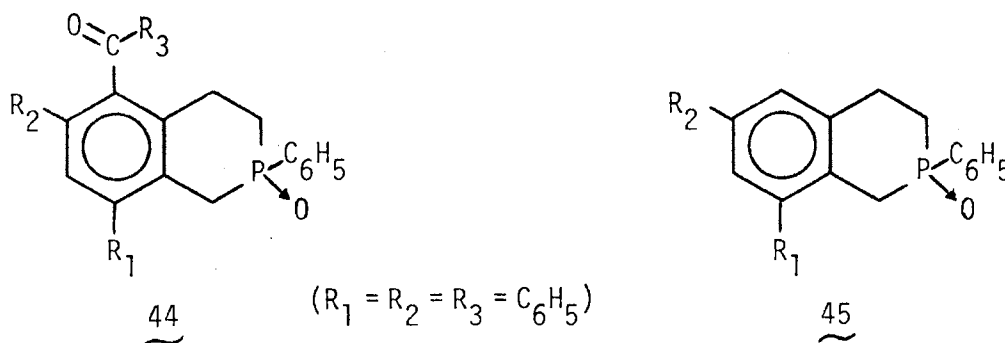
was further characterized as the ethiodide, m.p. 93-94°.

In an entirely different approach, Bickelhaupt and co-workers<sup>31</sup> used Henning's synthesis<sup>51</sup> to prepare a 4-ketoisophosphinoline which served as a precursor for the preparation of 3-methyl-2-phosphanaphthalene. Diethyl benzylphosphonite (42) was condensed with the



appropriate bromo ester and, following hydrolysis, was cyclized to 43 by the use of polyphosphoric acid (as before, no concentration was given<sup>31</sup>). Several additional steps were required to produce the product, and the yield was extremely low.<sup>31</sup>

In an elegant reaction scheme,<sup>79</sup> Märkl and Baier prepared the enamines of 1-phenyl-4-phosphorinanone and its oxide with both morpholine and pyrrolidine. Treatment of these enamines with the corresponding

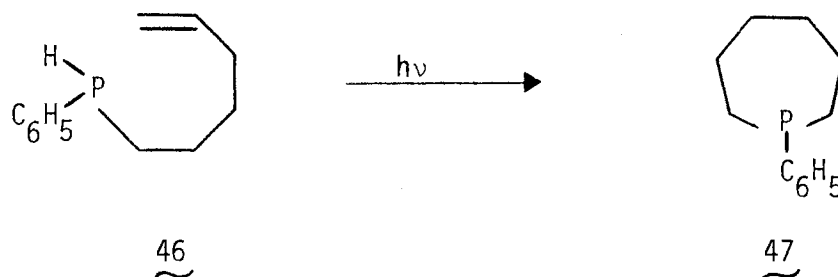


pyrylium salts caused a cycloaddition reaction which resulted in the formation of 44 and 45. Further use of this procedure gave the large eight-membered phosphacyclooctadiene derivatives.<sup>79</sup>

### Syntheses and Chemistry of Selected Seven- Membered C-P Heterocyclic Systems

#### A. Derivatives of Phosphepanes

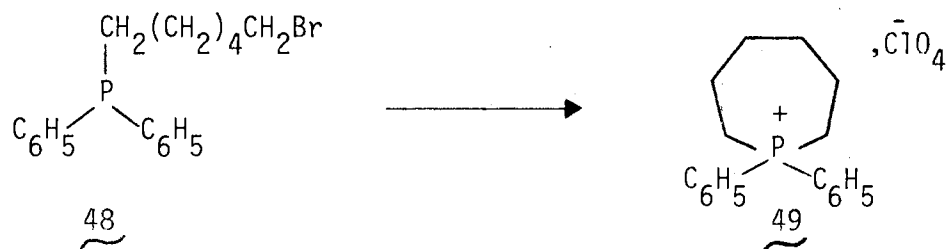
An interesting feature of the synthesis of the phosphepane ring system is that the phospholane and phosphorinane derivatives (5 and 6-membered ring systems, respectively) can be similarly prepared in good yields. Cyclic phosphines were prepared by UV irradiation of secondary alkenylphosphines.<sup>29</sup> 1-Phenylphosphepane (47) was obtained by irradiating (5-hexenyl)phenylphosphine (46) in boiling petroleum ether



with light (360 nm) for 80 hr. Distillation of 47 showed it to be somewhat impure and it was converted to the phosphine sulfide. Although the cyclization worked very well for the phospholane and phosphorinane derivatives, a limit seemed to be reached at phosphepane.

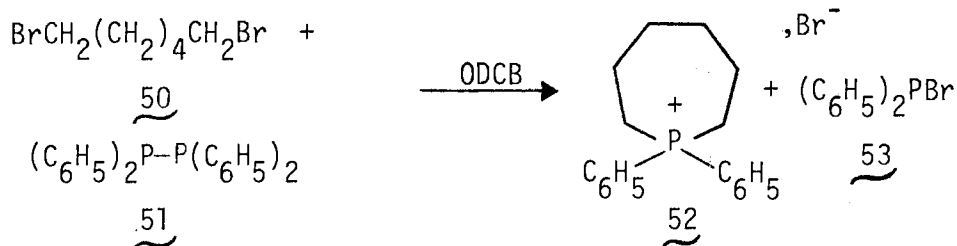
Märkl used dibromoalkanes in a novel synthesis of cyclic phosphonium salts.<sup>75</sup> A slow addition of diphenylphosphinopotassium in a mixture of dioxane and THF to a boiling solution of 1,6-dibromohexane gave 48, which at once underwent an internal cyclization to give 49 as





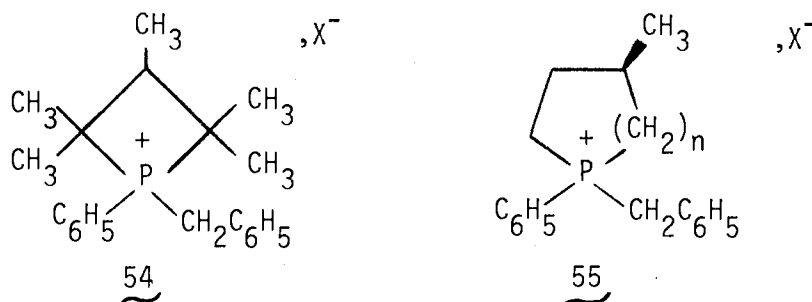
the perchlorate, m.p.  $208^\circ$  (36%).

In a related procedure,<sup>76</sup> Märkl once again used dibromoalkanes to produce cyclic salts. A solution of 2 moles of 1,6-dibromohexane (50) and 1 mole of tetraphenyldiphosphine (51) in o-dichlorobenzene was added dropwise to boiling o-dichlorobenzene. Heterocycle 52 was



isolated in 54% yield, m.p.  $245-247^\circ$ . Marsi and co-workers<sup>89</sup> later investigated this reaction in detail and concluded that no significant differences in yields could be detected when the ratio of 50 to 51 was changed from 2:1 to 1:1. It was also determined that 53 plays no significant role in the mechanism of the ring closure.

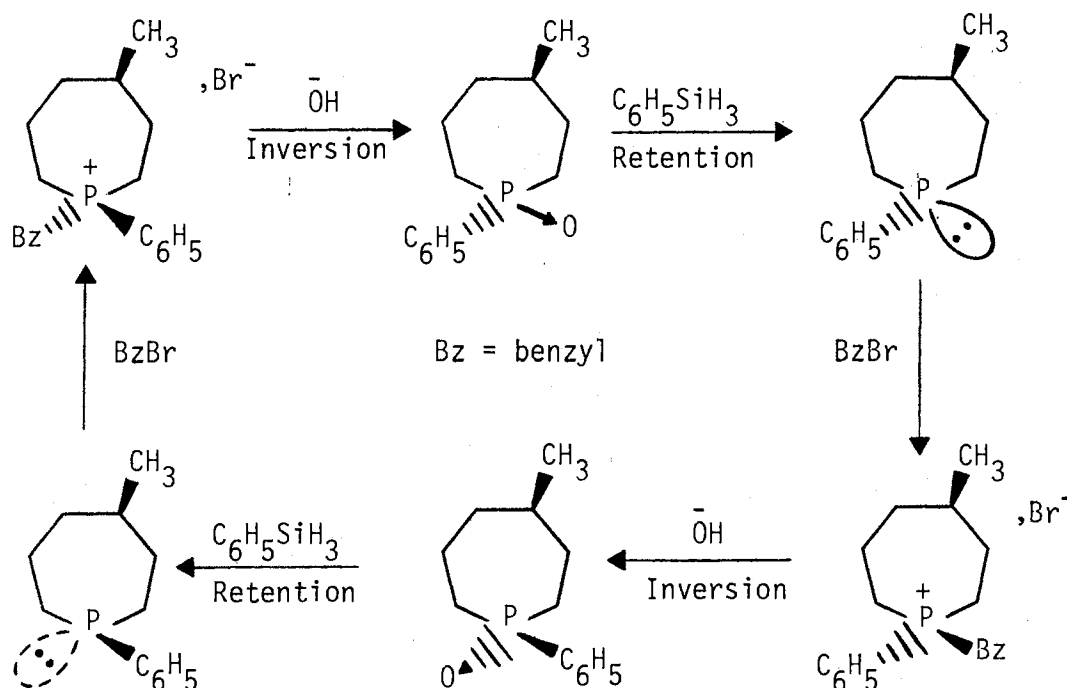
The stereochemistry of nucleophilic substitution at phosphorus



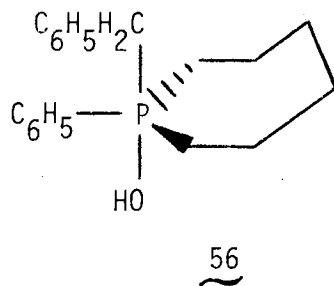
contained in saturated heterocyclic phosphonium salts has been extensively reviewed.<sup>69</sup> When the alkaline hydrolysis of the pure cis and trans phosphetanium salts 54 was performed, decomposition resulted in retention of configuration to give identical cis and trans oxides, respectively.<sup>28</sup> However, when cis/trans mixtures were treated similarly, different product ratios were obtained which suggested that isomer crossover must be taking place.

Retention of configuration was found to occur exclusively when either pure cis or trans phospholanium salts 55 ( $n=1$ ) or mixtures of cis/trans isomers were subjected to alkaline hydrolysis.<sup>35,85,86</sup> As expected, mixtures of isomeric oxides of different composition were obtained when pure cis and trans phosphorinanium salts 55 ( $n=2$ ) were hydrolyzed.<sup>88</sup>

It has now been shown that base-catalyzed cleavage of the cis- and trans-1-benzyl-4-methyl-1-phenylphosphhepanium salts occurred with complete inversion of configuration at phosphorus.<sup>87</sup> Using the knowledge



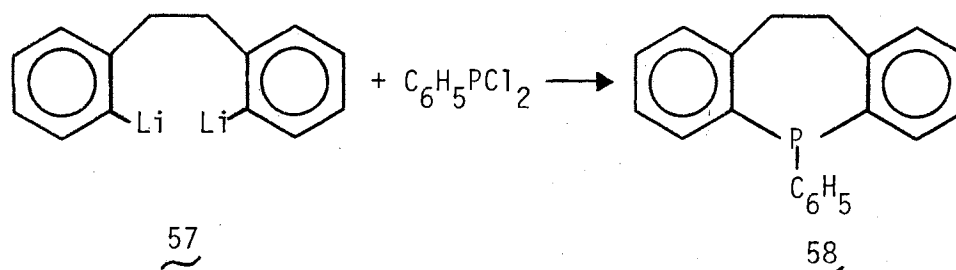
that the inversion of configuration at phosphorus converted the cis isomer into the trans isomer, one could speculate that the intermediate



in the seven-membered ring would possess bonding to P involving two equatorial bonds. Thus, the entering nucleophile ( $\bar{\text{O}}\text{H}$ ) and the potential leaving group [ $\text{C}_6\text{H}_5\bar{\text{C}}\text{H}_2$ ] would be bonded in apical positions.

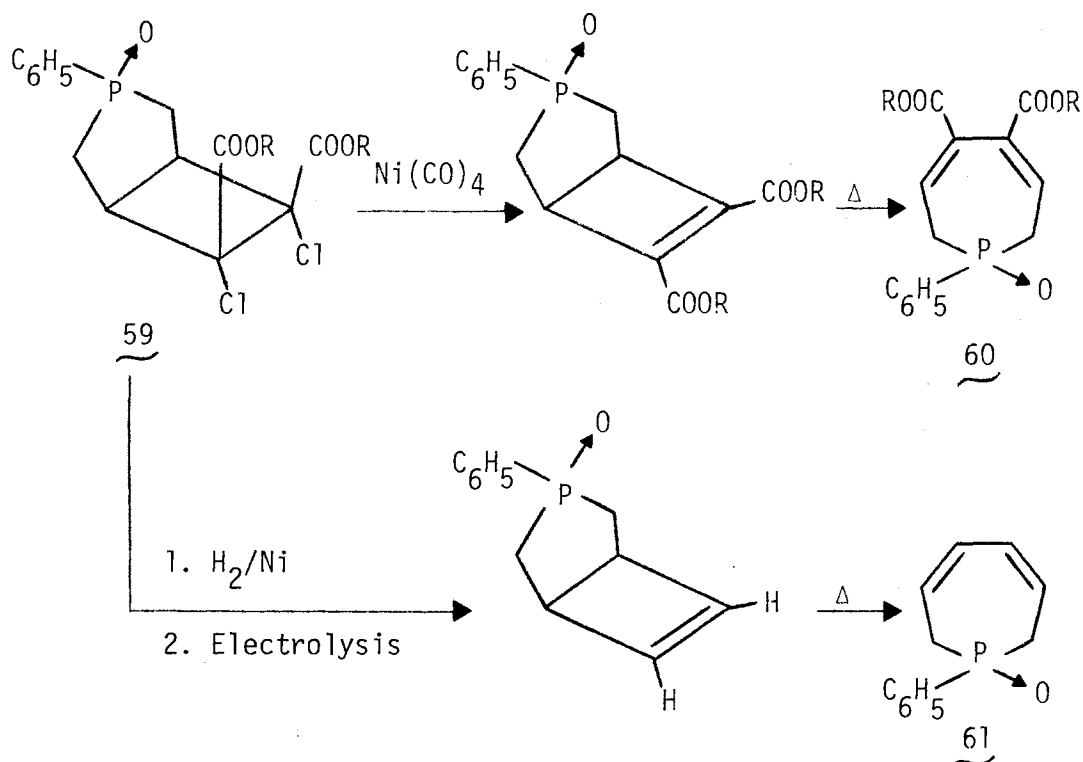
#### B. Derivatives of Phosphepin

Owing to scarcity of synthetic methods that makes the phosphepin a very rare ring system, most of the research in this area has been done within the past several years. 10,11-Dihydro-5-phenyl-5H-dibenzo[b,f]phosphepin (58) [and the corresponding arsenic analog] were



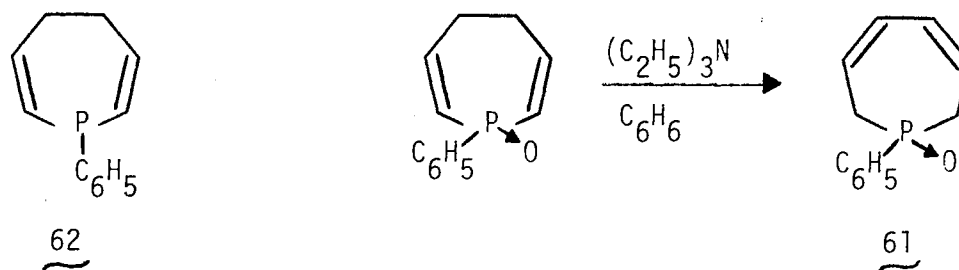
prepared similarly with the use of 2,2'-dibromobibenzyl.<sup>73</sup> The dilithio compound 57 in benzene-petroleum ether was treated with phenylphosphorous dichloride to give 58, which was also characterized as the 5-oxide (m.p. 173.5-174.5°) and the methiodide (m.p. 251-252°).

A Diels-Alder reaction was used to produce 59 which, upon treatment with  $\text{Ni}(\text{CO})_4$  followed by pyrolysis, gave 60, b.p.  $230^\circ/0.1 \text{ mm.}$ <sup>84</sup>



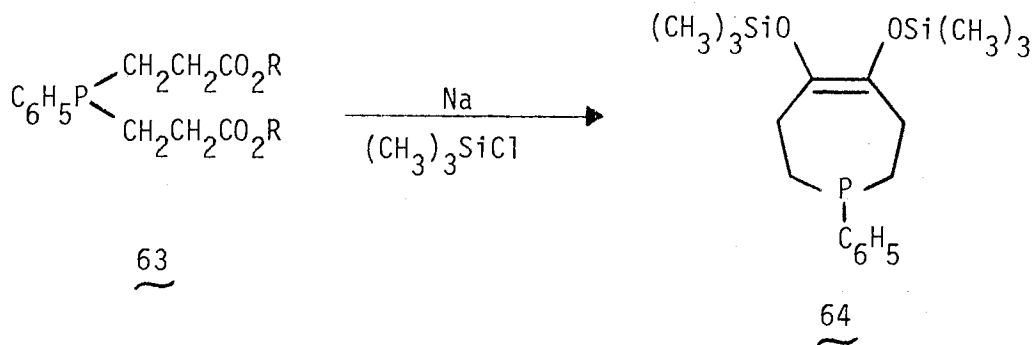
Similarly, 59 was hydrogenated and electrolyzed; these processes were followed by pyrolysis and gave 61, b.p.  $160^\circ/0.2 \text{ mm.}$  1-Phenyl-1-oxo-phosphapentadiene was made when 61 was treated with bromine followed by elimination of two equivalents of  $\text{HBr}$  with triethylamine.<sup>84</sup>

In a very recent article,<sup>80</sup> 62 and its arsenic analog were obtained



by the cycloaddition of phenylphosphine and 1,5-hexadiyne.<sup>80</sup> The oxide of 62 was also converted to 61 by the use of triethylamine.

In an attempt to synthesize C-P heterocycles with a ring size larger than six, an acyloin-type condensation was employed as a preparative method.<sup>115</sup> The intramolecular cyclization of 63 was carried out by



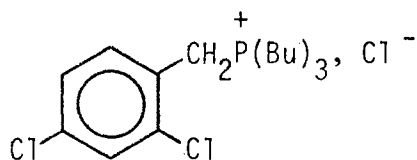
the Ruhlmann technique in the presence of trimethylsilyl chloride with toluene as the solvent to produce 64.<sup>115</sup> This process circumvents working in high dilutions as is necessary for the carbocyclic system. However, as the ring size increases, the corresponding yields of phosphorus heterocycles also decrease in the order 7>8>9 = 10>11 members in the ring.

#### Biological Activity of Phosphorus Compounds

When examining the literature concerning the biological activity of heterocyclic systems, it is evident that a vast amount of this work concerns the oxygen, sulfur, and nitrogen derivatives, plus combinations of them. Although some open-chain and heterocyclic phosphorus compounds have been tested, very few of them have a structure that does not contain at least one of the above hetero atoms.

One of the largest classes of phosphorus compounds to be tested for biological activity is the open-chain phosphonium salts. In an

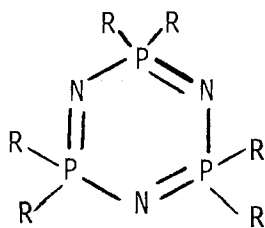
extensive review,<sup>7</sup> many successful applications were listed. The compound that probably has the most biological significance is phosfon [2,4-dichlorobenzyl)tributylphosphonium chloride] (65). Although its major



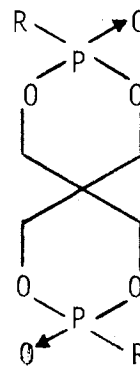
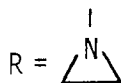
65

uses are plant protection<sup>119</sup> and plant growth regulation,<sup>22</sup> to list all of its applications is impractical.

Organophosphorus chemistry has made significant contributions to the area of insecticides and pesticides. Several recent reviews<sup>38,98</sup> have covered many of the technical considerations plus the enormous amount of chemistry that is involved. One of the first compounds to be used as a sexual chemosterilant was 66, which was found effective



66

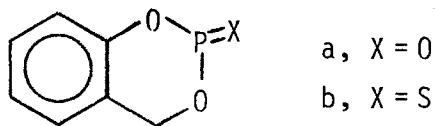


67

against Callitroga hominivorax.<sup>23</sup> It is interesting to note that when derivatives of 66 are used without the 1-aziridinyl groups, the

compounds are inactive. When, as in 67, two aziridinyl groups are present, the chemistry is much the same as that of 66.<sup>21</sup>

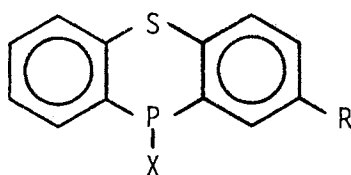
Salioxon (68a) and Salithiov (68b) (trade names) are compounds that



68

are effective insecticides, their toxicity in mice being much less than that of parathion<sup>36</sup> (oral LD<sub>50</sub> for 68a: 30 mg/kg, 68b: 91 mg/kg). Used along with malathion, 68a acts synergistically against resistant house flies and the silkworm. Aryl groups decrease insecticidal activity and increase synergistic properties. Small alkyl groups increase insecticidal activity and diminish the synergistic action with malathion; these observations are explained by steric effects.<sup>36</sup>

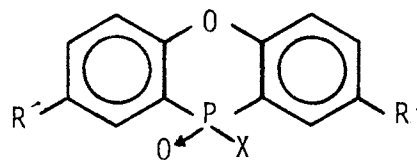
Recently several tricyclic derivatives have shown biological activity. Heterocycle 69 has caused depression of spontaneous activity



69

R = Cl, S $\text{CH}_3$ , O $\text{CH}_3$

X = (CH<sub>2</sub>)<sub>3</sub>N(CH<sub>3</sub>)<sub>2</sub>



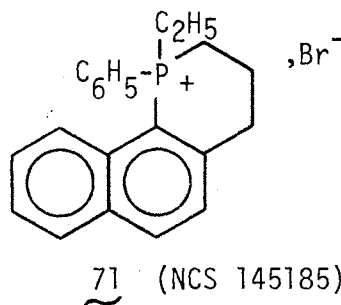
70

R' = Cl, Br, lower alkyl, lower alkoxy

X = lower alkyl, lower alkoxy

in mice in the 30-50 mg/kg dosage range,<sup>118</sup> while 69 ( $X = -CH_2C_6H_5$ ,  $R=H$ ) and the 10-phenyl 10-sulfide of 69 have shown fungicidal activity.<sup>16</sup> The oxygen analog 70 has also been used as a fungicide.<sup>109</sup> It is worthy of note that the nitrogen analog of 69 [phenothiazine;  $PX = NCH_2CH_2N(CH_3)_2$ ] has had some antiParkinson activity, and like atropine, possesses significant anticholinergic, antihistaminic, sedative, and local anaesthetic properties.<sup>106</sup>

Recently, the cyclic phosphonium system 71 was prepared and testing has confirmed the compound to be active against 3P531<sup>C</sup> system



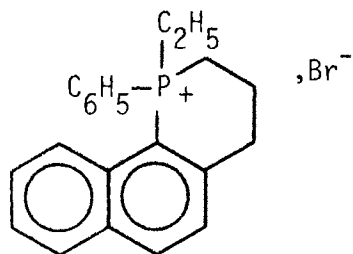
[P388 lymphocytic leukemia cell line].<sup>24</sup> This small breakthrough may be an indication that interest in this class of compounds will increase not only from a medicinal point of view, but also from a synthetic standpoint.



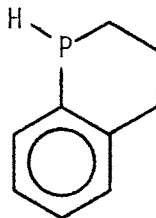
## CHAPTER II

### RESULTS AND DISCUSSION

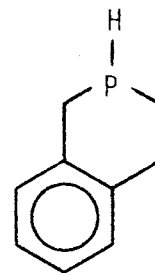
Biological activity of carbon-phosphorus (C-P) heterocycles has rarely been recorded. One reason for this fact lies in the scarcity of good synthetic methods for this class of organophosphorus compounds. A major impetus for this research developed in part from encouragement by the National Cancer Institute which determined the initial (and later reconfirmed) moderate activity for 71<sup>24</sup> (NSC 145185) against P388



71 (NCS 145185)



91



92

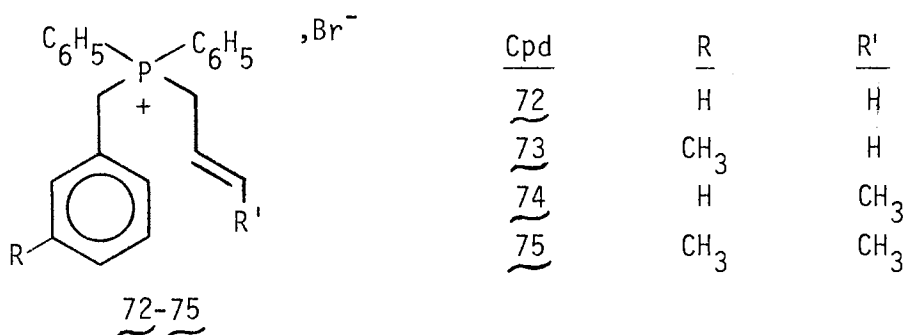
lymphocytic leukemia. The basic ring structure in 1-ethyl-1,2,3,4-tetrahydro-1-phenylbenzo[h]phosphinolinium bromide (71) is that of phosphinoline (91). The isophosphinoline structure is shown as 92.

Although a few phosphinolines,<sup>12,24,47,70,81,82,92</sup> isophosphinolines,<sup>12,31,70,79</sup> and phosphepins<sup>80,84,115</sup> can be found in scattered reports only in the past 20 years, they are generally prepared with

multi-step reaction sequences. Thus, one objective became to devise an approach to C-P heterocycles in these families utilizing short reaction schemes from readily available starting materials.

Three 4,7-disubstituted 1,2,3,4-tetrahydro-2,2-diphenylisophosphinolinium hexafluorophosphates and two 8-substituted 2,3,4,5-tetrahydro-5-methyl-2,2-diphenyl-1H-benzo[c]phosphepinium hexafluorophosphates have been prepared (Table I). Similarly, four 1-substituted and 1,7,8-trisubstituted 1,2,3,4-tetrahydro-4-methyl-1-phenylphosphinolinium hexafluorophosphates were synthesized (Table II). Model compounds were obtained with the intention of testing the critical cyclization step using 115% polyphosphoric acid (PPA) as the cyclizing reagent before longer syntheses were initiated for 82-90. Model compounds consisted of eight  $\beta$ -alkenyl-substituted phosphonium salts (Figures I and II) and one vinyl-substituted phosphonium salt (Figure III), two of which had previously been reported in lower yield.<sup>13,105</sup>

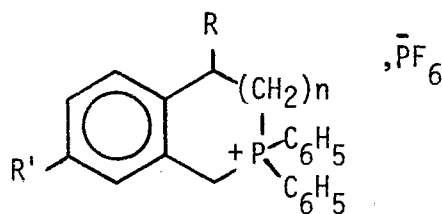
Our initial efforts were concerned with the development of approaches to the open-chain  $\beta$ -alkenylarylmethyldiphenylphosphonium bromides 72-75. All early attempts to prepare benzyldiphenylphos-



phine by the reaction of benzylmagnesium chloride and diphenylphosphinous chloride resulted in oxide formation (identified by melting point,<sup>34</sup> IR, and NMR). This probably accounts for the moderate yield

TABLE I

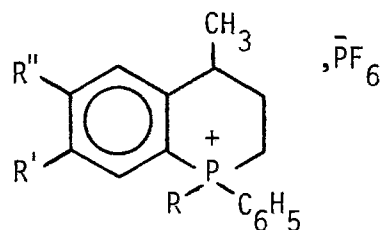
## 1,2,3,4-TETRAHYDROISOPHOSPHINOLINIUM HEXAFLUOROPHOSPHATE AND 2,3,4,5-TETRAHYDRO-1H-BENZO [c]PHOSPHEPINIUM HEXAFLUOROPHOSPHATE DERIVATIVES



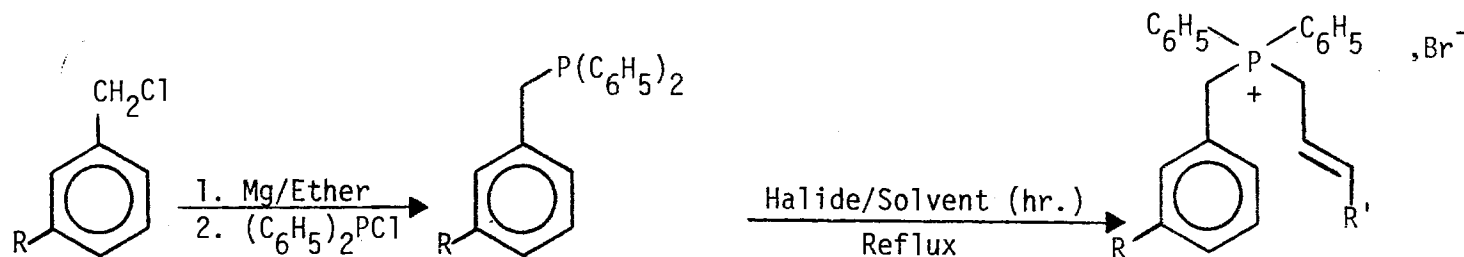
Compound Name	Cpd.	n	R	R'	m.p., °C	Yield %
1,2,3,4-Tetrahydro-2,2-diphenylisophosphinolinium Hexafluorophosphate	<u>82</u>	1	H	H	174-176	51
1,2,3,4-Tetrahydro-4-methyl-2,2-diphenylisophosphinolinium Hexafluorophosphate	<u>83</u>	1	CH <sub>3</sub>	H	172.5-174.5	73
1,2,3,4-Tetrahydro-4,7-dimethyl-2,2-diphenylisophosphinolinium Hexafluorophosphate	<u>84</u>	1	CH <sub>3</sub>	CH <sub>3</sub>	185.5-187	28
2,3,4,5-Tetrahydro-5-methyl-2,2-diphenyl-1H-benzo [c]phosphepinium Hexafluorophosphate	<u>85</u>	2	CH <sub>3</sub>	H	214-216	30
2,3,4,5-Tetrahydro-5,8-dimethyl-2,2-diphenyl-1H-benzo [c]phosphepinium Hexafluorophosphate	<u>86</u>	2	CH <sub>3</sub>	CH <sub>3</sub>	233-235	24

TABLE II

## 1,2,3,4-TETRAHYDROPHOSPHINOLINIUM HEXAFLUOROPHOSPHATE DERIVATIVES



Compound Name	Cpd.	R	R' = R''	R' + R''	m.p., °C	Yield %
1,2,3,4-Tetrahydro-1,4-dimethyl-1-phenylphosphinolinium Hexafluorophosphate	<u>87</u>	CH <sub>3</sub>	H		179.5-182	67
1-Ethyl-1,2,3,4-tetrahydro-4-methyl-1-phenylphosphinolinium Hexafluorophosphate	<u>88</u>	C <sub>2</sub> H <sub>5</sub>	H		145-147	42
1,2,3,4-Tetrahydro-4-methyl-1,1-diphenylphosphinolinium Hexafluorophosphate	<u>89</u>	C <sub>6</sub> H <sub>5</sub>	H		203.5-205	82
1,2,3,4-Tetrahydro-4-methyl-1,1-diphenylbenzo[h]phosphinolinium Hexafluorophosphate	<u>90</u>	C <sub>6</sub> H <sub>5</sub>		benzo	192-194.5	33



R = H, CH<sub>3</sub>

Halide	Solvent	(hr.)	Cpd.	R	R'
CH <sub>2</sub> =CHCH <sub>2</sub> Br	/ C <sub>6</sub> H <sub>6</sub>	(24)	<u>72</u>	H	H
CH <sub>2</sub> =CHCH <sub>2</sub> Br	/ C <sub>6</sub> H <sub>6</sub>	(24)	<u>73</u>	CH <sub>3</sub>	H
CH <sub>3</sub> CH=CHCH <sub>2</sub> Br	/ C <sub>6</sub> H <sub>5</sub> CH <sub>3</sub>	(24)	<u>74</u>	H	CH <sub>3</sub>
CH <sub>3</sub> CH=CHCH <sub>2</sub> Br	/ Ether-C <sub>6</sub> H <sub>6</sub>	(24)	<u>75</u>	CH <sub>3</sub>	CH <sub>3</sub>

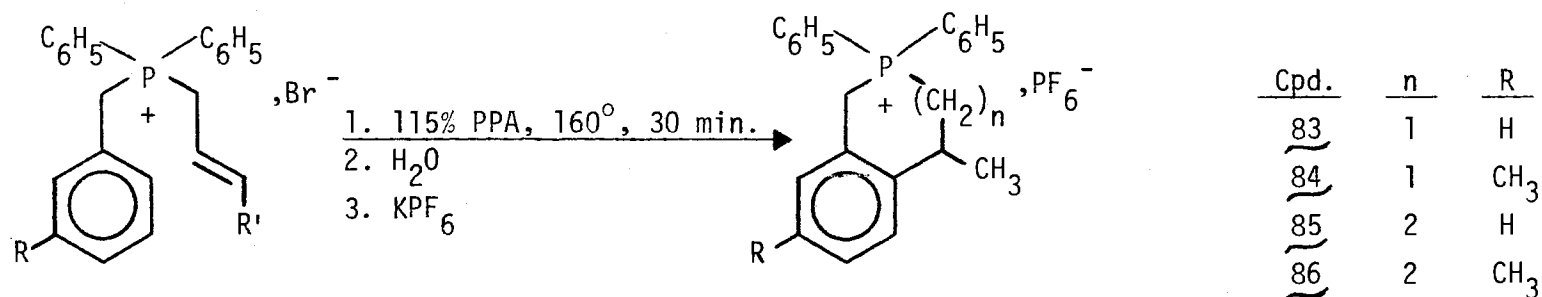
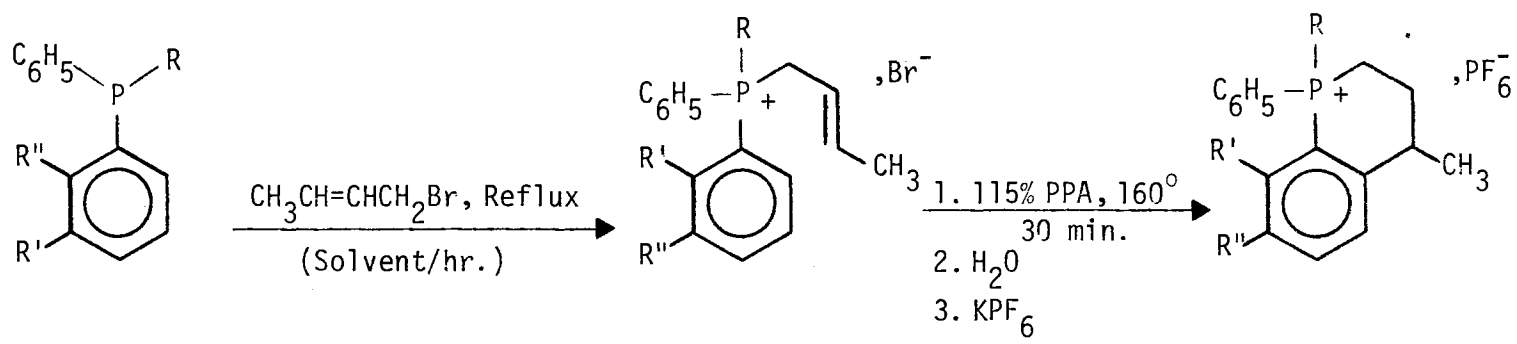


Figure 1. Preparation of 1,2,3,4-Tetrahydroisophosphinolinium Hexafluorophosphate and 2,3,4,5-Tetrahydro-1H-benzo[c]phosphepinium Hexafluorophosphate Derivatives 83-86



R	R'=R''	Cpd.	Solvent / hr.	R	R'=R''	Cpd.	R	R'=R''
CH <sub>3</sub>	H	<u>78</u>	Xylene / 18	CH <sub>3</sub>	H	<u>87</u>	CH <sub>3</sub>	H
C <sub>2</sub> H <sub>5</sub>	H	<u>79</u>	Toluene / 12	C <sub>2</sub> H <sub>5</sub>	H	<u>88</u>	C <sub>2</sub> H <sub>5</sub>	H
C <sub>6</sub> H <sub>5</sub>	H	<u>80</u>	Xylene / 19	C <sub>6</sub> H <sub>5</sub>	H	<u>89</u>	C <sub>6</sub> H <sub>5</sub>	H
C <sub>6</sub> H <sub>5</sub>	benzo	<u>81</u>	Benzene / 12	C <sub>6</sub> H <sub>5</sub>	benzo	<u>90</u>	C <sub>6</sub> H <sub>5</sub>	benzo

Figure 2. Preparation of 1,2,3,4-Tetrahydrophosphinolinium Hexafluorophosphate Derivatives 87-90

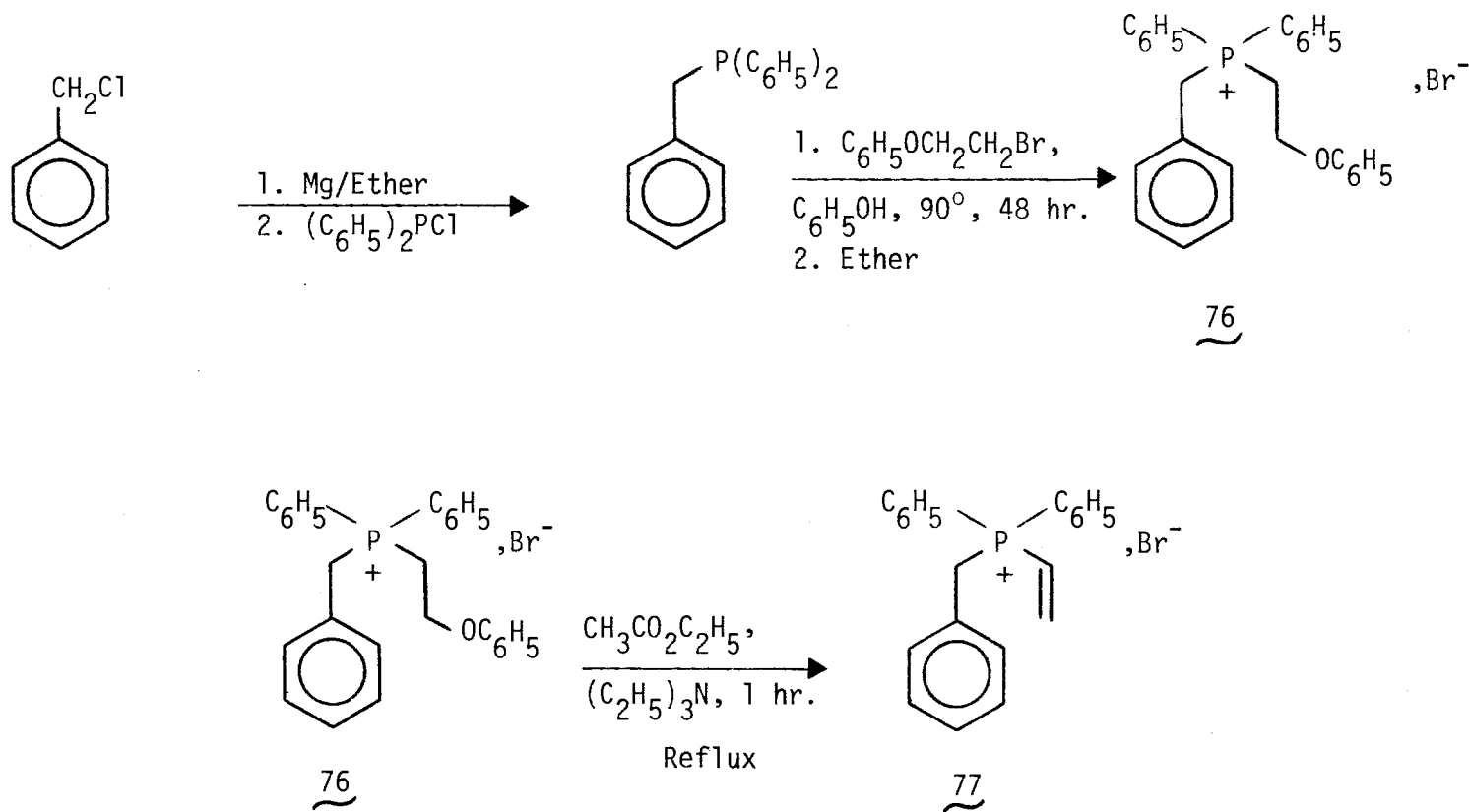
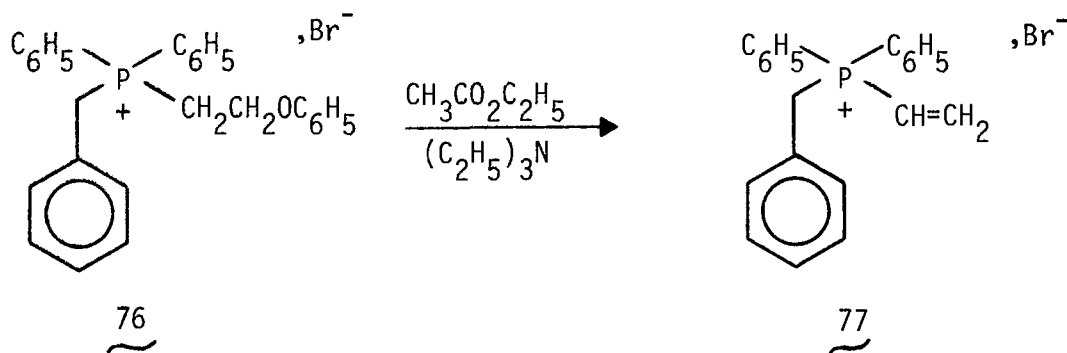


Figure 3. Preparation of Benzylidiphenylvinylphosphonium Bromide (**77**)

(54%) reported in the preparation of this phosphine by Browning and co-workers.<sup>17</sup> Therefore, we devised the procedure in Figure I for preparing the phosphine and utilized an inverse-Grignard flask. The intermediate crude phosphine was transferred without isolation to a lower flask where it was quaternized with an appropriate alkyl halide (dissolved in a suitable solvent) to give the corresponding  $\beta$ -alkenyl-arylmethyldiphenylphosphonium salt. In later experimentation, it was discovered that the yields of the phosphonium salts in the quaternization step were increased as higher-boiling solvents were used, such as benzene, toluene, and xylene.

Benzylidiphenylvinylphosphonium bromide (77) was isolated through a modification of both our general procedure and one employed by Shutt and Trippett.<sup>105</sup> The freshly prepared benzylidiphenylphosphine



(Figure (III)) was added to  $\beta$ -bromophenetole using phenol as the solvent at 90°C) with a reaction time of 48 hr. to give 76. When 76 was treated with a solution of ethyl acetate in the presence of a catalytic amount of triethylamine, 77 was produced.

The tertiary phosphines in Figure II had previously been prepared in our Laboratory by various methods, except triphenylphosphine, which was commercially available. It should be noted that 1-bromo-2-butene,



b.p. 103-106°, allowed the use of higher-boiling solvents such as toluene and xylene for the quaternization.

Polyphosphoric acid is an extremely useful cyclizing agent which has become very popular in organic synthesis. Several reviews have illustrated the broad range of functional groups that can be treated with this reagent to promote cyclization.<sup>67,101,113</sup> Its versatility arises from the fact that its mild action seldom causes charring of organic compounds even though it is a strong dehydrating agent. PPA does not cause phosphonation of aromatic compounds under any reported conditions and holds rearrangements to a minimum. PPA is quite useful in that PPA solutions can be heated to over 300°C and are easily decomposed by pouring into ice water. The reagent is often one of choice over such agents as sulfuric acid, hydrogen fluoride, phosphoric anhydride, and aluminum chloride for cyclization reactions.

Our cyclizations were performed with the use of a special 115% polyphosphoric acid that was commercially available from the FMC Corporation<sup>110</sup> through the generosity of Mr. J. P. Cassidy. The composition of this acid along with other phosphoric acids are shown below:

% P <sub>2</sub> O <sub>5</sub> in H <sub>3</sub> PO <sub>4</sub>		Composition of 115% H <sub>3</sub> PO <sub>4</sub>	
% H <sub>3</sub> PO <sub>4</sub>	% P <sub>2</sub> O <sub>5</sub>	P <sub>2</sub> O <sub>5</sub> , %	83.2
115	83.2	P <sub>2</sub> O <sub>5</sub> distributed as	
105	76.0	orthophosphoric acid %	5
85	61.5	pyrophosphoric acid %	16
75	54.0	triphosphoric acid %	17
		tetraphosphoric acid %	16
		higher polymer acid %	46

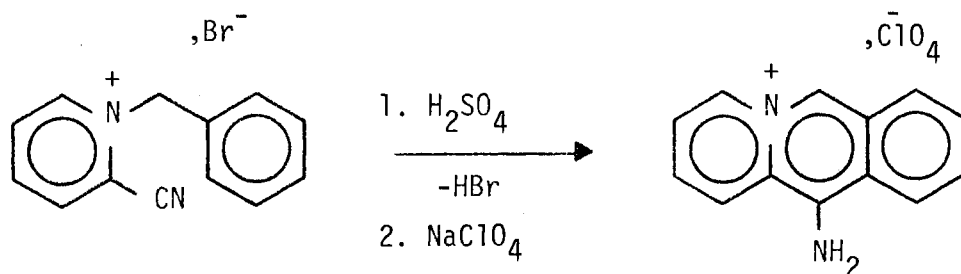
We discovered that a preparation of 115% PPA from addition of P<sub>2</sub>O<sub>5</sub> to

commercial  $\text{H}_3\text{PO}_4$  failed to promote cyclization in all phosphonium salts subjected to a variety of conditions. Thus, the FMC 115% PPA has properties uniquely required in the synthesis.

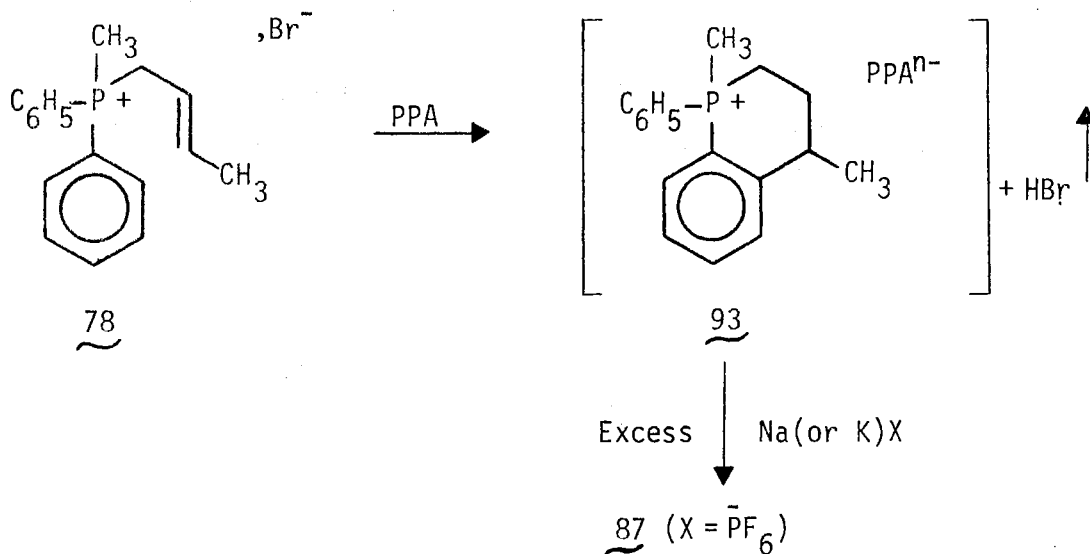
The general cyclization procedure was first uncovered by Morris and Berlin in the attempted preparation of several isophosphinolinium heterocyclic derivatives. In our development of the method for cyclizations we have found that addition of 1 gram of the  $\beta$ -alkenyl-substituted phosphonium salt to 25-30 ml. of PPA at  $160^\circ\text{C}$  followed by a 30-min. stirring period gave excellent results on a general basis. The resulting, golden-colored solution was cooled to  $110$ - $120^\circ$  and slowly poured into 100-200 ml. of ice water and stirred until the mixture became homogeneous. The crude C-P heterocycle could be precipitated upon addition of a large excess of a saturated aqueous salt ( $\text{NaCl}$ ,  $\text{NaBr}$ , or  $\text{KPF}_6$ ) solution. Benzylidiphenylvinylphosphonium bromide (77) had to be heated with PPA at  $300^\circ\text{C}$  for 1.25 hr. in what was otherwise an identical experiment to produce heterocycle 82.

It should be pointed out that preliminary results suggest the cyclization of the open-chain phosphonium salts are not limited by the bromide as the anion of the salt. Other anions such as  $\text{Cl}^-$  and  $\text{PF}_6^-$  also served but only two cases were tested. It is worth citing that the crude C-P heterocycle can be precipitated with saturated salt ( $\text{NaCl}$ ,  $\text{NaBr}$ ,  $\text{NaPF}_6$ ) solutions, but the  $\text{PF}_6^-$  anion seems to cause a higher degree of insolubility than any other anion tested. In fact, the formation of a homogeneous solution from addition of the reaction mixture to ice water is not easily understood. Since a gas is evolved during the cyclization process (presumably  $\text{HBr}$  or  $\text{HCl}$  depending upon the anion present in the original phosphonium salt),<sup>15</sup> the only

intuitively reasonable anion remaining in solution is that of  $\text{PPA}^{\text{n-}}$ . A similar loss of  $\text{HBr}$  was observed in the preparation of 11-aminoacridizinium perchlorate by the action of concentrated sulfuric acid on



1-benzyl-2-cyanopyridinium bromide.<sup>15</sup> Thus, using 78 as starting material, one might envision an intermediate such as 93 as being in solution prior to the "salting out" process with excess  $\text{NaX}$ .



The structures of all new materials described herein are supported by IR, NMR, and mass spectral data listed in Tables III, IV, and V-VIII in addition to elemental analysis found in the Experimental.

Preparation of  $\beta$ -Alkenylarylmethyldiphenylphos-  
phonium Bromides 72-75, Benzyldiphenylvinyl-  
phosphonium Bromide (77), and Selected  
Alkyl(or aryl)-2-butenyldiphenyl-  
phosphonium Bromides 78-81

Several synthetic methods have been employed for the preparation of quaternary phosphonium compounds, but the most widely used process is the reaction of phosphines with a compound RX (R may be H, alkyl, or acyl radical; X can be a halogen or an acyl radical).<sup>6</sup> It was initially planned to use primarily benzyl-substituted diphenylphosphines in direct quaternizations with selectively substituted allylic bromides to form  $\beta$ -alkenylarylmethyldiphenylphosphonium bromides 72-75. These phosphonium salts possess the capability for conversion to C-P heterocycles via the use of 115% polyphosphoric acid.

For perhaps the simplest method for our study the procedure used by Browning and co-workers to prepare benzyldiphenylphosphine<sup>17</sup> was followed, and we obtained instead the phosphine oxide which had the same melting point as the previously prepared oxide.<sup>34</sup> We therefore used a modification of this procedure with the aid of an inverse-Grignard flask. Without isolation, the crude phosphine was allowed to react with the appropriate allylic halide to produce the corresponding quaternary phosphonium salt derived from benzyldiphenylphosphine.

In a 300-ml. inverse-Grignard flask was placed magnesium turnings which was covered with anhydrous diethyl ether. To this was added 5 drops of ethyl bromide and several iodine crystals. When the reaction

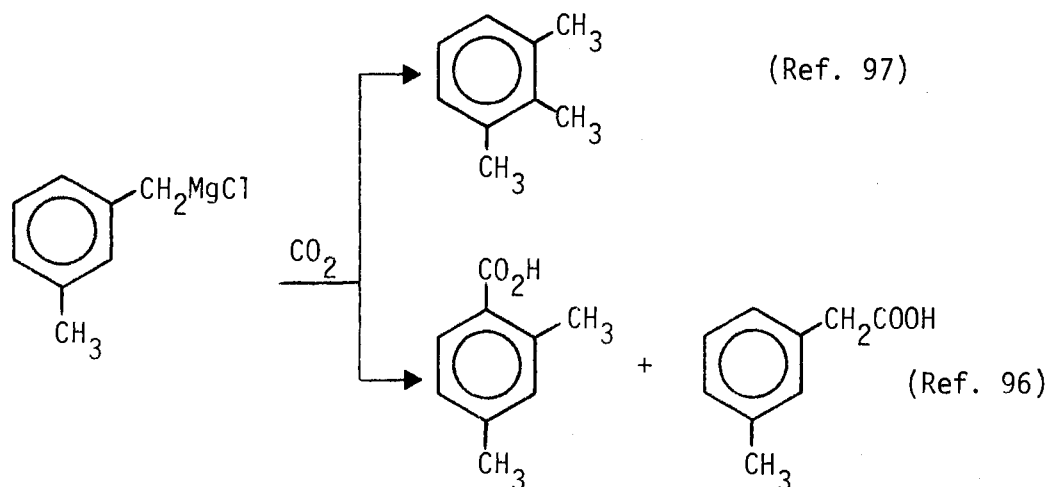
started, an equimolar amount of benzyl chloride in ether was slowly added; this solution was boiled for 15-30 min. When this reaction was complete, an equimolar amount of diphenylphosphinous chloride in diethyl ether was slowly added. After the addition was complete, the mixture was boiled for 1-2 hr. The solution of phosphine was then filtered through the porous disk in the lower portion of the Grignard flask into a lower reaction vessel containing the appropriate halide in a suitable solvent. We were able to separate the insoluble magnesium salts and any unreacted magnesium by this procedure.

Compound 74 was obtained (49% yield based on the starting benzyl halide) when benzyldiphenylphosphine was treated with 1-bromo-2-butene using toluene as the solvent as illustrated in Figure 1. In an earlier identical experiment, it was found that 74 was obtained (26% yield) when diethyl ether was the solvent with reaction times approximately the same in each case. Similarly, 72 was prepared (52% yield) using benzene as the solvent.

The next analog to be similarly prepared was allyl(3-methylbenzyl)-diphenylphosphonium bromide (73). Earlier work concerning the Grignard formation of m-methylbenzyl chloride stated that abnormal rearranged reaction products had been isolated.<sup>96,97</sup>

It was thought for several years that the carbonation of (m-methylbenzyl)magnesium chloride resulted in the formation of the abnormal product, 2,6-dimethylbenzoic acid.<sup>97</sup> Later it was reported that the results of Mousseron and Du<sup>97</sup> were in error, and that the abnormal product was actually 2,4-dimethylbenzoic acid plus an undisclosed amount of m-tolylacetic acid.<sup>96</sup> Conclusions of this sort have been published in reference texts.<sup>60</sup> Using extremely pure isomeric

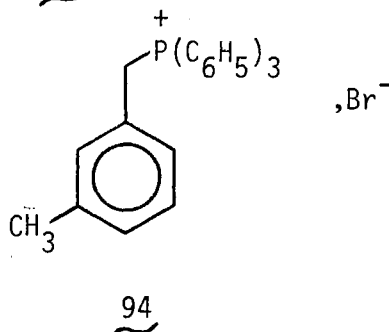
methylbenzyl chlorides, Benkeser and co-workers determined that the



only product isolated in the carbonation of the individual methylbenzyl-magnesium chlorides was the normal tolylacetic acid in each case.<sup>10</sup>

Using this knowledge, we similarly prepared 73 and 75 by the scheme in Figure 1. When benzene was the solvent in the preparation, 73 was isolated in a yield of 48%. When ether was the quaternizing solvent, the yield was lowered to 25% (over a 6-day period of reflux). Compound 75 was isolated (35% yield) when an approximate 2.75:1 mixture of diethyl ether-benzene solution was used in the quaternization process. In these preparations, 72 and 73 were prepared when a 1.8-2 molar excess of allyl bromide was employed, while with 74 and 75 a 1.3-molar excess of 1-bromo-2-butene was used.

The NMR spectra of 73 and 75 showed the expected proton absorption



at  $\delta$  2.06 and  $\delta$  2.05 ( $\underline{m}$ - $\text{CH}_3\text{C}_6\text{H}_4$ , s, 3H), respectively, while the proton absorption for ( $\underline{m}$ -methylbenzyl)triphenylphosphonium bromide (94) appeared at  $\delta$  2.15<sup>59</sup> and 2.06<sup>48</sup> ( $\underline{m}$ - $\text{CH}_3\text{C}_6\text{H}_4$ , s, 3H) when compared at 60 MHz.

In an attempt to prepare vinylphosphonium salts, Shutt and Trippett<sup>105</sup> noted that diphenylvinylphosphine quaternized normally with methyl and benzyl iodides. However, other alkyl halides such as benzyl bromide and ethyl bromo- and iodoacetate gave amorphous polymeric phosphonium salts which contained very little alkyl halide. Subsequently, they permitted benzyldiphenylphosphine to react with  $\beta$ -bromophenetole using phenol as the solvent and treated the resulting phosphonium salt with a mixture of ethyl acetate and a catalytic amount of triethylamine to produce 77. We followed our general method to prepare benzyl-diphenylphosphine, and upon addition to the  $\beta$ -bromophenetole-phenol solution at 90°, the ether was expelled from the reaction flask. After a 48-hr. heating period, the phenolic solution was slowly poured into anhydrous ether to precipitate the phosphonium salt, which was treated with ethyl acetate-triethylamine to give 77 (69% yield), m.p. 220-222° (lit.<sup>105</sup> 62%, m.p. 211-212°). Again the 60 MHz NMR spectra are very similar. Shutt and Trippett observed a chemical shift of  $\tau$  3.2-4.0 (m, 3H) for the vinylic protons,<sup>105</sup> while our shift was  $\tau$  3.2-4.3 (m, 3H).

The  $\beta$ -alkenyl-substituted phosphonium salts prepared in Figure II utilized methyldiphenylphosphine,<sup>95</sup> ethyldiphenylphosphine,<sup>94,95</sup> and 1-naphthyldiphenylphosphine,<sup>57</sup> which had been previously prepared and characterized in our Laboratory. Triphenylphosphine was obtained from Eastman Kodak Company as mentioned earlier.

In these preparations, we mixed the phosphine and halide directly in the appropriate solvent using a variation of a method previously reported.<sup>93</sup> Due to the limited quantity of 1-bromo-2-butene, we used a 1.4-1.8 molar-excess of the phosphines except in the preparation of 79 and 81. In these cases we used a 1.4-1.8 molar-excess of the halo-alkene, respectively.

2-Butenyltriphenylphosphonium bromide (80) (84% yield) had previously been synthesized using a slight excess of the phosphine when benzene was employed as the solvent. Our yield was increased (94%) when boiling xylene was the quaternizing solvent, using about half the reaction time previously reported.<sup>13</sup>

Numerous solvent systems have been recorded for the purification of phosphonium salts.<sup>8</sup> We found that the most successful method involved dissolution of the salt in a minimum amount of methylene chloride or chloroform followed by the dropwise addition of anhydrous diethyl ether. This was continued until reprecipitation of the salt could be initiated by scratching the sides of the flask with a spatula or until the solution became cloudy. When methyl or ethyl alcohol was used in these purification procedures, great difficulty was encountered in removing the last traces of solvent. Since phosphonium salts tend to be hygroscopic, we never used water as a solvent.

The IR absorptions of the  $\beta$ -alkenyl-substituted phosphonium salts 72-75, 78-81, and benzyldiphenylvinylphosphonium bromide (77) are listed in Table III. The properties of all compounds listed are in excellent agreement with a survey done by Witschard and Griffin.<sup>120</sup> They reported the IR spectra of forty-eight simple phosphonium salts and two phosphoranes in the 650-5000  $\text{cm}^{-1}$  range. Characteristic



TABLE III  
 INFRARED SPECTRA OF OPEN-CHAIN PHOSPHONIUM SALTS<sup>a</sup>

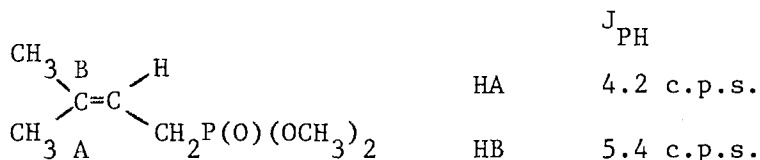
Cpd.	-P-C <sub>6</sub> H <sub>5</sub>	CH <sub>2</sub> (Wag)	CH(Wag)	Miscellaneous Bands
72 ~	1443(s), 1114(vs), 997(m), 722(w)	940(s), 865(m)		1199(m), 833(m), 808(m), 745(vs), 691(vs)
73 ~	1433(s), 1111(vs), 999(m), 730(w)	942(s), 862(s)		1190(m), 824(s), 809(s), 758(s), 745(s), 694(s)
74 ~	1443(s), 1111(vs), 997(m), 725(w)		980(m)	1484(m), 920(m), 862(s), 840(s), 752(vs), 690(vs)
75 ~	1431(s), 1110(s), 998(m), 714(w)		976(m)	913(m), 855(m), 831(s), 741(vs), 688(vs)
77 ~	1433(s), 1111(s), 995(m), 719(s)		979(w)	1488(m), 797(s), 755(s), 701(s)
78 ~	1433(s), 1119(vs), 996(m), 718(m)		977(s)	939(s), 898(s), 760(vs), 691(s)
79 ~	1433(s), 1119(vs), 955(w), 724(m)		975(s)	920(m), 814(m), 767(vs), 738(vs)
80 ~	1433(s), 1110(vs), 998(m), 720(s)		968(m)	851(s), 765(m), 749(s), 691(s)
81 ~	1431(m), 1111(s), 999(w), 717(w)		971(s)	833(m), 801(s), 777(s), 690(s)

<sup>a</sup>Samples were in KBr pellets.

absorptions have been observed at 1430-1440, 1100-1120, 995-1005, and 710-730  $\text{cm}^{-1}$  when the compounds were either di-, tri-, or tetraphenyl-substituted.<sup>120</sup> When only one phenyl group was present, the 710-730  $\text{cm}^{-1}$  band disappeared.

The NMR spectra of these open-chain phosphonium salts along with  $^{31}\text{P}$  spectra are displayed in Plates I-XIII and the values are condensed in Table IV. Compounds 72-75 and 77 exhibit a characteristic doublet for the benzylic protons, while every compound except 77 gives the doublet of doublets corresponding to the methylene protons adjacent to phosphorus ( $-\text{P}-\text{CH}_2-\text{CH}=\text{C}$ ). It appears from the complex methyl absorption of the 2-butenylphosphonium compounds that a mixture of cis-trans isomers exists.

We would expect to see a doublet for the  $\text{CH}_3$  protons for a single isomer, but, when both isomers are present, the pair of doublets could be superimposed, and form the triplet pattern. But long-range coupling



in the system shown has been observed at 60 MHz and this could also complicate the analysis.<sup>42</sup>

Several reviews concerning  $^{31}\text{P}$  NMR spectra of organophosphorus compounds have recently been published.<sup>45,91</sup> The open-chain compounds 72, 74, 78, and 80 show chemical shift differences to be relatively small ( $\delta$  -23.96,  $\delta$  -24.79,  $\delta$  -21.84, and  $\delta$  -21.14, respectively, from 85%  $\text{H}_3\text{PO}_4$ ). These values compare very well with those of many open-chain phosphonium salts such as dimethyldiphenylphosphonium bromide,

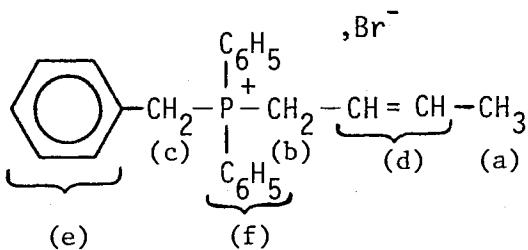
TABLE IV

## NMR COUPLING CONSTANTS AND CHEMICAL SHIFTS OF PRODUCTS

Structure	Cpd.	Plate	Solvent	$\delta$ (values) (p.p.m.) <sup>a</sup>	Assignments
<p>(d) (b) (a) (e) (c)</p>	<u>72</u>	I	DCCl <sub>3</sub>	4.26 (d of d)	CH <sub>2</sub> (a)
				$J_{PH} = 15$ c.p.s	
				$J_{HH} = 6$ c.p.s	
				4.99 (d)	CH <sub>2</sub> (b)
				$J_{PCH} = 14$ c.p.s	
				5.16-5.80 (m)	CH=CH <sub>2</sub> (c)
			7.13 (s)	Ar-H (d)	
			7.5-8.14 (m)	Ar-H (e)	
<p>(a) (e) (f) (c) (b) (g) (d)</p>	<u>73</u>	III	DCCl <sub>3</sub>	2.1 (s)	CH <sub>3</sub> (a)
				4.28 (d of d)	CH <sub>2</sub> (b)
				$J_{PH} = 15$ c.p.s.	
				$J_{HH} = 6$ c.p.s.	
				4.92 (d)	CH <sub>2</sub> (c)
			$J_{PH} = 15$ c.p.s.		
			5.14-5.76 (m)	CH=CH <sub>2</sub> (d)	

TABLE IV (Continued)

Structure	Cpd.	Plate	Solvent	$\delta$ (values) (p.p.m.) <sup>a</sup>	Assignments
				6.78 (s) -----	Ar-H (e) -----
				6.99 (s) -----	Ar-H (f) -----
				7.46-8.06 (m) -----	Ar-H (g) -----
	74	IV	DCCl <sub>3</sub>	1.24-1.64 (m) -----	CH <sub>3</sub> (a) -----
				4.15 (d of d) -----	CH <sub>2</sub> (b) -----
				J <sub>PH</sub> = 15 c.p.s. J <sub>HH</sub> = 7 c.p.s.	
				4.91 (d) -----	CH <sub>2</sub> (c) -----
				J <sub>PH</sub> = 15 c.p.s.	
				4.90-5.96 (m) -----	CH=CH (d) -----
				7.10 (s) -----	Ar-H (e) -----
				7.46-8.02 (m) -----	Ar-H (f) -----
	75	VI	DCCl <sub>3</sub>	1.24-1.70 (m) -----	CH <sub>3</sub> (a) -----
				2.08 (s) -----	CH <sub>3</sub> (b) -----
				4.17 (d of d) -----	CH <sub>2</sub> (c) -----
				J <sub>PH</sub> = 15 c.p.s.	



(Formula on next page)

TABLE IV (Continued)

Structure	Cpd.	Plate	Solvent	$\delta$ (values) (p.p.m.) <sup>a</sup>	Assignments
<p>(b) (f) CH<sub>3</sub> H (g) (h) , Br<sup>-</sup> (d) (c) (e) (a)</p>	75			$J_{\text{HH}} = 7$ c.p.s. 4.86 (d) CH <sub>2</sub> (d) $J_{\text{PH}} = 15$ c.p.s. 4.90-6.0 (m) CH=CH (e) 6.77 (s) Ar-H (f) 6.98 (s) Ar-H (g) 7.48-8.16 (m) Ar-H (h)	
<p>, Br<sup>-</sup> (a) (d) (b) (c) (e)</p>	77	VII	DCCl <sub>3</sub>	5.07 (d) CH <sub>2</sub> (a) $J_{\text{PH}} = 15$ c.p.s. 5.91-6.62 (m) CH <sub>2</sub> (b) 7.18 (m) Ar-H (c) 6.97-7.40 (m) CH (d) 7.46-8.06 (m) Ar-H (e)	

TABLE IV (Continued)

Structure	Cpd.	Plate	Solvent	$\delta$ (values) (p.p.m.) <sup>a</sup>	Assignments
	<u>78</u>	VIII	DCCl <sub>3</sub>	1.44-1.74 (m)	CH <sub>3</sub> (a)
				2.82 (d)	CH <sub>3</sub> (b)
				$J_{PH} = 14$ c.p.s.	
				4.82 (d of d)	CH <sub>2</sub> (c)
				$J_{PH} = 15$ c.p.s.	
				$J_{HH} = 8$ c.p.s.	
				5.06-6.38 (m)	CH=CH (d)
			7.54-8.2 (m)	Ar-H (e)	
	<u>79</u>	X	DCCl <sub>3</sub>	1.06-1.48 (d of t)	CH <sub>3</sub> (a)
				$J_{PH} = 20$ c.p.s.	
				$J_{HH} = 7$ c.p.s.	
				1.50-1.74 (m)	CH <sub>3</sub> (b)
				3.12-3.56 (s) <sup>b</sup>	CH <sub>2</sub> (c)
				$J_{PH} = 13$ c.p.s.	
				$J_{HH} = 7$ c.p.s.	
			4.25 (d of d)	CH <sub>2</sub> (d)	
			$J_{PH} = 15$ c.p.s.		

TABLE IV (Continued)

Structure	Cpd.	Plate	Solvent	$\delta$ (values) (p.p.m.) <sup>a</sup>	Assignments
				$J_{\text{HH}} = 7$ c.p.s.	
				5.02-6.2 (m)	CH=CH (e)
				7.58-8.24 (m)	Ar-H (f)
	<u>80</u>	XI	$\text{DCCl}_3$	1.50-1.70 (m)	$\text{CH}_3$ (a)
				4.42-4.76 (d of d)	$\text{CH}_2$ (b)
				$J_{\text{PH}} = 15$ c.p.s.	
				$J_{\text{HH}} = 7$ c.p.s.	
				5.08-6.12 (m)	CH=CH (c)
				7.54-8.0 (m)	Ar-H (d)
	<u>81</u>	XIII	$\text{DCCl}_3$	1.36-1.64 (m)	$\text{CH}_3$ (a)
				4.72 (d of d)	$\text{CH}_2$ (b)
				$J_{\text{PH}} = 14$ c.p.s.	
				$J_{\text{HH}} = 7$ c.p.s.	
				5.0-6.14 (m)	CH=CH (c)
				7.34-8.46 (m)	Ar-H (d)

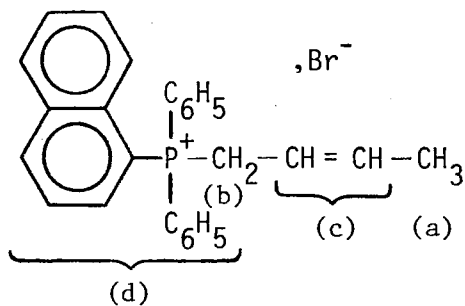
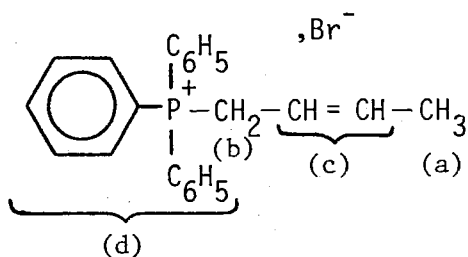


TABLE IV (Continued)

Structure	Cpd.	Plate	Solvent	$\delta$ (values) (p.p.m.) <sup>a</sup>	Assignments
	82	XIV	DCCl <sub>3</sub> (5 drops CF <sub>3</sub> CO <sub>2</sub> H)	2.90-3.56 (m)	CH <sub>2</sub> CH <sub>2</sub> (a)
				4.12 (d)	CH <sub>2</sub> (b)
				$J_{PH} = 14$ c.p.s.	
				7.2-7.88 (m)	Ar-H (c)
	83	XVI	DCCl <sub>3</sub> (5 drops CF <sub>3</sub> CO <sub>2</sub> H)	1.56-1.80 (d of d)	CH <sub>3</sub> (a)
				$J_{HH} = \sim 2$ c.p.s.	
				2.35-2.80 (m)	CH (b)
				3.10-3.64 (m)	CH <sub>2</sub> (c)
				3.90-4.24 (2d)	CH <sub>2</sub> (d)
				$J_{PCH} = \sim 10$ c.p.s.	
				7.22-7.96 (m)	Ar-H (e)



TABLE IV (Continued)

Structure	Cpd.	Plate	Solvent	$\delta$ (values) (p.p.m.) <sup>a</sup>	Assignments
	84	XIX	DCCl <sub>3</sub> (5 drops CF <sub>3</sub> CO <sub>2</sub> H)	1.56-1.80 (d of d)	CH <sub>3</sub> (a)
				$J_{\text{PCH}} = \sim 6$ c.p.s.	
				$J_{\text{HH}} = \sim 2$ c.p.s.	
				2.30 (s)	CH <sub>3</sub> (b)
				2.41-2.80 (m)	CH (c)
				3.10-3.56 (m)	CH <sub>2</sub> (d)
				3.88-4.16 (2d)	CH <sub>2</sub> (e)
			$J_{\text{PCH}} = \sim 10$ c.p.s.		
			7.08-7.96 (m)	Ar-H (f)	
	85	XXI	DCCl <sub>3</sub> (5 drops CF <sub>3</sub> CO <sub>2</sub> H)	1.48 (d)	CH <sub>3</sub> (a)
				$J_{\text{HH}} = 7$ c.p.s.	
				1.66-2.96 (m)	CH <sub>2</sub> CH <sub>2</sub> (b)
				3.02-3.42 (m)	CH (c)
				3.86-4.72 (d of t)	CH <sub>2</sub> (d)
			$J_{\text{PH}} = 14$ c.p.s.		

TABLE IV (Continued)

Structure	Cpd.	Plate	Solvent	$\delta$ (values) (p.p.m.) <sup>a</sup>	Assignments
				7.06-7.98 (m)	Ar-H (e)
	86	XXIV	DCCl <sub>3</sub> (5 drops CF <sub>3</sub> CO <sub>2</sub> H)	1.47 (d) $J_{HH} = 7$ c.p.s.	CH <sub>3</sub> (a)
				1.64-2.94 (m)	CH <sub>2</sub> CH <sub>2</sub> (b)
				2.30 (s)	CH <sub>3</sub> (c)
				3.04-3.38 (m)	CH (d)
				3.8-4.66 (d of t)	CH <sub>2</sub> (e)
				$J_{PH} = 14$ c.p.s.	
				6.96 (s)	Ar-H (f)
				7.24-8.02 (m)	Ar-H (g)
	87	XXVI	DCCl <sub>3</sub> (5 drops CF <sub>3</sub> CO <sub>2</sub> H)	1.47 (d) $J_{HH} = 6$ c.p.s.	CH <sub>3</sub> (a)
				2.32-2.5 (2d)	CH <sub>3</sub> (b)
				$J_{PH} = 14$ c.p.s.	
				1.88-3.18 (m)	CH <sub>2</sub> CH <sub>2</sub> (c)

TABLE IV (Continued)

Structure	Cpd.	Plate	Solvent	$\delta$ (values) (p.p.m.) <sup>a</sup>	Assignments
				3.18-3.56 (m)	CH (d)
				7.42-7.92 (m)	Ar-H (e)
	88	XXIX	DCCl <sub>3</sub> (5 drops CF <sub>3</sub> CO <sub>2</sub> H)	1.12-1.46 (m)	CH <sub>3</sub> (a)
				1.45 (d)	CH <sub>3</sub> (b)
				$J_{\text{HH}} = 7$ c.p.s.	
				1.98-3.10 (m)	CH <sub>2</sub> CH <sub>2</sub> , CH <sub>2</sub> (c)
				3.18-3.52 (m)	CH (d)
				7.42-7.92 (m)	Ar-H (e)
	89	XXXI	DCCl <sub>3</sub> (5 drops CF <sub>3</sub> CO <sub>2</sub> H)	1.47 (d)	CH <sub>3</sub> (a)
				$J_{\text{HH}} = 7$ c.p.s.	
				1.84-3.56 (m)	CH <sub>2</sub> CH <sub>2</sub> , CH (b)
				7.22-8.0 (m)	Ar-H (c)

TABLE IV (Continued)

Structure	Cpd.	Plate	Solvent	$\delta$ (values) (p.p.m.) <sup>a</sup>	Assignments
	90	XXXIV	DCCl <sub>3</sub> (5 drops CF <sub>3</sub> CO <sub>2</sub> H)	1.28 (d) $J_{HH} = 7$ c.p.s. 2.04-3.58 (m) 7.03-8.38 (m)	CH <sub>3</sub> (a) CH <sub>2</sub> CH <sub>2</sub> ,CH (b) Ar-H (c)

<sup>a</sup>The multiplicity of each peak is indicated as follows: singlet, s; doublet, d; triplet, t; multiplet, m.

<sup>b</sup>This absorption appears as a sextet.

$\delta$  -22.1.<sup>49</sup> But it should be noted that phosphonium salts have occasionally been reported to have positive  $\delta$  values.<sup>45</sup>

The cyclic derivatives of the open-chain compounds 83, 85, 87, and 89, also show expected shifts ( $\delta$  -17.17,  $\delta$  -14.22,  $\delta$  9.77, and  $\delta$  -10.74). The variations in these shifts compared to the open-chain precursors could be due possibly to angular strain at phosphorus which could influence the orbital symmetry around P and thus the  $^{31}\text{P}$  chemical shift. The  $\text{PF}_6^-$  has value of  $\delta$  +144.32 and  $\delta$  +144.35 in 87 and 89, respectively, compared to  $\text{KPF}_6$  in  $\text{H}_2\text{O}$  (all compared to 85%  $\text{H}_3\text{PO}_4$  standard-external), which has a  $\delta$  value of +144.68.

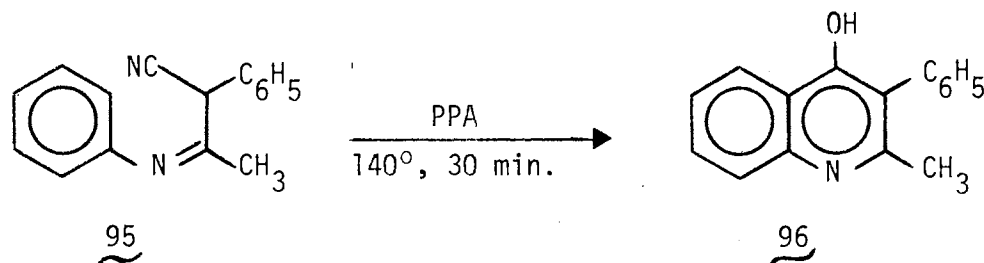
Mass spectral results are listed in Tables V-VIII and will be discussed later. Elemental analysis can be found in the Experimental section.

Cyclization of  $\beta$ -Alkenylarylmethyldiphenylphos-  
 phonium Bromides 72-75, Benzyldiphenyl-  
 vinylphosphonium Bromide (77),  
 and Selected Alkyl(or aryl)-  
 2-butenyldiphenylphospho-  
 nium Bromides 78-81  
 Using 115% Poly-  
 phosphoric Acid  
 (PPA)

Polyphosphoric acid has proved to be a very effective cyclizing agent in the synthesis of a wide variety of heterocyclic systems.<sup>67</sup> On a general basis, the yields of cyclized products are usually superior to those by other agents, but frequently PPA does not induce

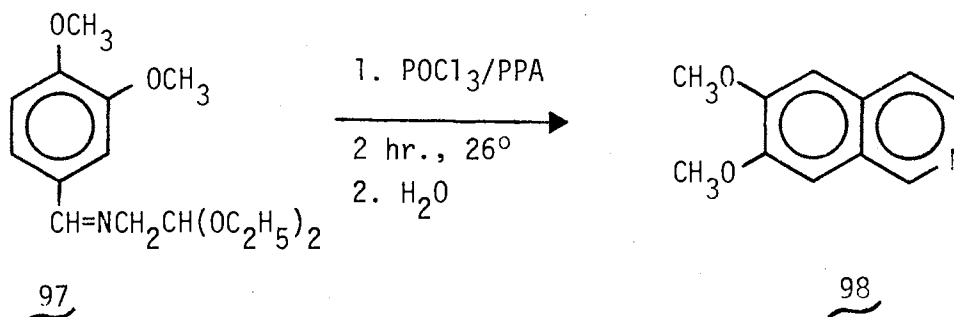
cyclization.<sup>108</sup> The two most widely used heterocyclic derivatives to be prepared by this method involve those containing oxygen and nitrogen, although reactions of several sulfur and arsenic compounds have been studied in some detail.<sup>5,20,30,64,65</sup>

Due to their widespread occurrence and applications, the preparation of nitrogen heterocyclic compounds via polyphosphoric acid cyclization processes has become increasingly important. The various nitrogen systems that have been synthesized with this reagent are too numerous to list and discuss, but the preparation of some quinoline and isoquinoline derivatives using polyphosphoric acid are included because of the relationship of the structures to those of our compounds. 4-Hydroxy-2-methyl-3-phenylquinoline (96) was obtained from the anil 95



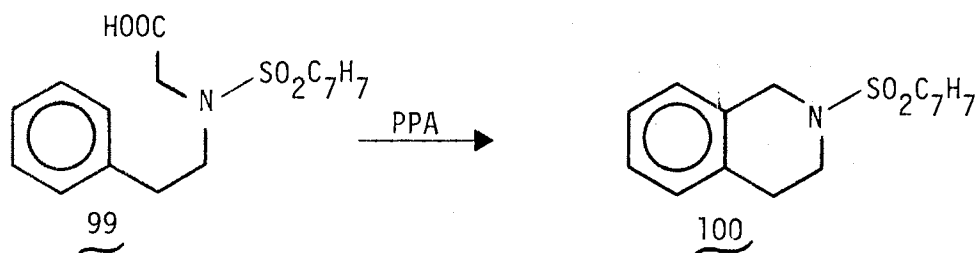
in 79% yield when subjected to PPA.<sup>50</sup> However, a similar preparation using the Conrad-Limpach method gave 96 in only 4% yield.<sup>1</sup> Similarly, 4-hydroxy-2,3-diphenylquinoline was made in 39% yield.<sup>50</sup>

Several isoquinoline derivatives have been prepared through a

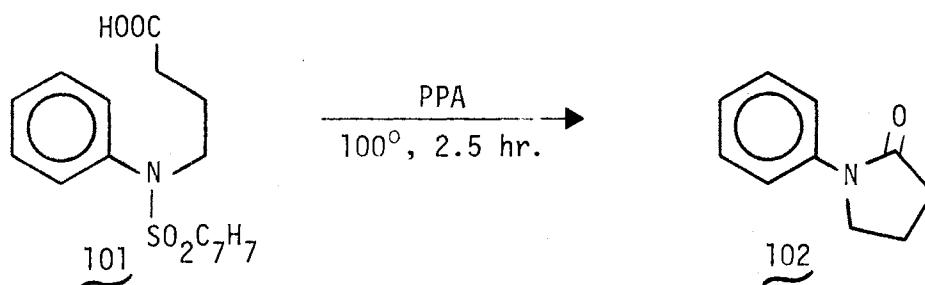


Pomeranz-Fritsch reaction. Popp and McEwen noted that a veratrylidene-amino acetal (97) was converted in 53% yield to 6,7-dimethoxyisoquinoline (98) by the use of phosphorus oxychloride in polyphosphoric acid.<sup>100</sup> Likewise, 7,8-dimethoxyisoquinoline was prepared using PPA, but the cyclization step failed when 72%  $H_2SO_4$  was employed.<sup>32</sup>

A tetrahydroisoquinoline derivative was made by heating the toluene sulfonamide of N- $\beta$ -phenylethylglycine (99) with polyphosphoric

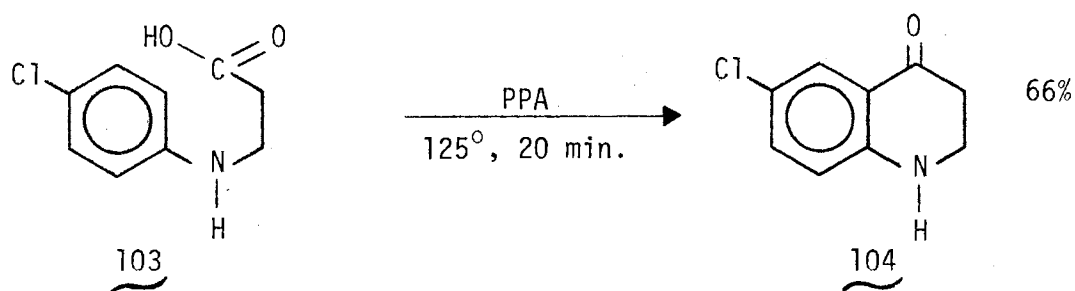


acid. Compound 100, instead of the ketone product normally to be expected, was isolated in a yield of 59%.<sup>102</sup> When the toluene sulfonamide of N-phenyl- $\gamma$ -aminobutyric acid (101) was subjected to the action



of polyphosphoric acid, 1-phenyl-2-pyrrolidinone (102) was obtained.<sup>4</sup>

In a very similar reaction for the preparation of ketophosphines used by Mann and co-workers using the open-chain propionic acid (see Chapter I),<sup>40</sup> Koo found that the cyclization of 103 could be effected directly in one step using polyphosphoric acid.<sup>66</sup> Apparently, the subtleties of the mechanism for formation of 14 and 104 in the related cyclizations are vital for understanding the observed seemingly incompatible results.



A few scattered methods have been reported with polyphosphoric acid as the cyclizing agent in the preparation of C-P heterocycles.<sup>31,40,79</sup> It was hoped that the model compounds we prepared, due to the  $\beta$ -alkenyl-substituted branching, would undergo an intramolecular cyclization and produce the desired C-P heterocycles when treated with 115% polyphosphoric acid. Our general method of cyclization utilized very basic laboratory equipment, moderate reaction conditions, and employed a very simple workup procedure.

Our standard technique for the cyclization was to use approximately 1 gram of unsaturated phosphonium salt per 30 ml. of 115% PPA. The PPA was placed in a beaker of appropriate size which was heated to  $150\text{-}160^{\circ}$ . The  $\beta$ -alkenyl-substituted phosphonium bromides were slowly added over a 10-min. period with stirring. A gas, presumably HBr, was given off about 10-15 sec. after the addition.<sup>15</sup> When the addition was completed, stirring was continued for 30 min. During this period, the reaction mixture turned from colorless to a light golden-colored solution. Several authors have noted the formation of intense colors during PPA cyclizations and have suggested color development as a means of determining the severity of conditions to be used.<sup>59,112</sup>

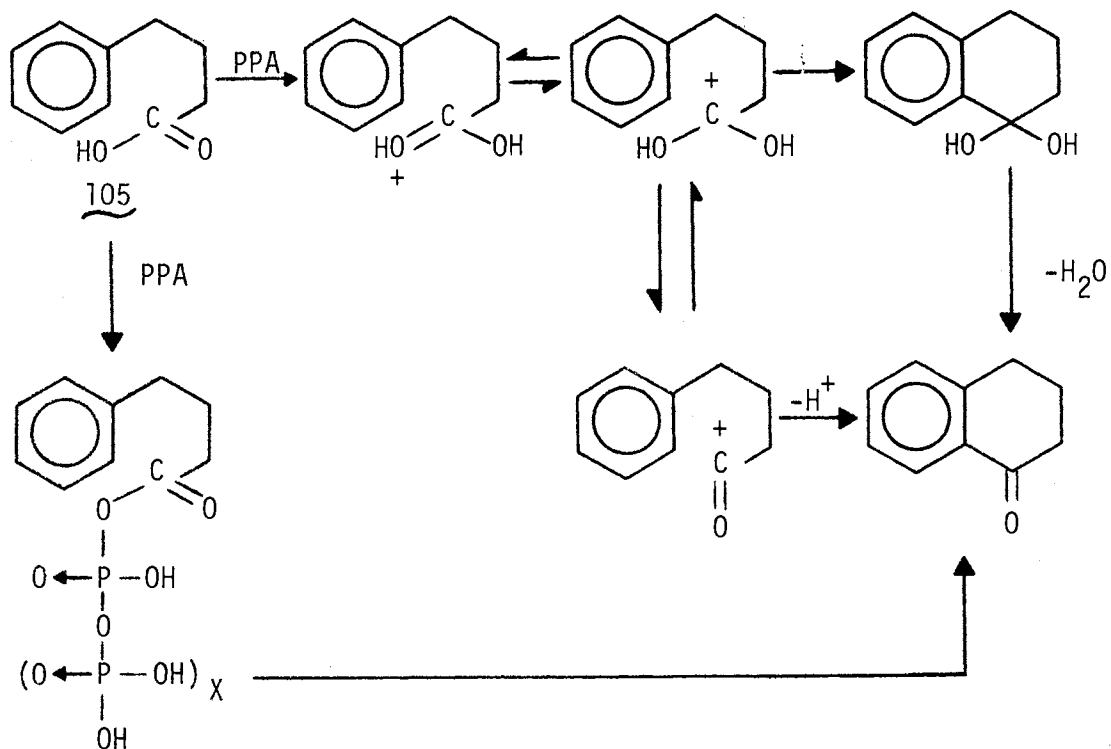


When the reaction was completed, the golden-colored mixture was cooled to 110-115° and slowly poured into 200-250 ml. of ice water. Decomposition of the PPA was accomplished by continued stirring, which gave a clear homogeneous solution (discussed in an earlier section of this chapter). The crude C-P heterocycle was then precipitated by addition of a large excess of a saturated salt solution (NaCl, NaBr, or KPF<sub>6</sub>). The solid was collected by vacuum filtration, purified by the same method employed for the open-chain unsaturated phosphonium salts, and dried in vacuo to give the pure cyclic phosphonium salts listed in Tables I and II.

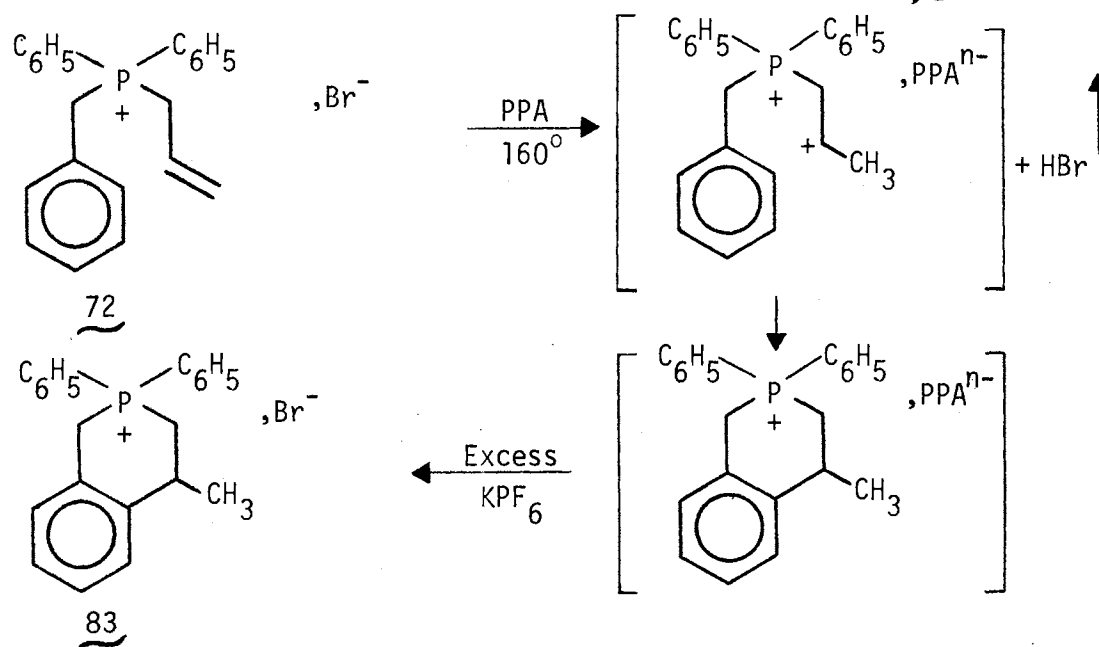
Moderate to very good yields were obtained using our cyclization process. In earlier work, a variety of reaction temperatures were tested and it was found that temperatures below 150° did not promote cyclization but resulted in a metathesis depending upon the salt added to precipitate the phosphonium compound from H<sub>2</sub>O. Benzylidiphenylvinylphosphonium bromide was very resistant to the acidic conditions at 160° and also 180°, but at 300° for 1.25 hr., cyclization readily took place.

Very little work has been done concerning the mechanism of the action of PPA due to the complexity of the composition of the acid. The high viscosity prevents easy isolation of the intermediates by simple crystallization, and kinetic methods are difficult to apply.

Nevertheless, some generalizations on the mechanism of PPA action have been made. Polyphosphoric acid can act as a protic acid as well as a phosphorylating agent simultaneously.<sup>2</sup> Thus in the condensation of  $\gamma$ -phenylbutyric acid (105), pathways involving either protonation or the formation of a mixed anhydride have been postulated as shown.<sup>2</sup>

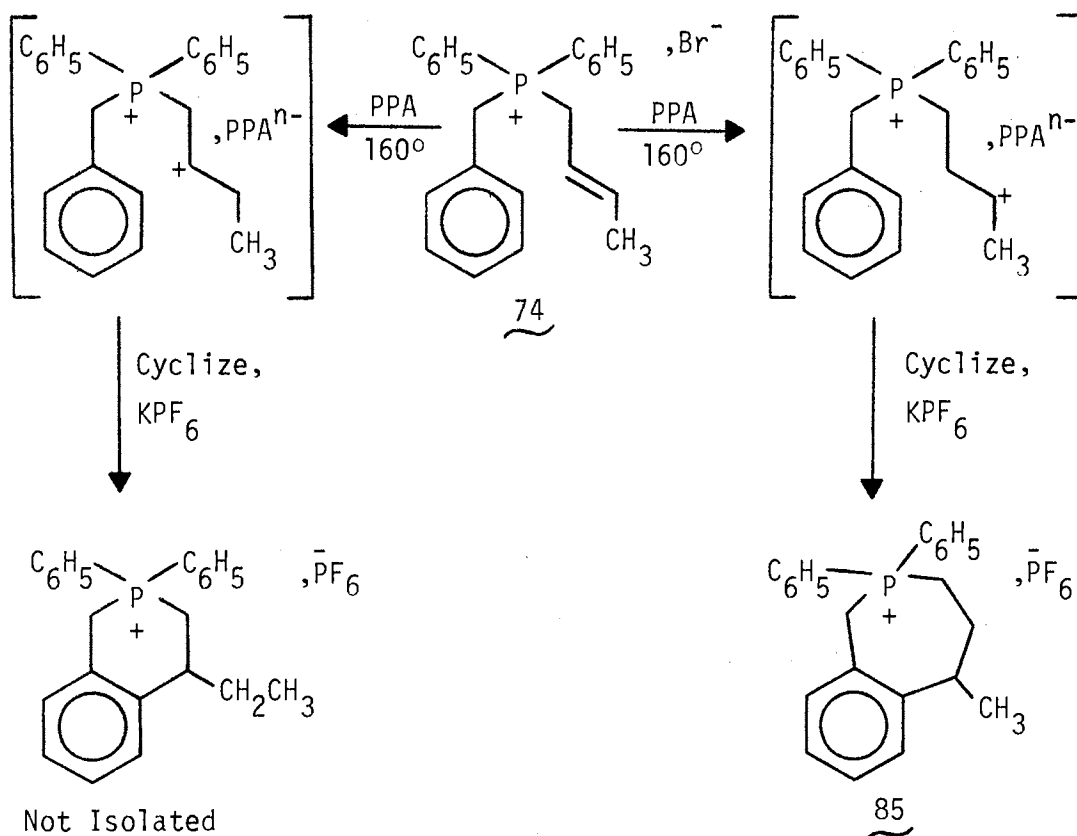


Our  $\beta$ -alkenyl systems are fairly resistant to phosphorylation (this has been reported to occur mainly in alcohols, amino alcohols, hydroxy acids, esters, amides, and nitriles)<sup>110</sup> and therefore probably reacts by protonation on the double bond. When compound 72 is



treated with PPA, the suspected protonated species probably participates in an electrophilic aromatic substitution to give a cyclic intermediate which then rearomatizes. Addition of an excess of a saturated  $\text{KPF}_6$  solution precipitates 83.

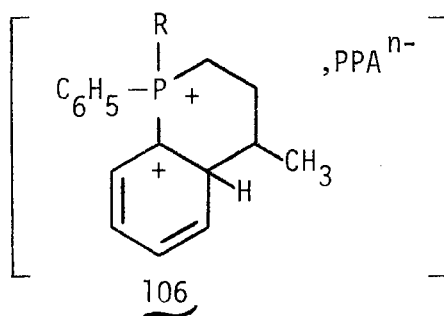
The 2-butenyl group attached to P offers opportunity for protonation to occur at two points and form two different cation intermediates. Protonation can occur at the  $\beta$ -carbon (in relation to the P atom) and subsequent cyclization can give the six-membered ring, or at the  $\gamma$ -carbon, whereupon ring closure would give the seven-membered ring system 85. Only one product was isolated as a product of this reaction



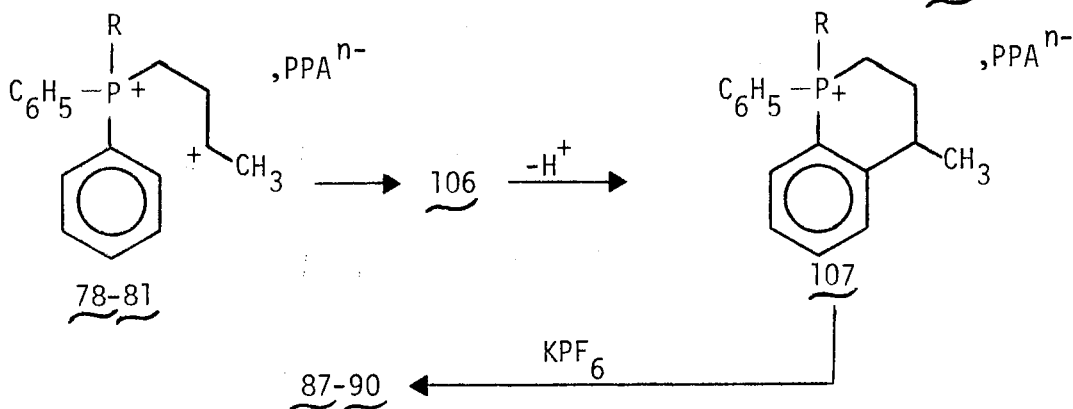
(as well as in others having the 2-butenyl function), and it was shown to possess a methyl group on the saturated ring (as determined by the characteristic doublet in the NMR spectra) and not an ethyl substituent.

This can possibly be explained by hyperconjugation effects at the  $\gamma$ -carbon in the cation since there are 5 hydrogens available as compared to just 4 hydrogens adjacent to the  $\beta$ -carbon. Protonation at the  $\gamma$ -carbon atom would also place the two positive centers further apart.

A phenomenon that is very difficult to rationalize is the nature of the intermediate normally expected to form when the alkyl(or aryl)-2-butenyldiphenylphosphonium bromides 78-81 are subjected to cyclization with PPA. Formation of an electron-deficient system (like 106)

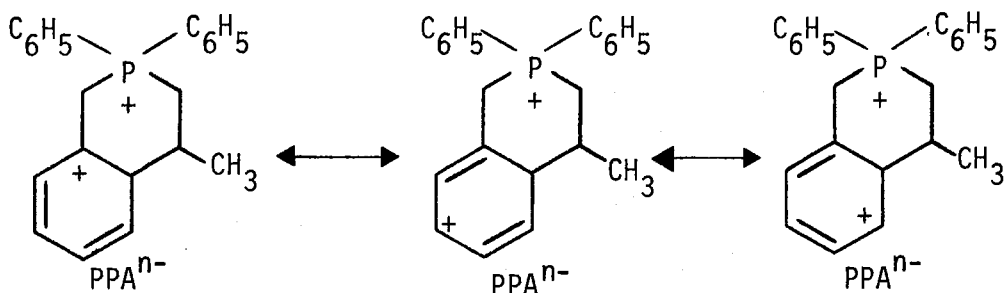


attached to quaternized P would expectedly be a very high-energy process. Although this species could rapidly eliminate a proton to form the aromatic nucleus, the driving force of the initial reaction may be unique. Actually, an initial  $\pi$ -complex could form between a proton and the alkenyl phosphonium salt, a step common to most electrophilic aromatic substitution reactions.<sup>68</sup> Conceivably, a tight ion pair involving PPA anion could account for the stability of 107 and of



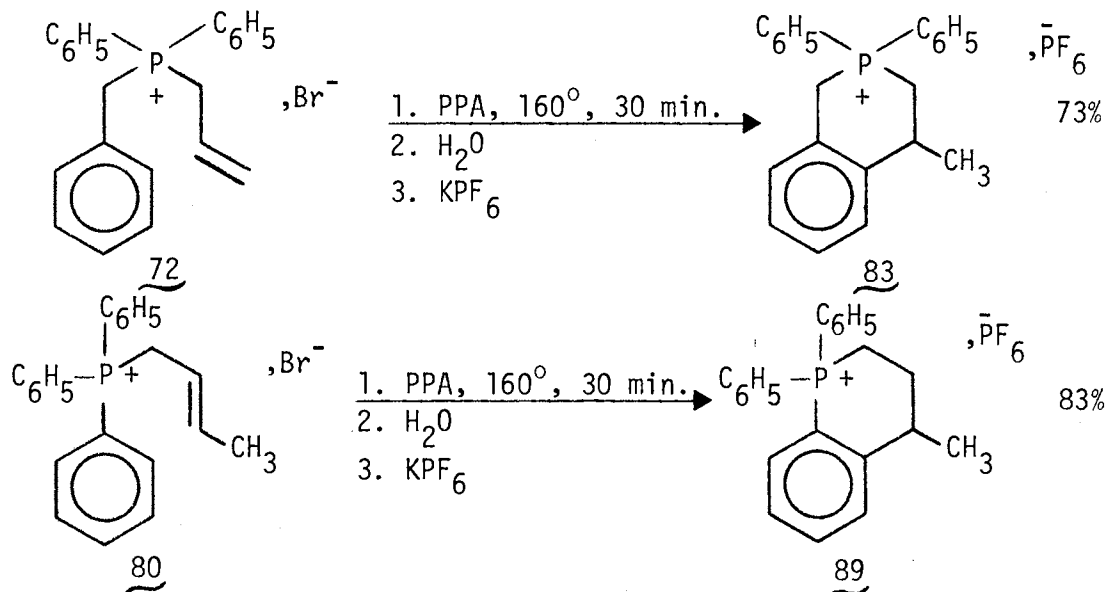
its probable precursor 106. This must remain speculation since no intermediates such as 107 precipitated. That PPA anion may be associated with the cation portion of 107 was indicated by the observation that only a saturated solution of  $KPF_6$  could precipitate salts 87-90 from a water solution. If the cation portion of 107 were strictly associated with only the original bromide anion in the open-chained phosphonium salt, one might expect at least slow precipitation since the bromides corresponding to 87-90 are not soluble in  $H_2O$  at the concentrations employed (as detected with 84) during the "salting out" from  $H_2O$  of the reaction product with  $KPF_6$ . Since PPA (and its anions) are infinitely soluble in  $H_2O$ , an association of the cation portion of 107 with  $H_2O$  molecules or the PPA anions (presumed to be highly solvated) prevents precipitation of the phosphonium salt. This, of course, assumes that essentially all of the bromide ion is converted to  $HBr$  which is lost during the reaction, so that the amount of  $Br^-$  as an anion competing with PPA anions in solution is minimized.

In the benzyl derivatives, the hybrid of the suspected intermediate cannot be described with usual valence bond-forms in which the  $P^+$  is adjacent to the electron-deficient ring. Thus, in view of current



theory of electrophilic aromatic substitution reactions,<sup>68</sup> one might predict moderate stability for the intermediate. However, in what might

be considered comparable cases, 72 and 80, the difference in yields of



the products 83 and 89, respectively, was not great. Indeed the difference may be due to purification techniques. A rigorous kinetic study, if a feasible one could be made, might reveal whether or not a difference in rate of formation of 83 and 89 existed.

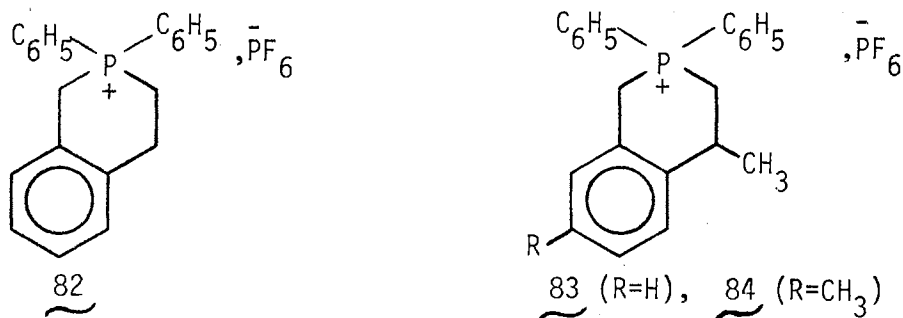
The stereochemistry of fused-ring C-P heterocycles has not been investigated very well. X-Ray analysis<sup>92</sup> of 1,2,3,4-tetrahydro-1,2,2,3,4,4-hexamethylphosphinoline 1-oxide (108) indicated that the



rings do not deviate much from planarity. Atoms P, C3, and C6 are 0.19, 0.29, and 0.03 Å<sup>o</sup> below the plane of the benzene ring. Atoms C2, C4, and C5 are 0.37, 0.02, and 0.12 Å<sup>o</sup> above this plane. In

contrast, X-ray analysis of 109 showed the two rings are not planar.<sup>114</sup> The P atom lies out of the plane of the pyrimidine ring by only  $0.07 \text{ \AA}$  but the phosphorinane ring is a half-twisted chair. In our systems 83-90 one might predict a similar situation. This is probably a function, in part, of the presence of the quaternized P atom, the orbital arrangement around which is believed to be near a perfect tetrahedron.<sup>54</sup> In contrast, one or more C-P $\rightarrow$ O angles in phosphine oxides may deviate considerably from  $109.5^\circ$  as in 108 where the angles range from  $104.3$  to  $113.9^\circ$ .<sup>92</sup> In trimethylphosphine oxide, one CH<sub>3</sub>-P $\rightarrow$ O angle is  $112.3^\circ$ .<sup>116</sup> This quite probably is due to d-orbital participation in the P=O bond as well as the size of groups attached to phosphorus.

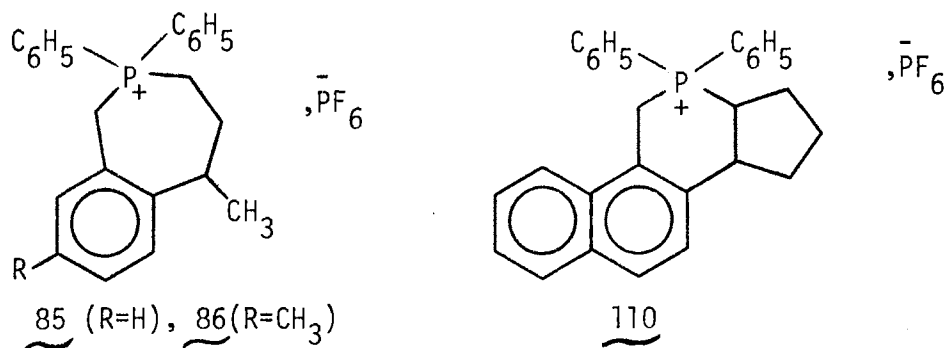
PMR analysis of selected members of our C-P heterocycles reveals some interesting data. In the spectrum of heterocycle 82, the benzylic protons adjacent to phosphorus appeared as a doublet (even at 25 Hz



sweep width), which suggests that the two rings are probably close to being coplanar. However, nonequivalence (two doublets) is seen for these corresponding protons in the spectra of 83 and 84 which would indicate that the presence of the methyl group on the saturated ring causes a different environment for one of the benzylic protons as expected. However, the  $\Delta\nu$  separating the centers of the two doublets

is only 7 Hz. Thus, the rings are near planarity in both compounds although the magnitude of the  $\Delta\nu$  value as a function of ring distortion (and thus the shielding effect of the  $\text{CH}_3$  group on a benzylic proton) is unknown at this time.

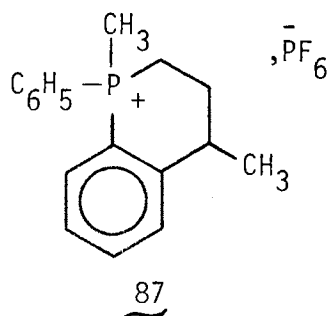
The seven-membered ring systems 85 and 86 would probably deviate more from planarity than the six-membered ring systems. The benzylic



protons are once again nonequivalent, but are shown as two distinct triplets. The presence of two triplets well separated is undoubtedly a result of the asymmetric center (and shielding of the  $\text{CH}_3$  group on one benzylic proton). The fact that the signals are triplets strongly implies geminal coupling from nonequivalent geminal protons, which is most simply rationalized on the basis of a nonplanar, seven-membered ring. Again the proximity of the  $\text{CH}_3$  group on the seven-membered ring to a benzylic proton is not easily estimated and any evaluation of shielding (or deshielding) effects must be treated with caution. The latter could contribute significantly to the nonequivalent nature of the benzylic protons to permit genuine nonequivalence. Morris and Berlin observed similar triplets for the benzyl protons in compound 110. When the signals were decoupled from  $^{31}\text{P}$ , two doublets appear, as would be anticipated from nonequivalent protons which are geminally coupled.



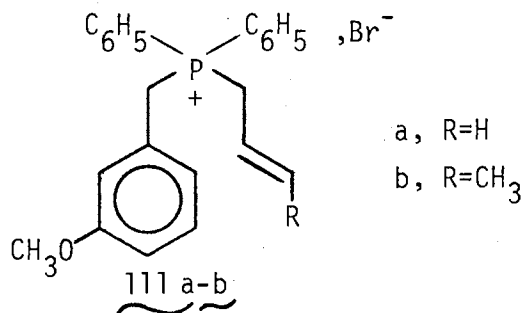
One other interesting system that should be noted is compound 87.



It appears from the signal pattern observed for the P-methyl group that 87 is a mixture of ( $\pm$ )-isomers. Generally one would expect to observe a doublet, but two doublets were found, indicating most probably the presence of isomers arising from a relationship of the groups on phosphorus with respect to the ring methyl group at the asymmetric carbon center. Obviously, X-ray analysis of several members of the family would be instructive as to the stereochemistry of the partially unsaturated ring of fused C-P heterocycles.

#### Other Attempted Cyclizations

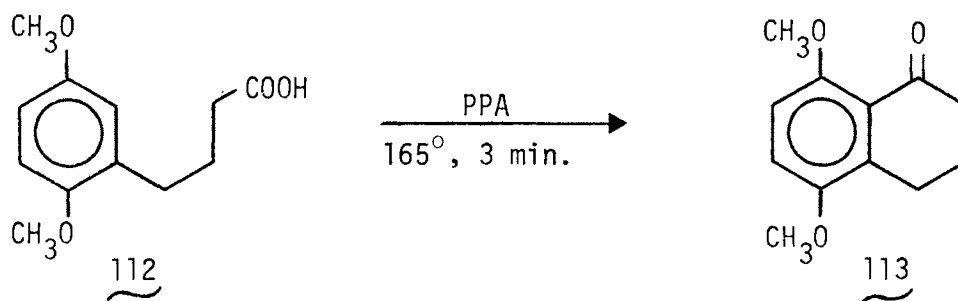
Due to the success of the cyclizations of the benzyl and the 3-methylbenzyl-substituted phosphonium bromides, we wished to add the 3-methoxybenzyl-substituted phosphonium bromides to the family of compounds studied. Using 3-methoxybenzyl chloride (prepared from the alcohol and  $\text{SOCl}_2$ )<sup>46</sup> as in similar previously accomplished preparations,  $\beta$ -alkenyl-3-methoxybenzyl-diphenylphosphonium bromides 111 a-b were



prepared in very good yields [R=H (72%), CH<sub>3</sub> (45%)]. The structures were supported by elemental and mass spectral analysis in addition to NMR and IR spectra.

When these compounds were subjected to our general cyclization procedure, several unusual observations were noted. When precipitation was attempted with NaBr, no solid resulted and the solution remained clear. When KPF<sub>6</sub> was employed in the precipitation step, a charred solid formed (upon sitting overnight, a large part of this solid was redissolved in the water) and filtration produced an oil which could not be recrystallized. When the aqueous layer was extracted with H<sub>2</sub>CCl<sub>2</sub> and the latter was treated with ether, a crude solid appeared and gave a NMR spectrum which was void of a signal for protons of the methoxy function. This solid could not be reprecipitated from H<sub>2</sub>CCl<sub>2</sub>/ether because of oil formation.

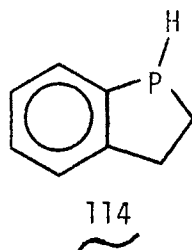
One possible reason for the complicated reaction mixture could result from cleavage of the methoxy group at 160° (30 min.). Interestingly, when  $\gamma$ -(2,5-dimethoxyphenyl)butyric acid (112) was



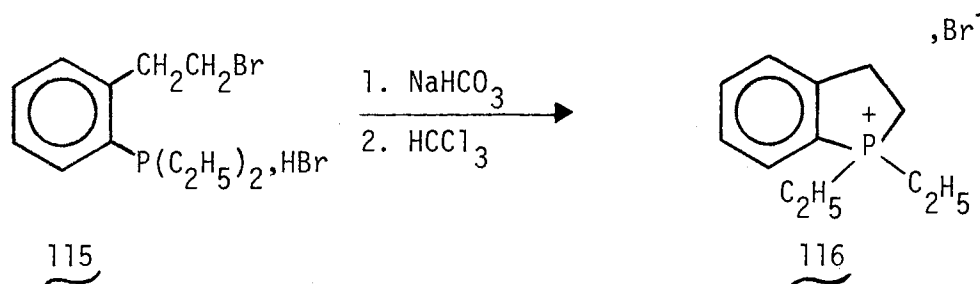
subjected to PPA at 165° for 3 min., the corresponding tetralone 113 was obtained in 93% yield.<sup>37</sup> In contrast, when 111a (R=H) was subjected to treatment with PPA at 160° for 5 min., the solid that was isolated (as the PF<sub>6</sub><sup>-</sup> salt) resembled starting material (by NMR),

although it undoubtedly underwent a metathesis. Work is being continued with this family.

Having prepared the 1,2,3,4-tetrahydrophosphinoline derivatives (Table II) with the use of our cyclization procedure, we considered the preparation of derivatives of the 5-membered phosphindole (114) ring



system. These compounds are usually obtained through long reaction sequences as the corresponding 1,2,3,4-tetrahydrophosphinolines (Chapter I). Thus, 1,1-diethylphosphindolinium bromide (116) was similarly prepared when 115 was treated with sodium bicarbonate followed by  $\text{HCCl}_3$  addition as before.<sup>71</sup>



We prepared a series of allyl-substituted phosphonium bromides 117a-c and triphenylvinylphosphonium bromide.<sup>104</sup> It was found that triphenylvinylphosphonium bromide was resistant to cyclization even at a temperature of  $300^\circ$  for 1 hr. as determined by NMR analysis.

A study of the effect of PPA on 117c ( $\text{R}=\text{C}_6\text{H}_5$ ) was conducted over a range from  $160^\circ$ - $300^\circ$  as shown in Figure 4. The products were isolated

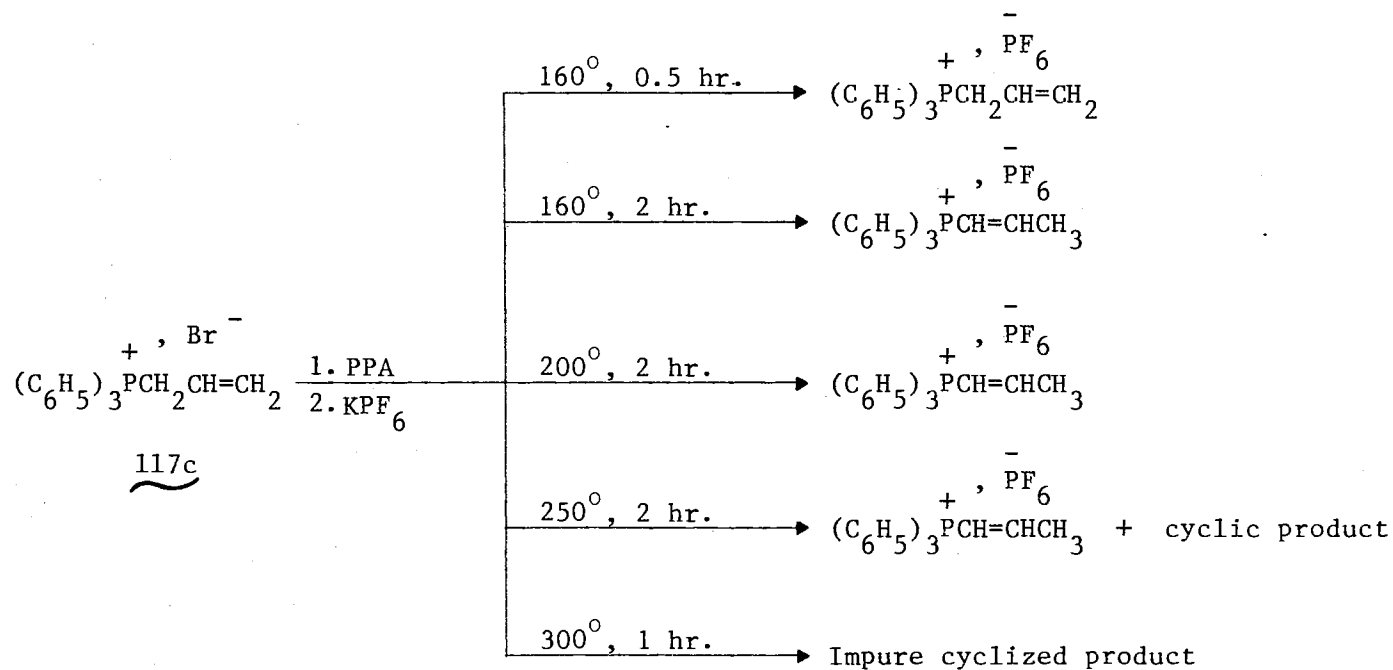
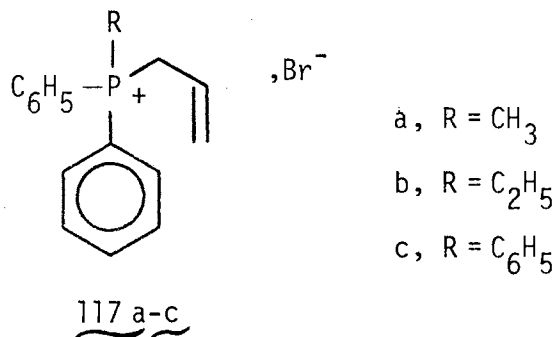
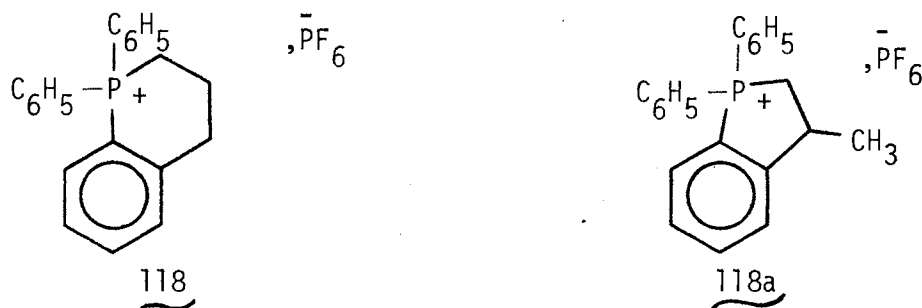


Figure 4. Effect of Temperature on the Reaction of Allyltriphenylphosphonium Bromide (117c) with 115% Polyphosphoric Acid



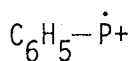
from H<sub>2</sub>CCl<sub>2</sub>/ether; the reaction was followed by NMR analysis. Isomerization occurred at 160°, but cyclization to a noticeable extent did not occur until 250°. At 300°, cyclization occurred with no unsaturated products formed, but an impurity was detected that could not be separated by simple purification methods. This impurity may be the 6-membered ring 118 which could be very difficult to distinguish



from 118a using NMR techniques. Similar results were found when pure 1-propenyltriphenylphosphonium chloride was allowed to react at 300° for 2 hr. in PPA. Other members of this family 117a-b (R=CH<sub>3</sub>, C<sub>2</sub>H<sub>5</sub>) also yielded cyclized products, but unfortunately the products were extremely impure.

## Mass Spectra of Prepared Phosphonium Salts

Although very little work has been advanced in mass spectral analysis of phosphonium salts, our results for C-P heterocyclic compounds agree quite well with those of Chen<sup>24</sup> and Snider.<sup>107</sup> Both open-chain and cyclic phosphonium salts gave similar patterns, but more rigorous investigations must be made before detailed fragmentation patterns can be interpreted. It should also be noted that no molecular



119

ions were observed for any compounds analyzed, but most of the patterns contained a peak at  $\underline{m/e}$  108 which corresponds to the phenylphosphinidene cation (119).<sup>26,41</sup>

The low resolution mass spectra of our open-chain phosphonium salts (Tables V and VI) all showed similar fragmentation patterns. The largest ion present in these systems corresponded to the appropriate tertiary phosphine produced by loss of either  $\text{C}_2\text{H}_3\text{Br}$ ,  $\text{C}_3\text{H}_5\text{Br}$ , or  $\text{C}_4\text{H}_7\text{Br}$ . Thus compounds 72, 74, and 77 had the largest peak at  $\underline{m/e}$  267 (which corresponds to benzylidiphenylphosphine,  $\text{C}_{19}\text{H}_{17}\text{P}$ ) while 73 and 75 showed  $\underline{m/e}$  290 (corresponding to (3-methylbenzyl)diphenylphosphine,  $\text{C}_{20}\text{H}_{19}\text{P}$ ) as the largest ion in each case, respectively. Identical results are found for compounds 78-81 and these are usually the base peaks in the spectra. Also worthy of note is  $\underline{m/e}$  91, which appeared in the spectra of 72, 74,

TABLE V

INTENSE IONS IN THE MASS SPECTRA OF  $\beta$ -ALKENYLARYLDIPHENYLPHOSPHONIUM  
BROMIDES 72-75 AND BENZYLDIPHENYLVINYLPHOSPHONIUM BROMIDE (77)<sup>a</sup>

Cpd.	Vacuum (mm)	Probe Temp. ( $^{\circ}$ C)	Source Temp. ( $^{\circ}$ C)	M <sup>*</sup> -121 (% RI) <sup>b</sup>	M <sup>*</sup> -135 (% RI) <sup>c</sup>	m/e (% RI)
<u>72</u>	$4.5 \times 10^{-6}$	180	180	276(36.5)		63(39), 77(41), 91(100), 107(34), 108(30), 183(37), 185(43), 227(66)
<u>73</u>	$1 \times 10^{-5}$	180	180	290(62)		77(17), 105(67), 108(39), 183(100), 185(94), 201(30), 291(49)
<u>74</u>	$1.6 \times 10^{-5}$	90	170		276(35)	55(82), 56(80), 57(55), 58(69), 59(51), 69(63), 77(59), 91(100), 108(26), 183(49), 185(41), 186(55), 201(43).
<u>75</u>	$1 \times 10^{-5}$	150	180		290(61)	77(12), 105(100), 107(12), 108(18), 129(12), 133(19), 152(13), 183(89), 185(69), 186(36), 239(21), 291(22)

TABLE V (Continued)

Cpd.	Vacuum (mm)	Probe Temp. ( $^{\circ}$ C)	Source Temp. ( $^{\circ}$ C)	$M^{*-121}$ (% RI) <sup>b</sup>	$M^{*-135}$ (% RI) <sup>c</sup>	<u>m/e</u> (% RI)
<u>77</u>	$5 \times 10^{-6}$	180	220			51(15), 65(15), 77(11), 91(72), 107(19), 108(18), 152(13), 183(86), 184(14), 185(100), 186(20), 276(46)

<sup>a</sup>All spectra were recorded at 70 eV;  $M^{*}$  symbolizes the cation portion of the particular molecule since at 70 eV (ionization potential) the molecular cation  $M^{+}$  was not observed either in open-chain or cyclic compounds.

<sup>b</sup>The symbol  $M^{*-121}$  refers to a m/e corresponding to loss of allyl bromide (m/e 121).

<sup>c</sup>The symbol  $M^{*-135}$  refers to a m/e corresponding to loss of 1-bromo-2-butene (m/e 135).



TABLE VI

 INTENSE IONS IN THE MASS SPECTRA OF ALKYL(OR ARYL)-  
 2-BUTENYLDIPHENYLPHOSPHONIUM BROMIDES 78-81<sup>a</sup>

Cpd.	Vacuum (mm)	Probe Temp. (°C)	Source Temp. (°C)	M <sup>*</sup> -135 (% RI) <sup>b</sup>	m/e (% RI)
<u>78</u>	2.6 x 10 <sup>-6</sup>	140	170	200(100)	39(13), 51(15), 54(10), 55(10), 77(13), 107(15), 183(58), 184(10), 185(38), 199(17), 201(15)
<u>79</u>	3.6 x 10 <sup>-6</sup>	145	170	214(96)	39(22), 51(22), 52(31), 107(28), 108(34), 109(17), 183(100), 184(16), 185(57), 186(26), 215(17)
<u>80</u>	1 x 10 <sup>-5</sup>	145	170	262(100)	54(12), 107(14), 108(35), 152(12), 183(97), 184(21), 185(21), 261(26), 263(43)
<u>81</u>	3 x 10 <sup>-6</sup>	135	170	312(100)	51(9), 55(14), 157(14), 183(61), 202(14), 203(11), 233(52), 234(12), 311(78) 313(21)

<sup>a</sup>All spectra were recorded at 70 eV; M<sup>\*</sup> symbolizes the cation portion of the particular molecule since at 70 eV (ionization potential) the molecular cation M<sup>+</sup> was not observed either in open-chain or cyclic compound.

<sup>b</sup>The symbol M<sup>\*</sup>-135 refers to a m/e corresponding to loss of 1-bromo-2-butene (m/e 135).

and 77 while m/e 105 is prevalent in 73 and 75 and corresponds to the tropylium-type ions.

The cyclic systems, as stated before, showed no molecular ion, but indeed a m/e corresponding to  $M^+ - 146$  ( $HPF_6$ ) as the largest ion. These results are shown in Tables VII and VIII. Since m/e 146 is not observed in the spectra, the loss of  $HPF_6$  probably results from electron impact inside the ionizing region and not thermal decomposition. The interpretation of the fragmentation of these cyclic intermediates is still speculative, however.

In order to obtain better spectral results for these classes of compounds, one could experiment with lower ion source temperature or lower electron voltage. In this manner the presence of fewer major peaks might simplify interpretation and possibly reveal the presence of a molecular ion.

#### Suggestions for Further Work

A few successful resolutions of cyclic quaternary phosphonium salts have recently been accomplished.<sup>24,107</sup> The resolution of quaternary phosphonium salts has been reviewed by Chen,<sup>24</sup> while all types of resolutions were discussed in reviews published in 1971.<sup>14,117</sup>

Chen prepared 1-ethyl-1,2,3,4-tetrahydro-1-phenylbenzo[h]phospholinium bromide (71) through a long and tedious reaction sequence.<sup>24</sup>

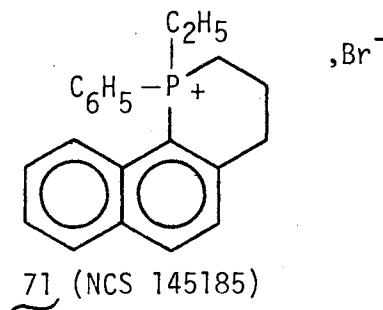


TABLE VII

INTENSE IONS IN THE MASS SPECTRA OF 1,2,3,4-TETRAHYDROISOPHOSPHINOLINIUM  
 HEXAFLUOROPHOSPHATE DERIVATIVES AND RELATED COMPOUNDS 82-86<sup>a</sup>

Cpd.	Vacuum (mm)	Probe Temp. (°C)	Source Temp. (°C)	M <sup>*</sup> -146 (% RI) <sup>b</sup>	m/e (% RI)
<u>82</u>	2.6 x 10 <sup>-6</sup>	150	190	302(100)	28(50), 91(17), 107(37), 108(22), 115(35), 117(22), 183(65), 184(15), 185(22), 301(91), 303(24)
<u>83</u>	8.6 x 10 <sup>-6</sup>	195	170	316(100)	77(23), 91(56), 107(67), 108(35), 114(56), 115(30), 128(23), 129(37), 131(35), 183(81), 185(28), 301(51), 315(58), 317(23)
<u>84</u>	4 x 10 <sup>-6</sup>	200	200	330(100)	87(15), 107(79), 115(15), 128(21), 129(20), 130(14), 183(32), 315(47), 316(14), 329(61), 331(27)
<u>85</u>	4.4 x 10 <sup>-6</sup>	200	180	330(88)	69(28), 91(29), 107(50), 108(40), 115(32), 121(27), 129(29), 130(34), 183(55), 315(100), 316(26), 329(37), 331(24)

TABLE VII (Continued)

Cpd.	Vacuum (mm)	Probe Temp. ( $^{\circ}$ C)	Source Temp. ( $^{\circ}$ C)	$M^{*-146}$ (% RI) <sup>b</sup>	$\underline{m/e}$ (% RI)
<u>86</u>	$4 \times 10^{-6}$	220	180	344(76)	77(58), 91(85), 107(94), 115(86), 121(95), 128(82), 129(79), 143(82), 144(55), 199(50), 329(87), 330(72), 345(66)

<sup>a</sup>All spectra were recorded at 70 eV;  $M^{*}$  symbolizes the cation portion of the particular molecule since at 70 eV (ionization potential) the molecular cation  $M^{+}$  was not observed either in open-chain or cyclic compounds.

<sup>b</sup>The symbol  $M^{*-146}$  refers to a  $\underline{m/e}$  corresponding to loss of hexafluorophosphoric acid ( $\underline{m/e}$  146).

TABLE VIII

 INTENSE IONS IN THE MASS SPECTRA OF 1,2,3,4-TETRAHYDROPHOSPHINOLINIUM  
 HEXAFLUOROPHOSPHATE DERIVATIVES 87-90<sup>a</sup>

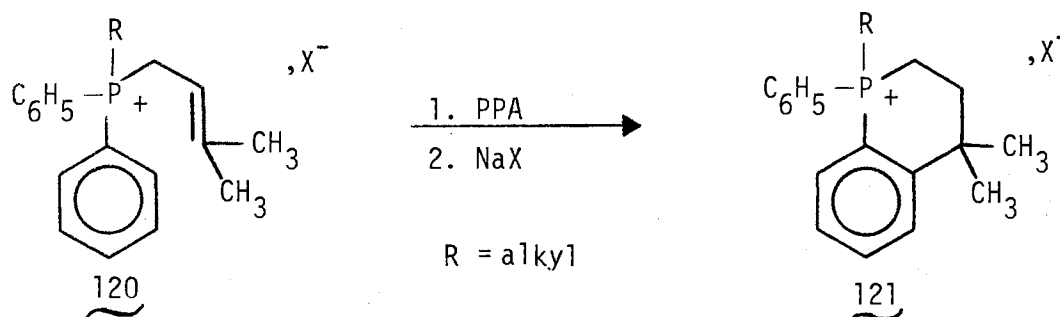
Cpd.	Vacuum (mm)	Probe Temp. (°C)	Source Temp. (°C)	$M^*-146$ (% RI) <sup>b</sup>	$m/e$ (% RI)
<u>87</u>	$4.0 \times 10^{-5}$	220	190	254(58)	91(31), 107(59), 115(34), 133(46), 225(46), 239(100), 240(73), 253(48)
<u>88</u>	$7.6 \times 10^{-5}$	240	180	268(37)	69(90), 107(84), 119(89), 131(99), 133(50), 169(44), 181(51), 225(60), 240(100), 267(43)
<u>89</u>	$5 \times 10^{-6}$	250	195	316(39)	77(21), 78(21), 107(100), 115(24), 147(17), 165(21), 178(17), 225(15), 301(29), 315(26)
<u>90</u>	$5 \times 10^{-5}$	250	200	366(50)	107(100), 108(42), 152(42), 166(48), 168(81), 179(60), 182(40), 183(62), 290(54), 365(33)

<sup>a</sup>All spectra were recorded at 70 eV;  $M^*$  symbolizes the cation portion of the particular molecule since at 70 eV (ionization potential) the molecular cation  $M^+$  was not observed either in open-chain or cyclic compounds.

<sup>b</sup>The symbol  $M^*-146$  refers to a  $m/e$  corresponding to loss of hexafluorophosphoric acid ( $m/e$  146).

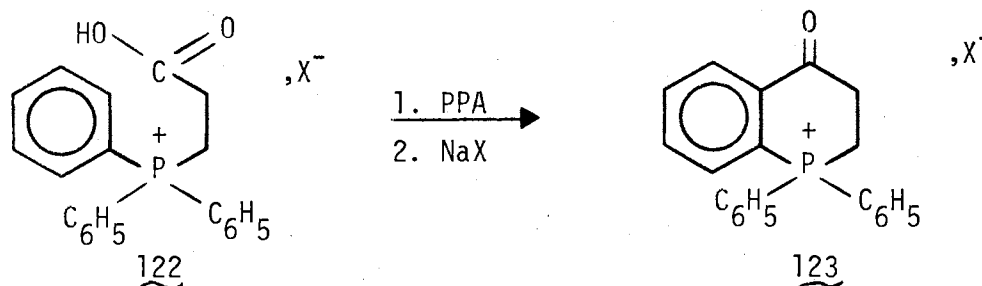
The diastereoisomeric salts were synthesized and separated by treatment of the (+)-phosphonium bromide 71 with excess optically active silver hydrogen dibenzoyltartrates [Ag L(+)-HDBT and Ag D(-)-HDBT] in water.<sup>24</sup> The identical melting points and opposite specific rotations strongly indicate their enantiomeric nature.

It is possible to use our method of cyclization to prepare compounds of this nature that have an optically active center only at



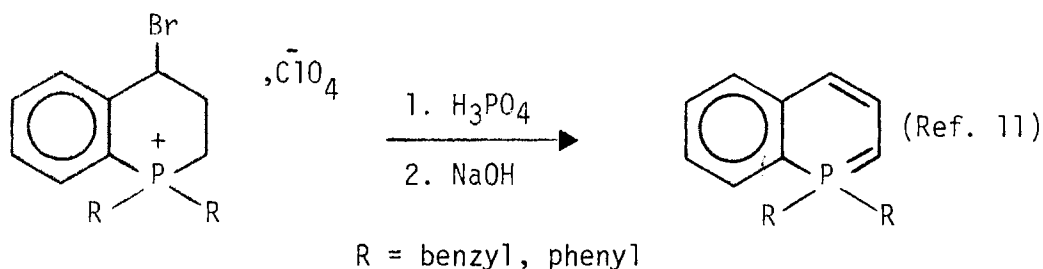
the phosphorus atom. By use of 1-bromo-3-methyl-2-butene and the appropriate phosphine to prepare 120, cyclization should produce 121, which could hopefully be resolved possibly using optically active hydrogen dibenzoyltartrates to separate isomers.

Although Mann and co-workers prepared 5,7-dimethyl-4-oxo-1-phenylphosphinolinium methopicate (see Chapter I, section I) with the use of PPA in very low yield,<sup>40</sup> it is conceivable that cyclization of acid 122



to 123 can be achieved in good yields. A possible rationale for the proposed cyclization could involve three points: (1) the acylium ion ( $\overset{+}{\text{R}}\overset{\cdot\cdot}{\text{C}}=\overset{+}{\text{O}}$   $\rightleftharpoons$   $\overset{+}{\text{R}}\overset{\cdot\cdot}{\text{C}}\equiv\overset{+}{\text{O}}$ ) has been postulated in PPA cyclizations involving carboxylic acids; (2) the inductive effect of the  $\text{P}^+$  atom is likely much less than with  $\text{N}^+$  or  $\text{C}^+$  since P is a larger atom (thus the benzene ring is less deactivated than when  $\text{N}^+$  or  $\text{C}^+$  is attached); and (c) possibly PPA anions can stabilize cationic intermediates.

The phosphorin analogs of benzene,<sup>3,78</sup> anthracene,<sup>61,62</sup> and phenanthrene<sup>63</sup> have been known for several years. It was demonstrated by Märkl and Heier that cyclic phosphonium salts could be used as precursors for the phosphanaphthalene derivatives (see Chapter I).<sup>81</sup>



These phosphorin derivatives are generally prepared through long reaction procedures. Using our methods to obtain cyclic phosphonium salts, a wide variety of phosphorin derivatives could be made. The phosphorus substituents could also be varied since only benzyl, phenyl, and one ethoxy derivative<sup>83</sup> have been prepared to date in the systems larger than phosphabenzene. The biological activity of these systems is certainly open for investigation.

## CHAPTER III

### EXPERIMENTAL <sup>a-f</sup>

Reagents. All liquids obtained from commercial sources were purified by distillation: From Aldrich Chemical Co. - 1-Bromo-2-butene b.p. 103-106°,  $n_D^{23.5}$  1.4770 [lit.<sup>111</sup> 103-105°,  $n_D^{20}$  1.4777];  $\beta$ -bromophenetole m.p. 33.5-35° [lit.<sup>11</sup> 35°]; *m*-methylbenzyl chloride b.p. 197-199°,  $n_D^{23.5}$  1.5335 [lit.<sup>56</sup> 195-196°,  $n_D^{25}$  1.5327]; diphenylphosphinous chloride b.p. 124-127°/0.8 mm,  $n_D^{23.5}$  1.6343 [lit.<sup>43</sup> 112-113°/0.5 mm,  $n_D^{20}$  1.6358]. From Eastman Kodak Company - Allyl bromide b.p. 69.5-70°,  $n_D^{23.5}$  1.4685 [lit.<sup>99</sup> 70-71°,  $n_D^{20}$  1.4654]; benzyl chloride b.p.

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<sup>a</sup>Melting points were obtained on a Thomas-Hoover capillary melting point apparatus and are uncorrected.

<sup>b</sup>Proton magnetic resonance spectra were taken on a Varian XL-100(15) high resolution NMR spectrometer operating at 100.1 MHz with tetramethylsilane (TMS) used as the internal standard.

<sup>c</sup><sup>31</sup>P magnetic resonance spectra were taken on a Varian XL-100(15) high resolution NMR spectrometer operating at 40.5 MHz using 85% H<sub>3</sub>PO<sub>4</sub> as the external standard.

<sup>d</sup>Infrared spectra were taken on a Beckman-5A spectrometer with samples in potassium bromide pellets.

<sup>e</sup>Low resolution mass spectra were obtained on a CEC 21-100 B double focusing mass spectrometer.

<sup>f</sup>Elemental analyses were performed by Galbraith Laboratories, Knoxville, Tennessee.



177-179°  $n_D^{23.5}$  1.5379 [lit.<sup>55</sup>,  $n_D^{25}$  1.5363]; triphenylphosphine m.p. 79.5-81° [lit.<sup>33</sup> 79.5°]. From FMC Corporation - 115% Polyphosphoric acid [82.3%  $P_2O_5$ , guaranteed minimum].

Solvents. Diethyl ether, benzene, and toluene were dried over sodium and filtered prior to use. Xylene [Fisher Scientific Company, A.C.S. Certified] was used without further purification.

General Procedure for the Synthesis of  $\beta$ -Alkenylarylmethyldiphenylphosphonium Bromides 72-75, Benzyldiphenylvinylphosphonium Bromide (77), and Selected Alkyl(or aryl)-2-butenyldiphenylphosphonium Bromides 78-81.

In a 300-ml. inverse Grignard flask under  $N_2$  was placed 1.09 g. (0.045 g-atoms) of Mg turnings and 20 ml of anhydrous ether. Into an attached 60-ml. addition funnel was placed 5.7 g (0.045 mole) of benzyl chloride in 40 ml. of anhydrous ether. A few very small crystals of iodine and 5 drops of ethyl bromide were added to the magnesium solution and mechanical stirring was initiated. When the reaction began, the benzyl chloride was slowly added dropwise over a 15-min. period. When the addition was complete, the solution was boiled for 30 min. To the addition funnel was added 9.92 g. (0.045 mole) of diphenylphosphinous chloride in 40 ml. of ether. This was slowly added dropwise to the Grignard mixture over a 20-min. period followed by a 1-hr. period at reflux.

In the lower, attached 300-ml. 3-necked, round-bottom flask was placed 8.0 g (0.066 mole) of allyl bromide in 100 ml. of anhydrous benzene. A  $N_2$  inlet tube was connected along with a water-cooled condenser. The benzene solution was heated almost to reflux, and then the contents in the upper flask were added dropwise over a 2.5-hr. period. When all liquid in the upper flask had drained, it was rinsed

with 25 ml. of ether which was also dripped into the lower flask. The ether, with continued heating and with a steady flow of  $N_2$ , was expelled from the lower flask. Allyl bromide (5.6 g., 0.046 mole) in 25 ml. of benzene was added to the lower flask. The upper flask was removed, and the solution was boiled with stirring for 24 hr. under  $N_2$ .

A precipitate formed and was collected by vacuum filtration, dissolved in a minimum amount of  $H_2CCl_2$ , and then reprecipitated by the addition of anhydrous diethyl ether until the solution became cloudy. This mixture was allowed to stand at room temperature for 24 hrs. A white solid precipitated and was collected by filtration and dried in vacuo to yield 9.3 g (52%) of 72, m.p. 201-203°. The NMR spectrum displayed in Plate I along with the IR and mass spectral results (Tables III and IV, respectively) support the structure of 72. The  $^{31}P$  NMR spectrum (Plate II) of 72 showed absorption at  $\delta$  -23.96 (15% in  $DCCl_3$ ) relative to 85%  $H_3PO_4$ .

Anal. Calcd. for  $C_{22}H_{22}BrP$ : P, 7.80.

Found: P, 7.58.

Preparation of Allyl(3-methylbenzyl)diphenylphosphonium Bromide

(73). The same molar quantities of magnesium, m-methylbenzyl chloride, and diphenylphosphinous chloride were used as in the previous procedure for 72. Allyl bromide (7.25 g., 0.06 mole) in 75 ml. of benzene was placed in the lower flask and, when the addition of the contents in the upper flask was completed, an additional 2.8 g. (0.023 mole) of allyl bromide in 25 ml. of benzene was added and this solution was boiled for 24 hr. with stirring. The precipitate was collected by filtration and purified by reprecipitation from  $H_2CCl_2$ /ether to give 8.9 g. (48%) of 73, m.p. 173-175°. Structural identification is supported by the NMR

spectrum (Plate III) along with IR and mass spectral values (Tables III and V).

Anal. Calcd. for  $C_{23}H_{24}BrP$ : P, 7.53.

Found: P, 7.50.

In another preparation, only ether was used for the synthesis of the phosphine and in the quaternization process. The yield of 73 decreased to 25% (a 6-day reflux period was used for the quaternization step) in what was otherwise an identical experiment.

Preparation of Benzyl-2-butenyldiphenylphosphonium Bromide (74).

The general procedure was used to prepare benzyldiphenylphosphine as for 72. The contents in the upper flask were slowly added to the lower vessel containing 8.1 g. (0.06 mole) of 1-bromo-2-butene in anhydrous toluene heated almost to reflux. After ether removal, the solution was boiled for 24 hr. and the crude salt was purified by reprecipitation from  $H_2CCl_2$ /ether to give 9.0 g (48%) of 74, m.p. 177-180°. Structure elucidation is supported by NMR analysis (Plate IV) along with IR and mass spectral values (Table III and V). The 40.5 MHz NMR spectrum of 74 (Plate V) shows  $^{31}P$  absorption at  $\delta$  -24.79 (15% in  $DCCl_3$ ) relative to 85%  $H_3PO_4$ .

Anal. Calcd. for  $C_{23}H_{24}BrP$ : P, 7.53.

Found: P, 7.64.

In a similar preparation, only ether was used for the synthesis of the phosphine and in the quaternization process. The yield of 74 decreased to 26% in what was an otherwise identical preparation.

Preparation of 2-Butenyl(3-methylbenzyl)diphenylphosphonium Bromide

(75). (3-Methylbenzyl)diphenylphosphine was prepared by the general procedure, and the contents in the upper flask were transferred to the

lower reaction vessel containing 8.1 g. (0.06 mole) of 1-bromo-2-butene in 10 ml. of anhydrous ether. After the addition was completed, 40 ml. of anhydrous benzene was placed in the reaction mixture and the solution was boiled for 48 hr. with stirring. The crude solid was purified as before to give 6.7 g. (35%) of 75, m.p. 170-173°. NMR analysis (Plate VI) along with IR and mass spectral data (Tables III and V) supports structure identification of 75.

Anal. Calcd. for  $C_{24}H_{26}BrP$ : P, 7.28.

Found: P, 7.19.

In an identical experiment using only ether throughout the entire process, the yield of 75 was decreased to 29% overall.

Preparation of Benzyldiphenylvinylphosphonium Bromide (77).<sup>105</sup> The general procedure was used to prepare benzyldiphenylphosphine. In the lower flask was placed 90.0 g. (0.96 mole) of phenol [Mallinckrodt Chemical Works, Analytical Reagent (loose crystals)] and 9.05 g. (0.045 mole) of  $\beta$ -bromophenetole, which were heated to 90°. The ether was driven off upon addition of the phosphine, and the solution was heated at 90° for 48 hr. with stirring. The solution was then cooled to approximately 40° and slowly poured into 500 ml. of anhydrous ether at 0° with stirring. The white solid was collected by filtration, dried in a vacuum oven for 12 hr. at 60°, and gave 10.6 g. of the compound that was used without further purification (decomposition had previously been reported in similar preparations).<sup>104</sup> Two grams of this compound were placed in a 100-ml. round-bottomed flask and boiled for 1 hr. with a solution of 50 ml. of ethyl acetate and 15 drops of triethylamine. The solid was filtered out and reprecipitated from  $H_2CCl_2$ /diethyl ether to give 1.1 g (69%, based on the intermediate benzyl-( $\beta$ -phenoxyethyl)-

diphenylphosphonium bromide of 77, m.p. 220-222° [lit.<sup>105</sup> 62%, m.p. 211-212°]. The NMR spectrum that had been previously reported<sup>105</sup> is slightly different from that of our compound (Plate VII, discussed in Chapter II). IR and mass spectral data also support 77 (Tables III and V).

Anal. Calcd. for C<sub>21</sub>H<sub>20</sub>BrP: P, 8.08.

Found: P, 8.16.

Preparation of 2-Butenylmethyldiphenylphosphonium Bromide (78).

A solution of 9.0 g. (0.045 mole) of methyldiphenylphosphine and 4.5 g. (0.033 mole) of 1-bromo-2-butene in 120 ml. of xylene<sup>93</sup> was boiled with stirring for 18 hr. under N<sub>2</sub>. The solid was collected by filtration and purified by reprecipitation from C<sub>2</sub>H<sub>5</sub>OH/diethyl ether and dried in vacuo to yield 9.8 g. (88%) of 78, m.p. 187-189°. Structural characterization is supported by NMR (Plate VIII) plus IR and mass spectral values (Tables III and VI). The <sup>31</sup>P magnetic resonance (Plate IX) of 78 occurred at δ -21.84 (15% in DCCl<sub>3</sub>) relative to 85% H<sub>3</sub>PO<sub>4</sub>.

Anal. Calcd. for C<sub>17</sub>H<sub>20</sub>BrP: P, 9.24.

Found: P, 9.32.

Preparation of 2-Butenylethyldiphenylphosphonium Bromide (79). A

solution of 6.0 g. (0.028 mole) of ethyldiphenylphosphine and 5.4 g. (0.04 mole) of 1-bromo-2-butene in 60 ml. of anhydrous toluene under N<sub>2</sub> was boiled with stirring for 12 hr. The solid was reprecipitated from H<sub>2</sub>CCl<sub>2</sub>/ether to give 7.5 g. (77%) of 79, m.p. 198-200°. Structure 79 is supported by NMR spectrum (Plate X) and also IR and mass spectral results (Tables III and VI).

Anal. Calcd. for C<sub>18</sub>H<sub>22</sub>BrP: P, 8.87.

Found: P, 9.15.

Preparation of 2-Butenyltriphenylphosphonium Bromide (80).<sup>13</sup> In a modified procedure used by Bohlmann and Mannhardt (discussed in Chapter II),<sup>13</sup> a solution of 11.8 g. (0.045 mole) of triphenylphosphine and 4.5 g. (0.033 mole) of 1-bromo-2-butene in 120 ml.<sup>93</sup> of xylene was boiled with stirring for 19 hr. under N<sub>2</sub>. Purification of the crude solid by H<sub>2</sub>CCl<sub>2</sub>/ether produced 12.4 g. (94%) of 80, m.p. 241-243° [lit.<sup>13</sup> 84%, 245°]. The NMR spectrum (Plate XI) along with IR and mass spectral data (Tables III and VI) support the proposed structure for compound 80. The 40.5 MHz NMR spectrum (Plate XII) of 80 showed <sup>31</sup>P absorption at δ -21.14 (15% in DCCl<sub>3</sub>) relative to 85% H<sub>3</sub>PO<sub>4</sub>.

Preparation of 2-Butenyl-1-naphthyldiphenylphosphonium Bromide (81). A solution of 5.0 g. (0.016 mole) of 1-naphthyldiphenylphosphine and 3.9 g. (0.029 mole) of 1-bromo-2-butene dissolved in 90 ml. of anhydrous benzene under N<sub>2</sub> was boiled for 12 hr. with stirring. Treatment of the crude salt with H<sub>2</sub>CCl<sub>2</sub>/ether gave 4.2 g. (59%) of 81, m.p. 259.5-261°. IR and mass spectral values (Tables III and VI), plus the NMR spectrum (Plate XIII), support the structure for 81.

Anal. Calcd. for C<sub>26</sub>H<sub>24</sub>BrP: P, 6.92.

Found: P, 7.00.

General Procedure for the Cyclization of β-Alkenylarylmethyldiphenylphosphonium Bromides 72-75, Benzyldiphenylvinylphosphonium Bromide (77), and Selected Alkyl(or aryl)-2-butenyldiphenylphosphonium Bromides (78)-(81) Using 115% Polyphosphoric Acid (PPA). Preparation of 1,2,3,4-Tetrahydro-4-methyl-2,2-diphenylisophospholinium Hexafluorophosphate (83). In a 100-ml. beaker was placed 60 ml. of 115% PPA which, was then heated on a hot plate to 160°. To this was slowly added 2.0 g. (0.005 mole) of 72 over a 10-min. period followed by an additional

30 min. of stirring. During the addition, a gas was given off, probably HBr.<sup>15</sup> Following the stirring period, the solution was cooled to 110-115° and slowly poured into 500 ml. of ice water, which produced a homogeneous solution upon stirring for 15 min. Precipitation of crude 83 occurred upon the addition of 50 ml. of a saturated aqueous KPF<sub>6</sub> solution. The solid was collected by filtration and dissolved in a minimum amount of H<sub>2</sub>CCl<sub>2</sub>, and the water layer was separated. The solid 83 was reprecipitated by the dropwise addition of anhydrous ether until the solution became cloudy. The solid was collected by filtration and a second reprecipitation from H<sub>2</sub>CCl<sub>2</sub>/ether gave 1.70 g. (73%) of 83, m.p. 172.5-174.5°. The NMR and IR spectra are displayed in Plate XVI and Plate XVIII, respectively, while mass spectral results are listed in Table VII.

The <sup>31</sup>P magnetic resonance (Plate XVII) of 83 showed <sup>31</sup>P absorption of the phosphonium function at δ -17.17 [15% in DCCl<sub>3</sub>/CF<sub>3</sub>CO<sub>2</sub>H(3:1) relative to 85% H<sub>3</sub>PO<sub>4</sub>].

Anal. Calcd. for C<sub>22</sub>H<sub>22</sub>F<sub>6</sub>P<sub>2</sub>: P, 13.40.

Found: P, 13.09.

Preparation of 1,2,3,4-Tetrahydro-4,7-dimethyl-2,2-diphenylisophosphinolinium Hexafluorophosphate (84). To 120 ml. of 115% PPA at 160° was slowly added 4.0 g (0.01 mole) of 73 with an additional 45-min. stirring period. After cooling the solution to 110°, it was slowly poured into 500 ml. of ice water and stirring was continued to produce a homogeneous mixture. A saturated aqueous NaBr solution (100 ml.) was added, but after a 6-hr. period, only a very small amount of the insoluble heterocycle had been precipitated. The mixture was therefore extracted with 3 x 200 ml. portions of H<sub>2</sub>CCl<sub>2</sub> and dried (anhydrous

MgSO<sub>4</sub>). The H<sub>2</sub>CCl<sub>2</sub> solution was reduced to ca. 50 ml., and the dropwise addition of ether produced the crude bromide of 84. The salt was dissolved in 90 ml. of anhydrous methanol and addition of 30 ml. of a saturated solution of KPF<sub>6</sub> with stirring produced a heavy precipitate. Purification by reprecipitation from H<sub>2</sub>CCl<sub>2</sub>/ether gave 1.30 g. (28%) of 84, m.p. 185.5-187°. The structure is supported by NMR and IR spectra (Plates XIX and XX) along with mass spectral results (Table VII).

Anal. Calcd. for C<sub>23</sub>H<sub>24</sub>F<sub>6</sub>P<sub>2</sub>: P, 13.00.

Found: P, 12.97.

Preparation of 1,2,3,4-Tetrahydro-2,2-diphenylisophosphinolinium Hexafluorophosphate (82). Phosphonium salt 77 (2.0 g., 0.005 mole) was slowly added to 70 ml. of 115% PPA at 300° with stirring for 1.25 hr. The very dark mixture was cooled to 120° and slowly poured into 250 ml. of ice water, and continued stirring gave a clear solution that was filtered through a glass wool plug to remove a small amount of insoluble material. A heavy precipitate separated when the clear homogeneous solution was treated with 35 ml. of a saturated KPF<sub>6</sub> solution. The solid was extracted (due to very slow filtration) with 2 x 200 ml. and 1 x 100 ml. portions of H<sub>2</sub>CCl<sub>2</sub>. Reduction of the volume of solvent to ca. 40 ml. followed by dropwise treatment of ether produced crude 82. Purification as in previous examples gave 1.20 g (51%) of 82, m.p. 174-176°. Its structure identification is supported by NMR and IR spectra (Plates XIV and XV) along with mass spectral analysis (Table VII).

Anal. Calcd. for C<sub>21</sub>H<sub>20</sub>F<sub>6</sub>P<sub>2</sub>: P, 13.82.

Found: P, 13.61.

Cyclization of 77 was attempted at the usual reaction temperature of 160° and also at 180°. NMR analysis of the reaction products



suggested that no cyclization had occurred in either case. Instead, a metathesis apparently took place in which 77 was converted to the hexafluorophosphate.

Preparation of 2,3,4,5-Tetrahydro-5-methyl-2,2-diphenyl-1H-benzo[c]phosphepinium Hexafluorophosphate (85). The cyclization of 74 (2.0 g., 0.0048 mole) was accomplished by the general procedure. The crude hexafluorophosphate salt 85 was purified by two reprecipitations using  $\text{H}_2\text{CCl}_2$ /ether to give 0.7 g (30%) of 85, m.p. 214-216°. The NMR and IR spectra (Plates XXI and XXIII) plus the mass spectral data (Table VII) support the structure of 85.

The 40.5 MHz NMR spectrum (Plate XXII) of 85 shows  $^{31}\text{P}$  absorption of the phosphonium function at  $\delta$  -14.22 (15% in  $\text{DCCl}_3/\text{CF}_3\text{CO}_2\text{H}(3:1)$ ) relative to 85%  $\text{H}_3\text{PO}_4$ .

Anal. Calcd. for  $\text{C}_{23}\text{H}_{24}\text{F}_6\text{P}_2$ : P, 13.00.

Found: P, 12.88.

Preparation of 2,3,4,5-Tetrahydro-5,8-dimethyl-2,2-diphenyl-1H-benzo[c]phosphepinium Hexafluorophosphate (86). Using our general procedure for cyclization, 75 (2.0 g., 0.0047 mole) was converted into the crude hexafluorophosphate salt 86. Two reprecipitations from  $\text{H}_2\text{CCl}_2$ /ether were required to give 0.55 g. (24%) of 86, m.p. 233-235°. NMR and IR spectra (Plates XXIV and XXV) along with mass spectral results (Table VII) support the proposed structure of 86.

Anal. Calcd. for  $\text{C}_{24}\text{H}_{26}\text{F}_6\text{P}_2$ : P, 12.63.

Found: P, 12.69.

Preparation of 1,2,3,4-Tetrahydro-1,4-dimethyl-1-phenylphosphinolinium Hexafluorophosphate (87). The phosphonium salt 78 (2.0 g., 0.006 mole) was slowly added to 70 ml. of 115% PPA at 160° and stirred for

30 min. The crude hexafluorophosphate salt 87 was purified by two reprecipitations from  $\text{H}_2\text{CCl}_2/\text{ether}$  and this procedure gave 1.6 g. (67%) of 87, m.p.  $179.5\text{--}182.0^\circ$ . Structure 87 was supported by NMR and IR spectra (Plates XXVI and XXVIII) along with mass spectral data (Table VIII).

The  $^{31}\text{P}$  magnetic resonance (Plate XXVII) absorption of the phosphonium function of compound 87 occurred at  $\delta -9.77$  and the  $\text{PF}_6^-$  moiety was found as a multiplet centered at  $\delta +144.32$  (25% in  $\text{CH}_3\text{CN} + 5$  drops  $\text{CF}_3\text{CO}_2\text{H}$ ) relative to 85%  $\text{H}_3\text{PO}_4$ .

Anal. Calcd. for  $\text{C}_{17}\text{H}_{20}\text{F}_6\text{P}_2$ : P, 15.48.

Found: P, 15.09.

Preparation of 1-Ethyl-1,2,3,4-tetrahydro-4-methyl-1-phenylphosphinolinium Hexafluorophosphate (88). Cyclization 79 (2.0 g., 0.0057 mole) was successfully performed using the general procedure. The crude hexafluorophosphate 88 that precipitated from 200 ml. of water was reprecipitated twice from  $\text{H}_2\text{CCl}_2/\text{ether}$  to yield 1.0 g. (42%) of 88, m.p.  $145\text{--}147^\circ$ . The proposed structure of 88 is supported by NMR and IR spectra (Plates XXIX and XXX) plus mass spectral data listed in Table VIII.

Anal. Calcd. for  $\text{C}_{18}\text{H}_{22}\text{F}_6\text{P}_2$ : P, 14.95.

Found: P, 14.90.

Preparation of 1,2,3,4-Tetrahydro-4-methyl-1,1-diphenylphosphinolinium Hexafluorophosphate (89). The phosphonium salt 80 (2.0 g., 0.005 mole) underwent cyclization via our general procedure. The heterocyclic salt 89 was precipitated from 300 ml. of water and purified with two reprecipitations to produce 1.9 g. (82%) of 89, m.p.  $203.5\text{--}205^\circ$ . NMR and IR analysis (Plates XXXI and XXXIII) along with mass

spectral results (Table VIII) support the proposed structure of 89.

The  $^{31}\text{P}$  magnetic resonance absorption of 89 (Plate XXXII) occurred at  $\delta -10.74$  for the phosphonium function and a multiplet centered at  $\delta +144.35$  (25% in  $\text{CH}_3\text{CN} + 5$  drops  $\text{CF}_3\text{CO}_2\text{H}$ ) corresponding to the  $\text{PF}_6^-$  group relative to 85%  $\text{H}_3\text{PO}_4$ .

Anal. Calcd. for  $\text{C}_{22}\text{H}_{22}\text{F}_6\text{P}_2$ : P, 13.40.

Found: P, 13.42.

Preparation of 1,2,3,4-Tetrahydro-4-methyl-1,1-diphenylbenzo[h]-phosphinolinium Hexafluorophosphate (90). The general cyclization procedure was used to convert 81 (2.0 g., 0.0044 mole) into the crude hexafluorophosphate 90. Two reprecipitations from  $\text{H}_2\text{CCl}_2/\text{ether}$  gave 0.75 g. (33%) of 90, m.p.  $192-194.5^\circ$ . The structure of 90 is supported by NMR and IR (Plates XXXIV and XXXV) data in addition to the mass spectral analysis (Table VIII).

Anal. Calcd. for  $\text{C}_{26}\text{H}_{24}\text{F}_6\text{P}_2$ : P, 12.09.

Found: P, 11.99.

Preparation of Allyl(3-methoxybenzyl)diphenylphosphonium Bromide (111a). The general method for the synthesis of  $\beta$ -alkenylarylmethyl-diphenylphosphonium bromides was employed. The same molar quantities of magnesium, *m*-methoxybenzyl chloride, and diphenylphosphinous chloride were used as in the preparation of 72. Allyl bromide (8.0 g., 0.066 mole) in 100 ml. of dry benzene was placed in the lower flask and when the addition of the contents in the upper flask was completed, an additional 4.29 g. (0.034 mole) of allyl bromide in 25 ml. of dry benzene was added. This solution was then boiled for 24 hr. with stirring. The precipitate was collected by filtration, reprecipitated from  $\text{H}_2\text{CCl}_2$  with the dropwise addition of ether, and dried in vacuo to

yield 13.8 g. (72%) of 111a, m.p. 174-176.5°; ir(KBr) 3.52, 6.26, 6.72, 6.95, 7.9, 8.96, 9.56, 9.7, 10.01, 10.7, 13.35, and 14.56  $\mu$ ; mass spectrum (70 eV, P @  $5 \times 10^{-6}$  mm, source temp. 180°C)  $m/e$  (rel. intensity) 306(52), 185(80), 183(100), 121(57), 91(42), 77(61), and 51(46); nmr ( $\text{DCCl}_3$ )  $\delta$  3.55 (s, 3,  $-\text{OCH}_3$ ), 4.1-4.42 (d of d, 2,  $-\text{P}-\text{CH}_2-\text{CH}$ ), 4.93 (d, 2,  $\text{Ar}-\text{CH}_2-\text{P}$ -), 5.14-5.66 (m, 3,  $-\text{CH}=\text{CH}_2$ ), 6.6-7.12 (m, 4,  $\text{H}-\text{Ar}-\text{CH}_2$ ), 7.55-8.08 (m, 10, aromatic,  $(\text{C}_6\text{H}_5)_2\text{P}$  ).

Anal. Calcd. for  $\text{C}_{23}\text{H}_{24}\text{BrOP}$ : P, 7.25.

Found: P, 6.90.

In a similar preparation, ether was used in the preparation of the phosphine and in the quaternization process. To the quaternization flask was added 50 ml. of dry benzene and the solution was boiled for 27 hr. The yield of 111a decreased to 28%.

Preparation of 2-Butenyl(3-methoxybenzyl)diphenylphosphonium Bromide (111b). The general procedure for the preparation of  $\beta$ -alkenyl-arylmethyldiphenylphosphonium bromides using the same molar quantities of magnesium, *m*-methoxybenzyl chloride, and diphenylphosphinous chloride was employed. 1-Bromo-2-butene (8.1 g., 0.06 mole) in 40 ml. of anhydrous ether was added to the lower flask and, when the contents in the upper flask had been drained, 40 ml. of anhydrous benzene was added and the solution was boiled for 48 hr. The precipitate was collected by filtration and reprecipitated from  $\text{H}_2\text{CCl}_2$ /ether to give 9.0 g. (45%) of 111b, m.p. 155-158°; ir(KBr) 3.52, 6.28, 6.7, 6.89, 7.89, 8.52, 9.01, 9.62, 10.02, 10.76, 13.45, and 14.4; mass spectrum (70 eV, P @  $5 \times 10^{-6}$ , source temp. 200°C, probe temp. 150°C)  $m/e$  (rel. intensity) 307(21), 306(100), 215(51), 201(22), 186(22), 185(84), 183(90), 121(28), 96(24), 94(24); nmr ( $\text{DCCl}_3$ )  $\delta$  1.24-1.68 (m, 3,  $=\text{CHCH}_3$ ), 3.55 (s, 3,  $\text{OCH}_3$ ),

3.96-4.36 (d of d, 2,  $-\text{P}-\underline{\text{CH}}_2-\text{CH}$ ), 4.87 (d, 2,  $\text{Ar}-\underline{\text{CH}}_2-\text{P}-$ ), 4.87-6.0 (m, 2,  $\underline{\text{CH}}=\underline{\text{CH}}$ ), 6.58-7.14 (M, 4,  $\underline{\text{H}}-\text{Ar}-\text{CH}_2$ ), 7.46-8.1 (m, 10, aromatic,  $(\text{C}_6\text{H}_5)_2\text{P}$ ).

Anal. Calcd. for  $\text{C}_{24}\text{H}_{26}\text{BrOP}$ : P, 7.02.

Found: P, 6.70.

Preparation of Allyldiphenyl-substituted Phosphonium Bromides

(117a-c). A solution of 11.8 g. (0.045 mole) of triphenylphosphine and 7.26 g. (0.06 mole) of allyl bromide in 155 ml. of dry benzene was boiled with stirring for 9 hr. The solid was collected by filtration and reprecipitated from  $\text{H}_2\text{CCl}_2$ /ether to give 15.6 g. (90%) of 117c, m.p. 222.5-227° (lit.<sup>58</sup> m.p. 225°).

Compound 117a was similarly prepared in 83% yield using the same molar quantities of reactants and reaction time. After purification by reprecipitation it had m.p. 159-161° (lit.<sup>94</sup> 161°).

Ethyldiphenylphosphine (6.0 g., 0.028 mole) and 6.05 g. (0.05 mole) of allyl bromide were refluxed in 60 ml. of dry benzene for 24 hr. The solid was filtered out and reprecipitated from  $\text{H}_2\text{CCl}_2$ /ether to give 7.69 (81%) of 117b, m.p. 161-162°; nmr ( $\text{DCCl}_3$ )  $\delta$  1.06-1.48 (2t, 3,  $-\text{P}-\text{CH}_2\underline{\text{CH}}_3$ ), 3.18-3.58 (m, 2,  $-\text{P}-\underline{\text{CH}}_2\text{CH}_3$ ), 4.22-4.52 (d of d, 2,  $-\text{P}-\underline{\text{CH}}_2-\text{CH}$ ), 5.2-5.7 (m, 3,  $-\underline{\text{CH}}=\underline{\text{CH}}_2$ ), and 7.56-8.11 (m, 10, aromatic,  $(\text{C}_6\text{H}_5)_2\text{P}$ ); ir(KBr) 3.5, 6.97, 8.97, 10.02, 10.52, 11.78, 12.5, 13.22, 13.55, and 14.45.

Anal. Calcd. for  $\text{C}_{17}\text{H}_{20}\text{BrP}$ : P, 9.24.

Found: P, 9.36.

Attempted Cyclization of Allyl-(3-methoxybenzyl)diphenylphosphonium

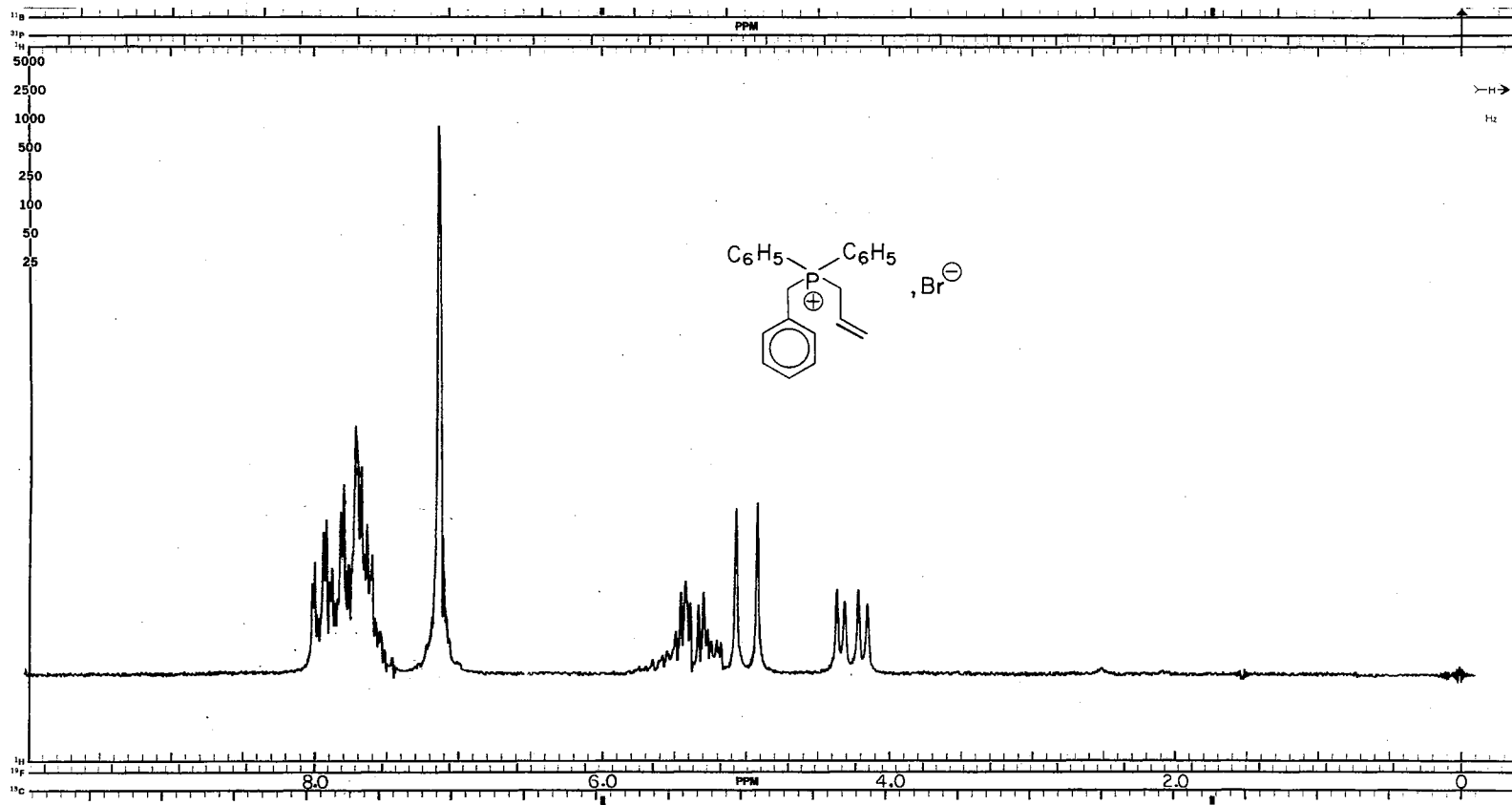
Bromide (111a). To 60 ml. of 115% polyphosphoric acid at 160° was slowly added 2.0 g. (0.0046 mole) of 111a over 10 minutes followed by a

30-min. stirring period. The solution was then cooled to 110-115° and slowly poured into 500 ml. of ice water and stirred until homogeneous. A saturated  $\text{KPF}_6$  solution (50 ml.) was added and a precipitate formed. After sitting overnight, most of the solid had dissolved. The residual dark precipitate was filtered out and promptly became oily on the filter paper. This oil was dissolved in  $\text{H}_2\text{CCl}_2$ , but resisted all attempts at recrystallization or purification. The aqueous layer was extracted with 3 x 130 ml. portions of  $\text{H}_2\text{CCl}_2$ , and the volume was reduced to 40 ml. To the  $\text{H}_2\text{CCl}_2$  solution was added dry ether (until the solution turned cloudy) and a white solid precipitated (overnight) and was collected by filtration. The NMR spectrum of the crude product showed that the methoxy group had probably been cleaved. The solid was dissolved in  $\text{H}_2\text{CCl}_2$  and again resisted all simple purification attempts.

Attempted Cyclization of Allyltriphenylphosphonium Bromide (117c).

To 60 ml. of 115% PPA at 300° was added 2.0 g. (0.0052 mole) of 117c. The solution was stirred for 1 hr. and turned very dark. The dark solution was cooled to 120° and then slowly poured into 200 ml. ice water; upon stirring, a fluffy, light brown material separated. The mixture was filtered to give a clear solution. A solution of  $\text{KPF}_6$  (40 ml. ) was added and a heavy brown precipitate formed and was filtered out. The solid was dissolved in  $\text{H}_2\text{CCl}_2$  and reprecipitated with ether (three times) to obtain 0.5 grams of an almost white solid. NMR analysis showed some cyclized product, but integration indicated an impurity was present; m.p. 161-164°. The impurity could not be removed by the reprecipitation method cited previously. Similar results were obtained for compounds 117a and 117b.

PLATE I



Allylbenzyldiphenylphosphonium Bromide (72)

Solvent. . .  $\text{DCCl}_3$

O.F. . . . 100.1 Hz

F.B. . . . . 2 Hz

R.F. . . . 67 db

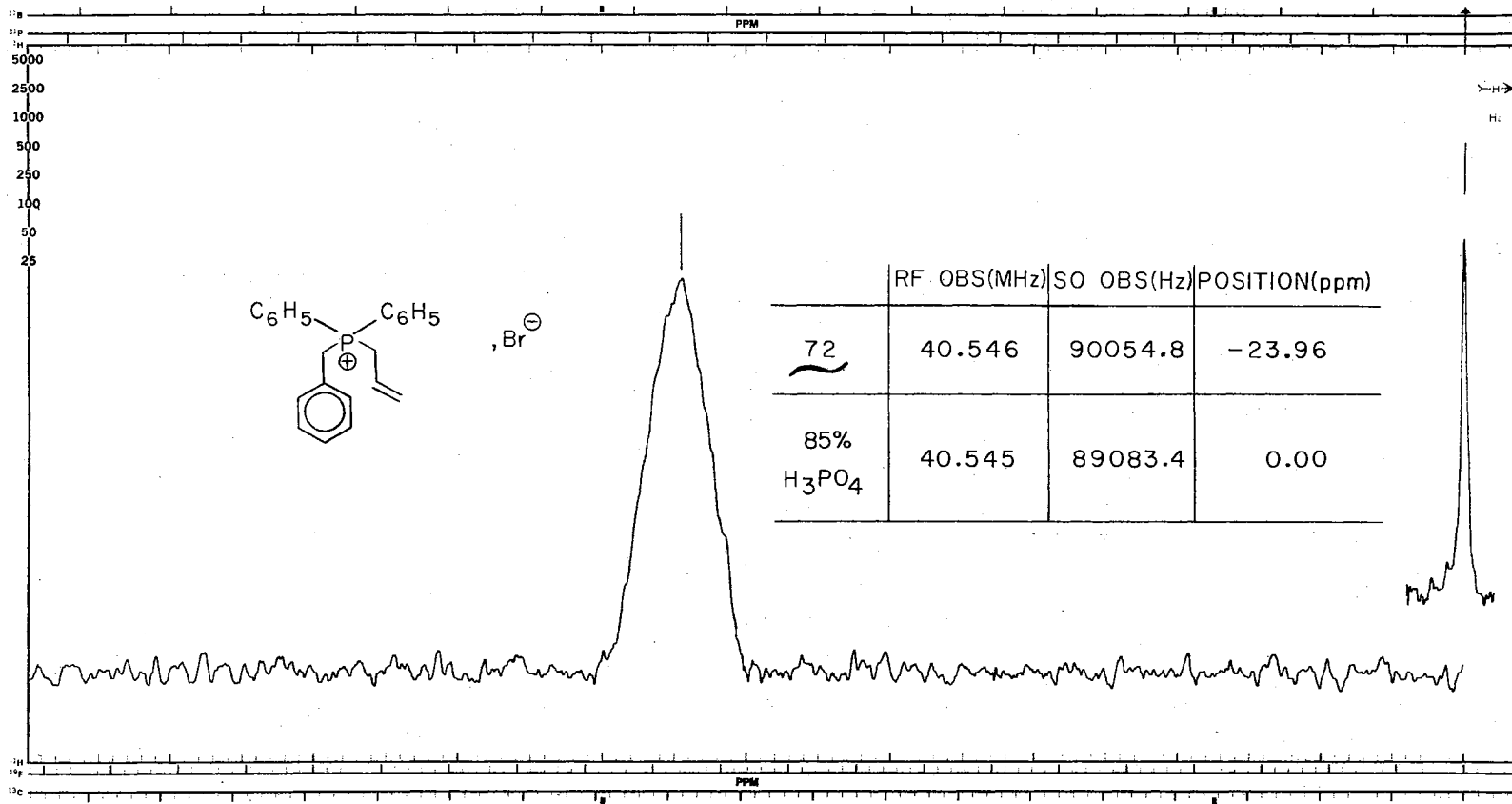
S.W. . . . 1000 Hz

S.T. . . . .250 sec

S.O. . . . 83701 Hz

S.A. . . . 2.0 Lock. .HOMO

PLATE II

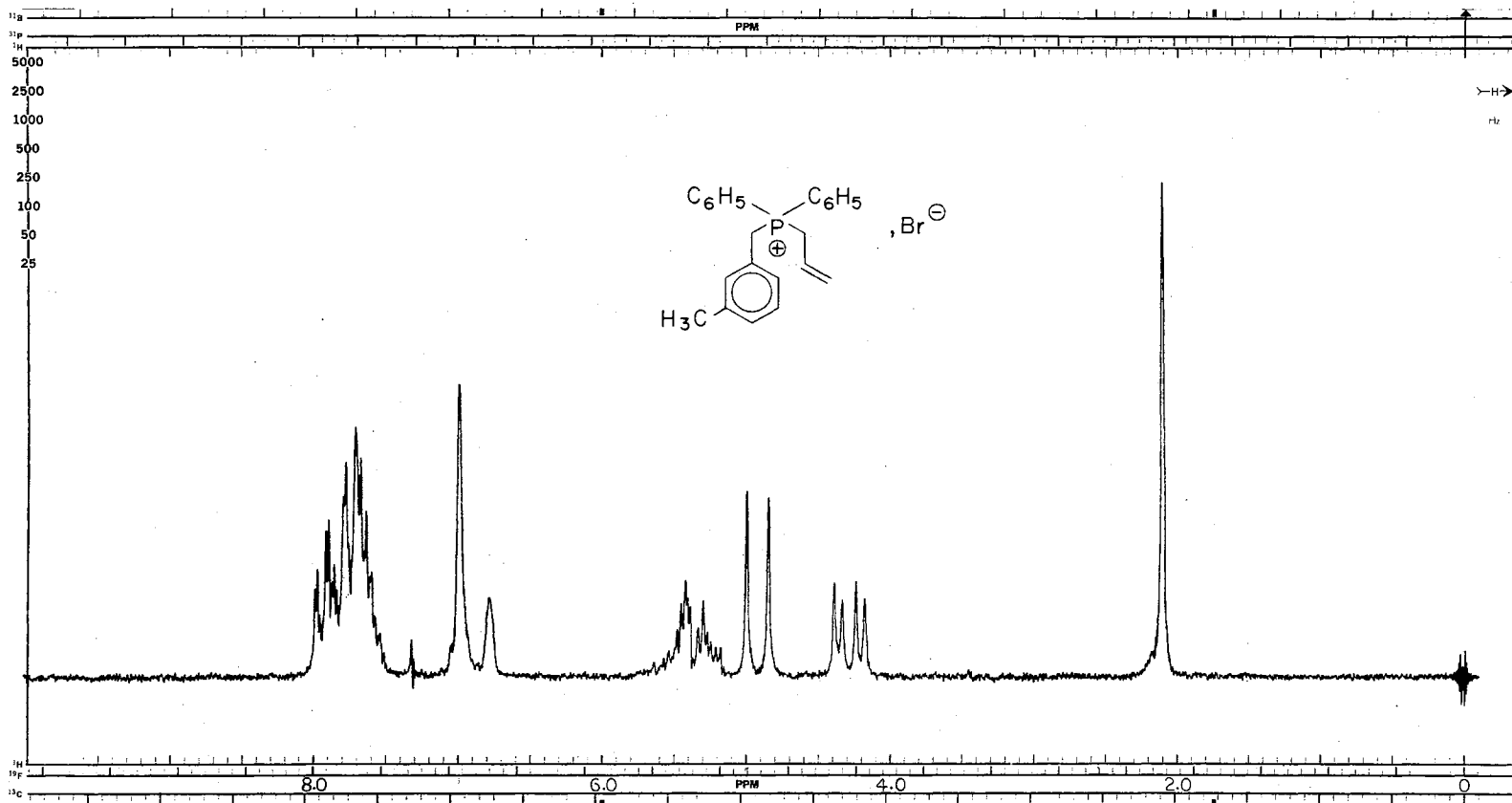


<sup>31</sup>P Spectrum of Allylbenzyltriphenylphosphonium Bromide (72)

Solvent. . . DCCl<sub>3</sub>      O.F. . . . 40.5 MHz      F.B. . . . . 2 Hz      R.F. . . . 86 db  
 S.W. . . . 1000 Hz      S.T. . . . .250 sec      S.O. . . . 89508 Hz      S.A. . . . .40      Lock . . . <sup>1</sup>H



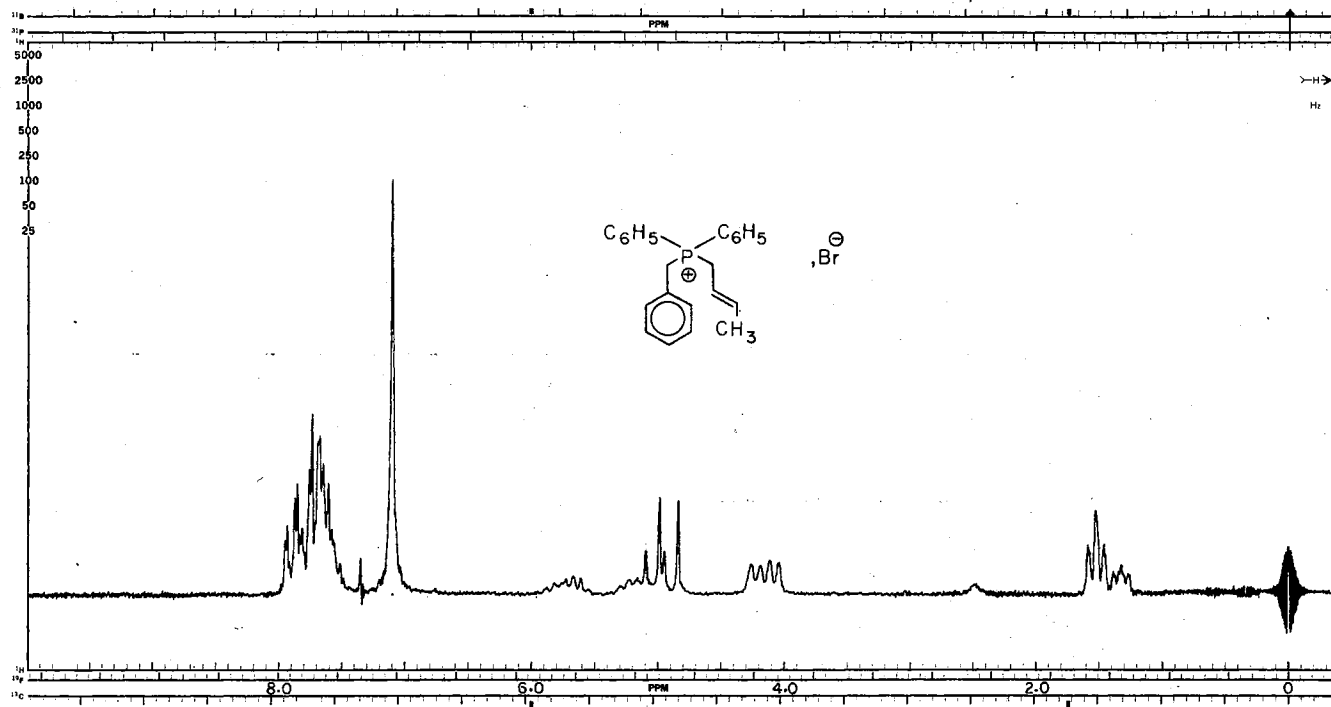
PLATE III



Allyl(3-methylbenzyl)diphenylphosphonium Bromide (73).

Solvent. . . DCCl <sub>3</sub>	O.F. . . . 100.1 Hz	F.B. . . . . 2 Hz	R.F. . . . 71 db
S.W. . . . 1000 Hz	S.T. . . . .250 sec	S.O. . . . 83701 Hz	S.A. . . . . 5.0 Lock. . HOMO

PLATE IV

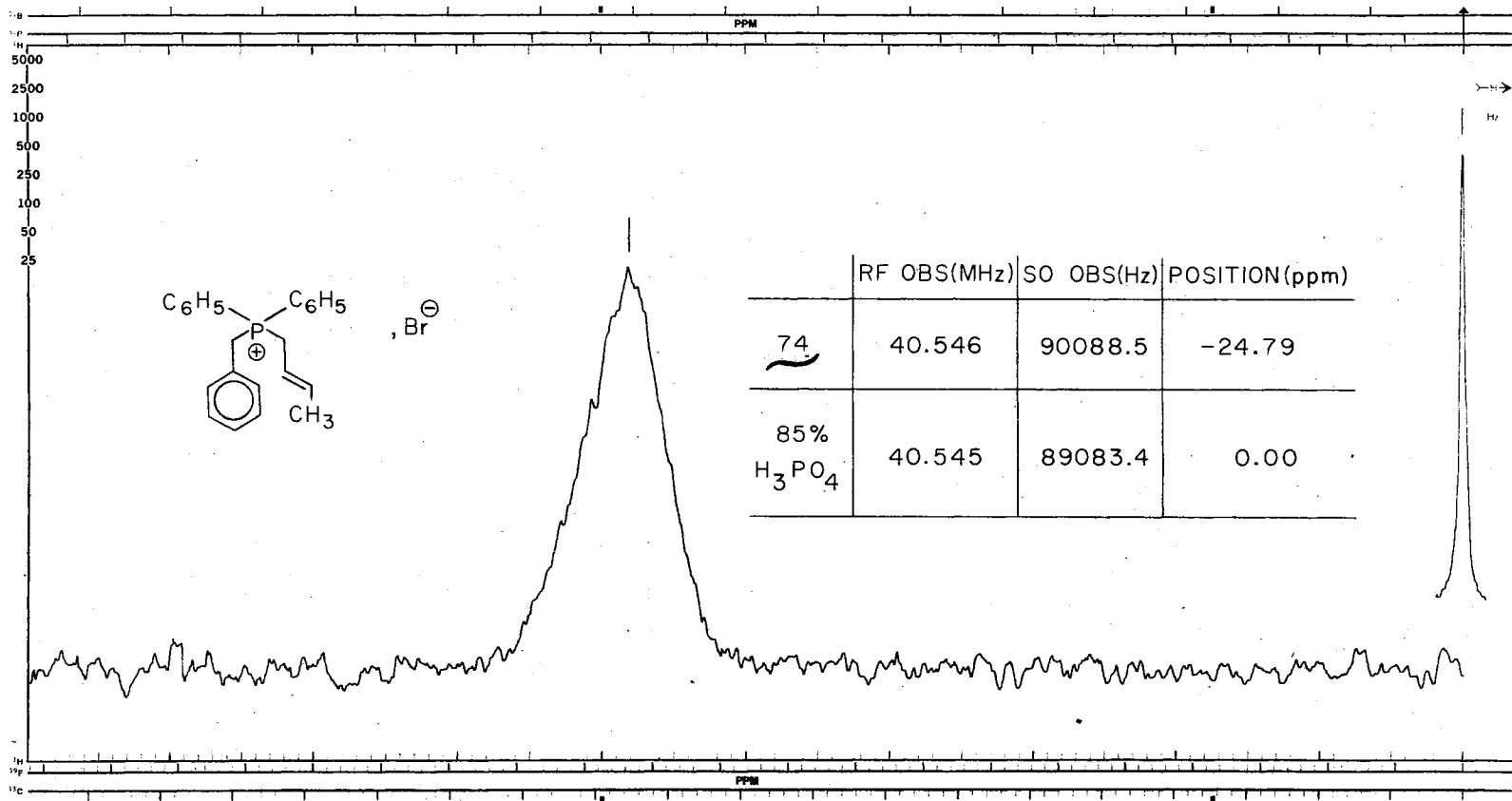


Benzyl(2-butenyl)diphenylphosphonium Bromide (74)

Solvent. . . DCCl<sub>3</sub> O.F. . . .100.1 Hz F.B. . . .4.0 Hz R.F. .66 db

S.W. . . . 1000 Hz S.T. . . . 500 sec S.O. . .83701 Hz S.A. . .3.2 Lock.HOMO

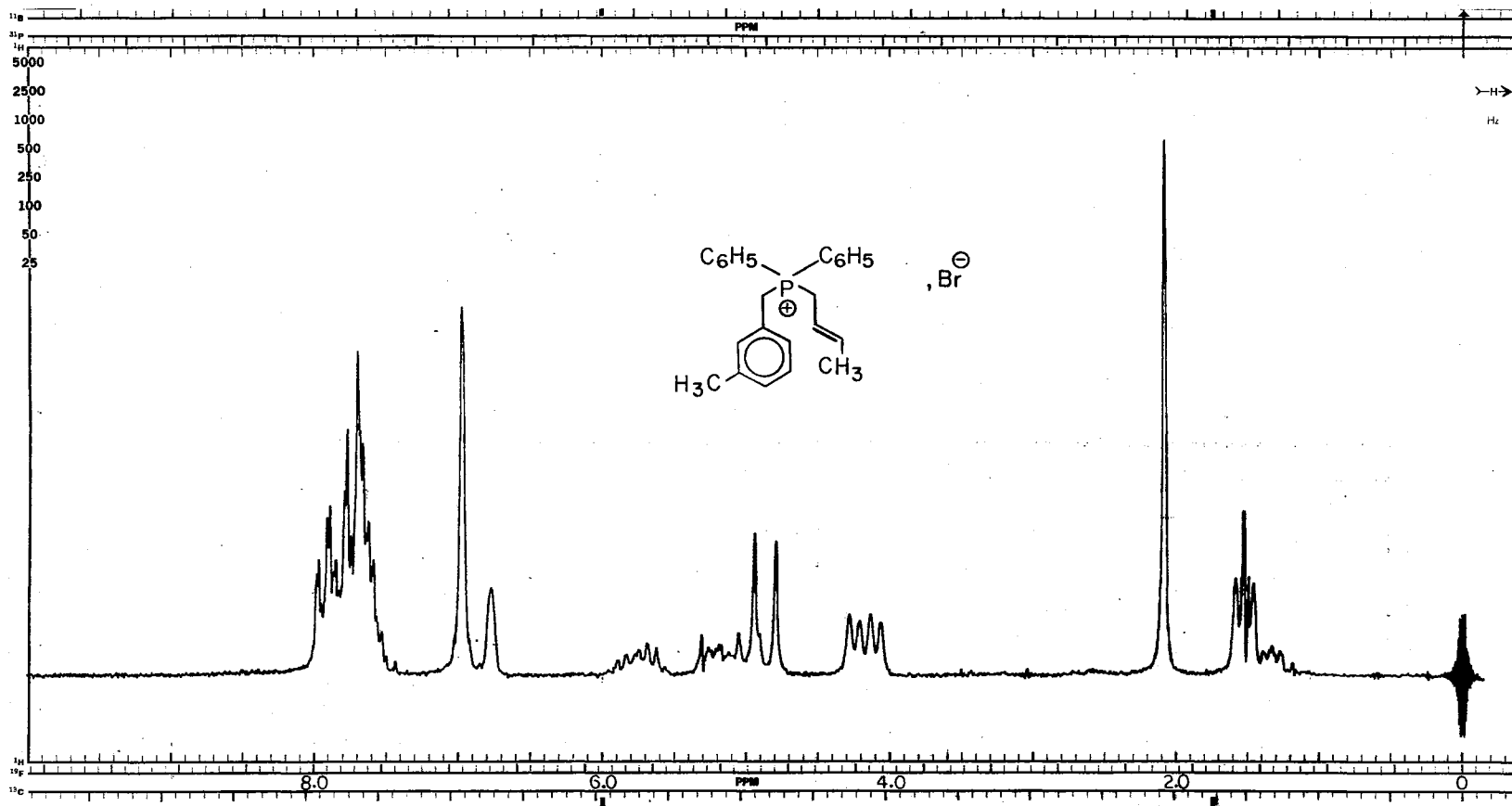
PLATE V



<sup>31</sup>P Spectrum of Benzyl(2-butenyl)diphenylphosphonium Bromide (74)

Solvent. . . DCCl<sub>3</sub>    O.F. . . . 40.5 Hz    F.B. . . . .0.4 Hz    R.F. . . . 86 db  
 S.W. . . . 1000 Hz    S.T. . . . 250 sec    S.O. . . .89505 Hz    S.A. . . . .40    Lock . . . . <sup>1</sup>H

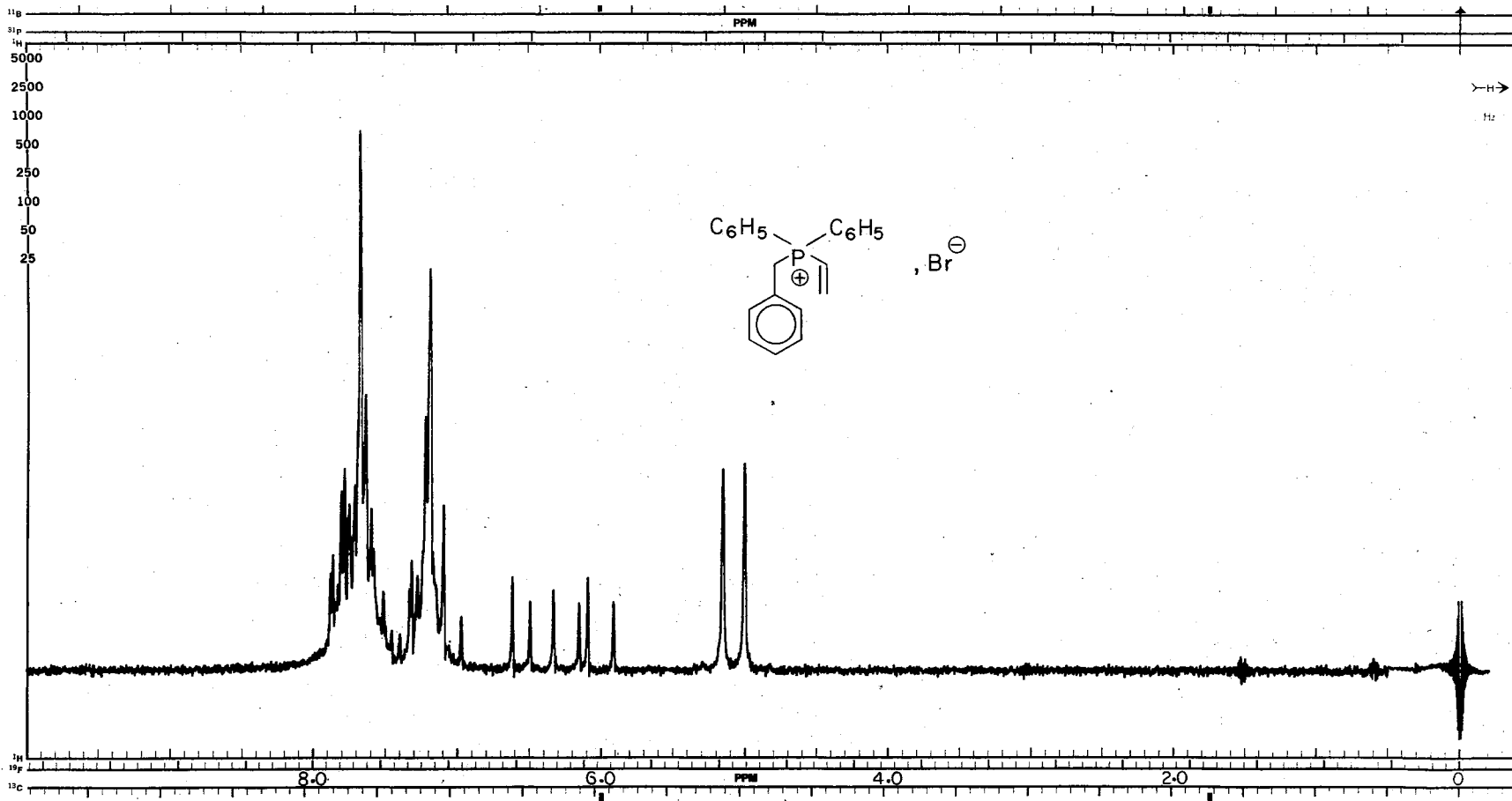
PLATE VI



2-Butenyl(3-methylbenzyl)diphenylphosphonium Bromide (75)

Solvent. . . . DCCl <sub>3</sub>	O.F. . . . . 100.1 Hz	F.B. . . . . 2.0 Hz	R.F. . . . . 69 db
S.W. . . . . 1000 Hz	S.T. . . . . .500 sec	S.O. . . . . 83701 Hz	S.A. . . . . 3.2 Lock. .HOMO

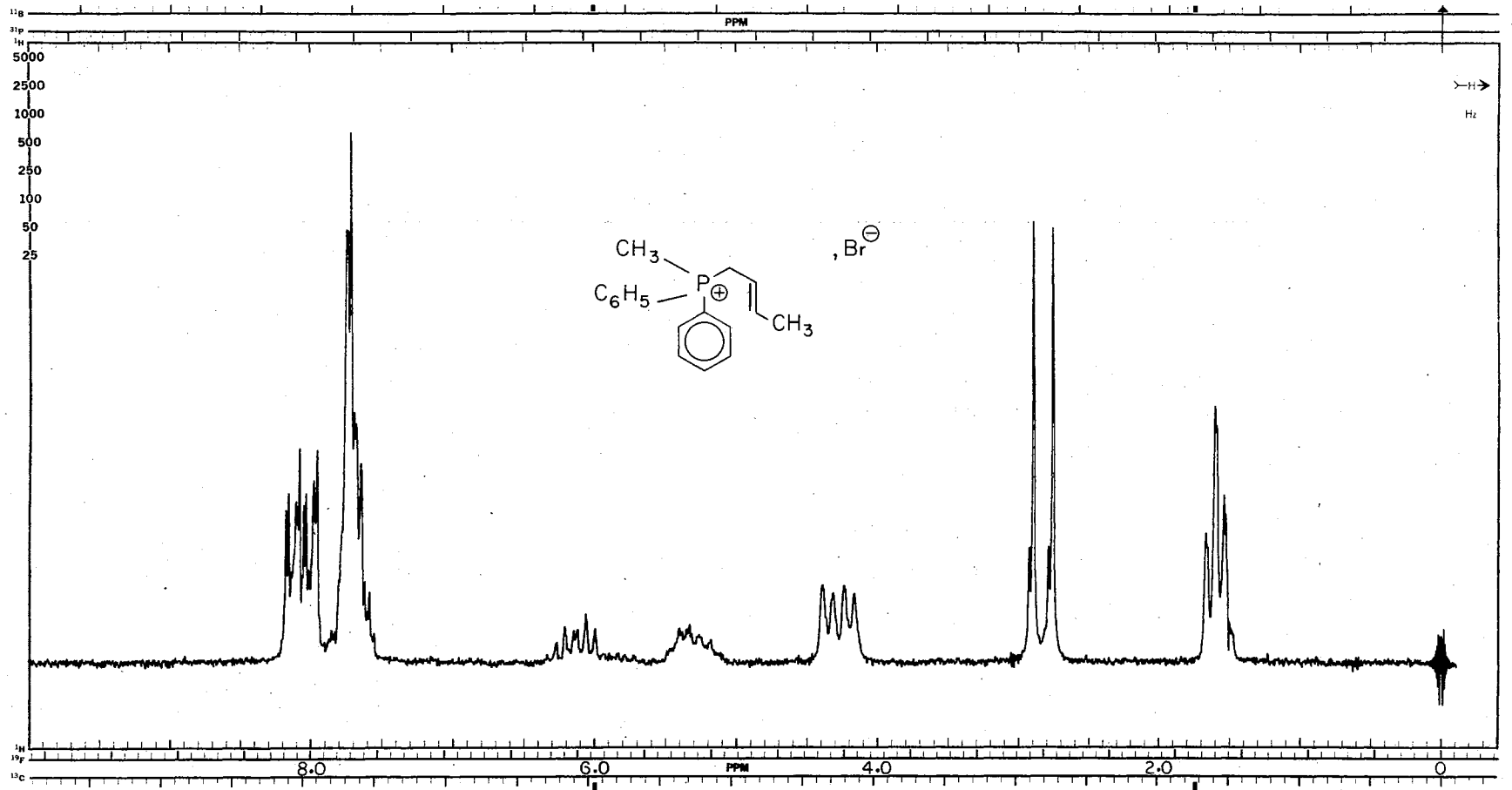
PLATE VII



Benzylidiphenylvinylphosphonium Bromide (77)

Solvent. . . DCCl <sub>3</sub>	O.F. . . . 100.1 Hz	F.B. . . . . 2 Hz	R.F. . . . 67 db
S.W. . . . 1000 Hz	S.T. . . . 1000 sec	S.O. . . . 83701 Hz	S.A. . . . 6.3    Lock. . . . HOMO

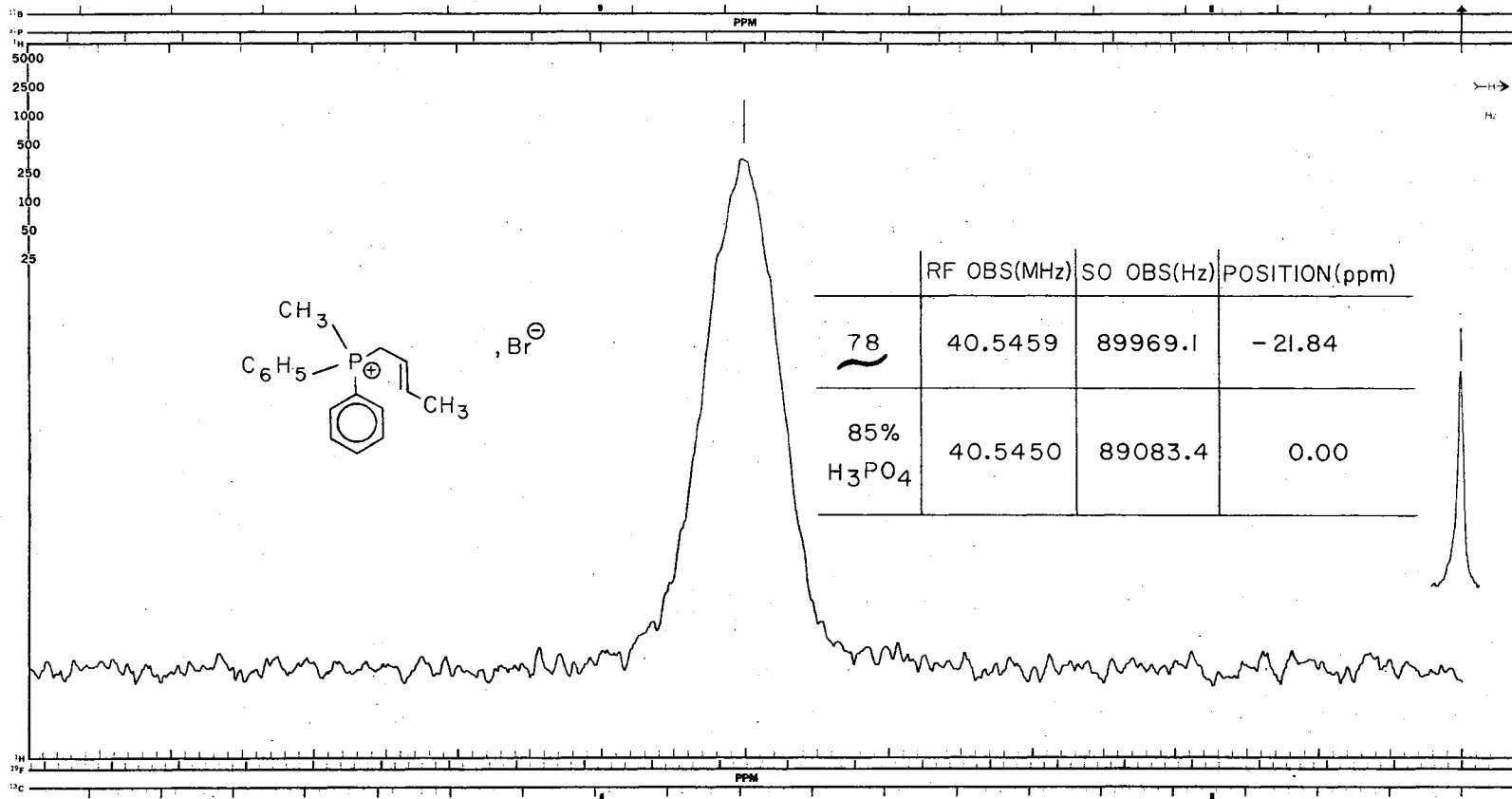
PLATE VIII



2-Butenylmethyldiphenylphosphonium Bromide (78)

Solvent. . . DCCl <sub>3</sub>	O.F. . . . 100.1 Hz	F.B. . . . . 1 Hz	R.F. . . . 52 db	
S.W. . . . 1000 Hz	S.T. . . . 1000 sec	S.O. . . . 83701 Hz	S.A. . . . 8.0	Lock . . . . HOMO

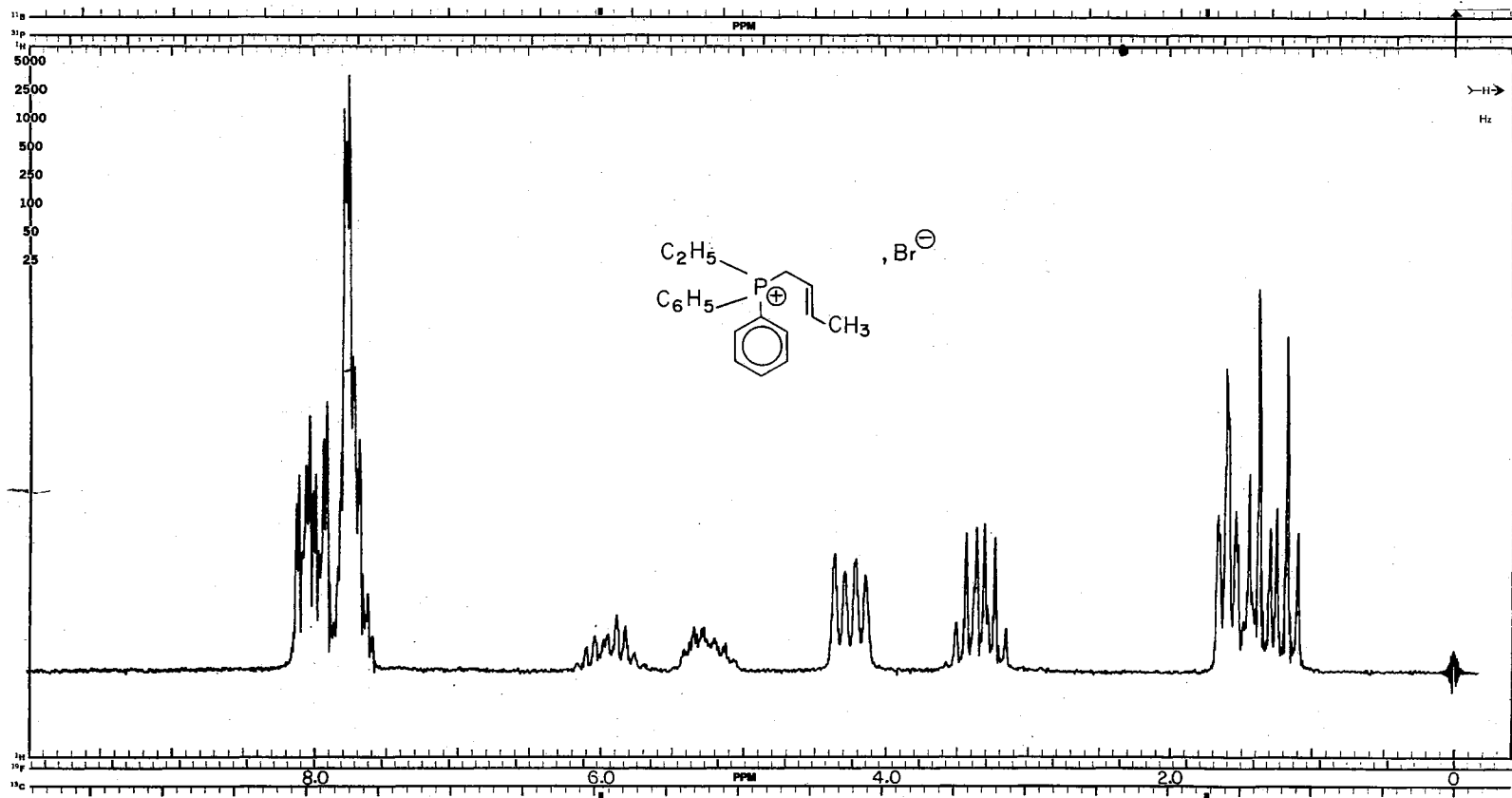
PLATE IX



<sup>31</sup>P Spectrum of 2-Butenylmethyldiphenylphosphonium Bromide (78)

Solvent . . . DCCl<sub>3</sub>      O.F. . . . 40.5 Hz      F.B. . . . .0.4 Hz      R.F. . . .86 db  
 S.W. . . . 1000 Hz      S.T. . . . 250 sec      S.O. . . . .89466 Hz      S.A. . . . . 32      Lock . . . . <sup>1</sup>H

PLATE X

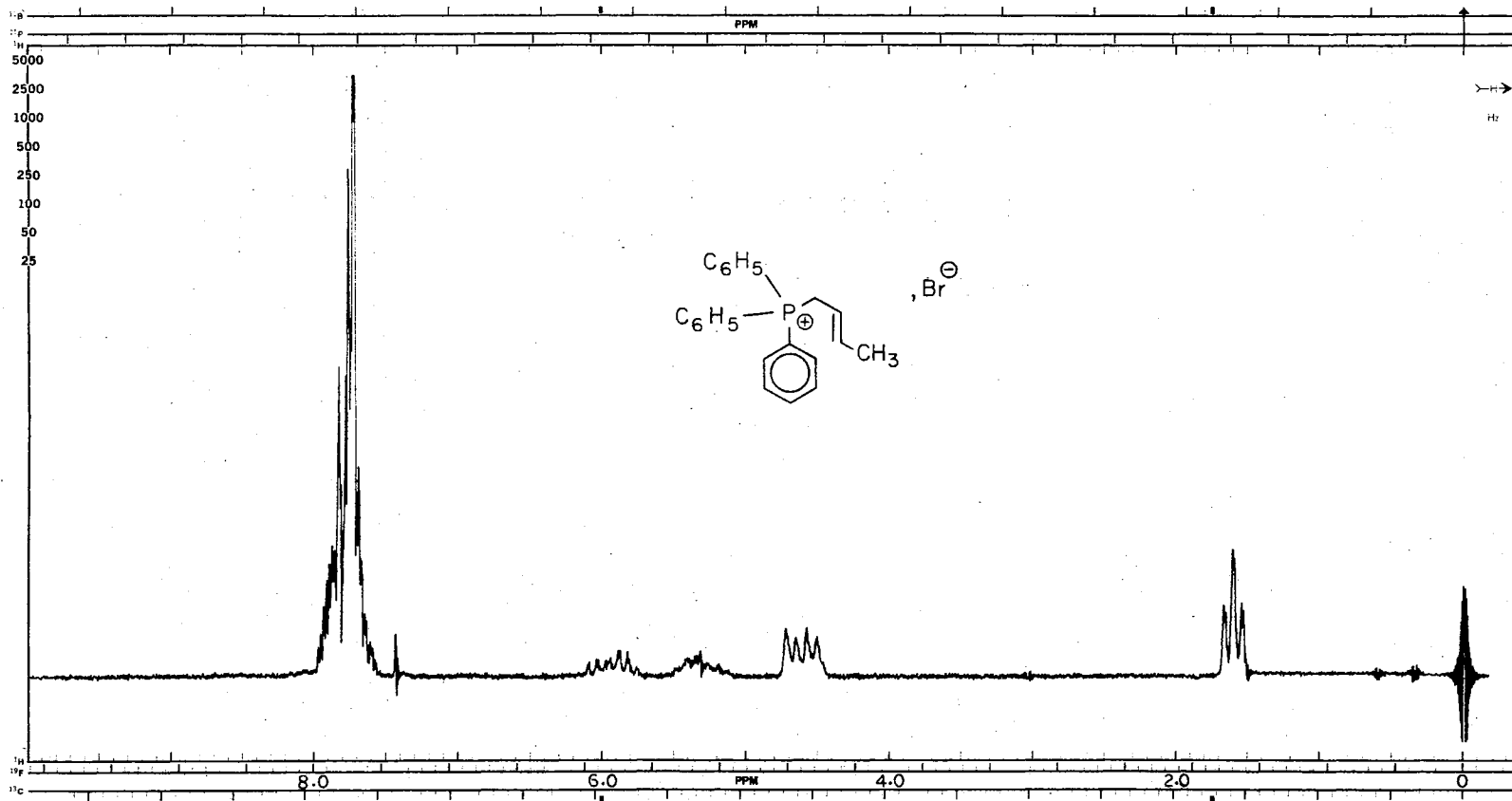


2-Butenylethyldiphenylphosphonium Bromide (79)

Solvent . . . DCCL <sub>3</sub>	O.F. . . . 100.1 Hz	F.B. . . . .2 Hz	R.F. . . .69 db
S.W. . . . .1000 Hz	S.T. . . . .500 sec	S.O. . . .83701 Hz	S.A. . . .3.2 Lock . . .HOMO



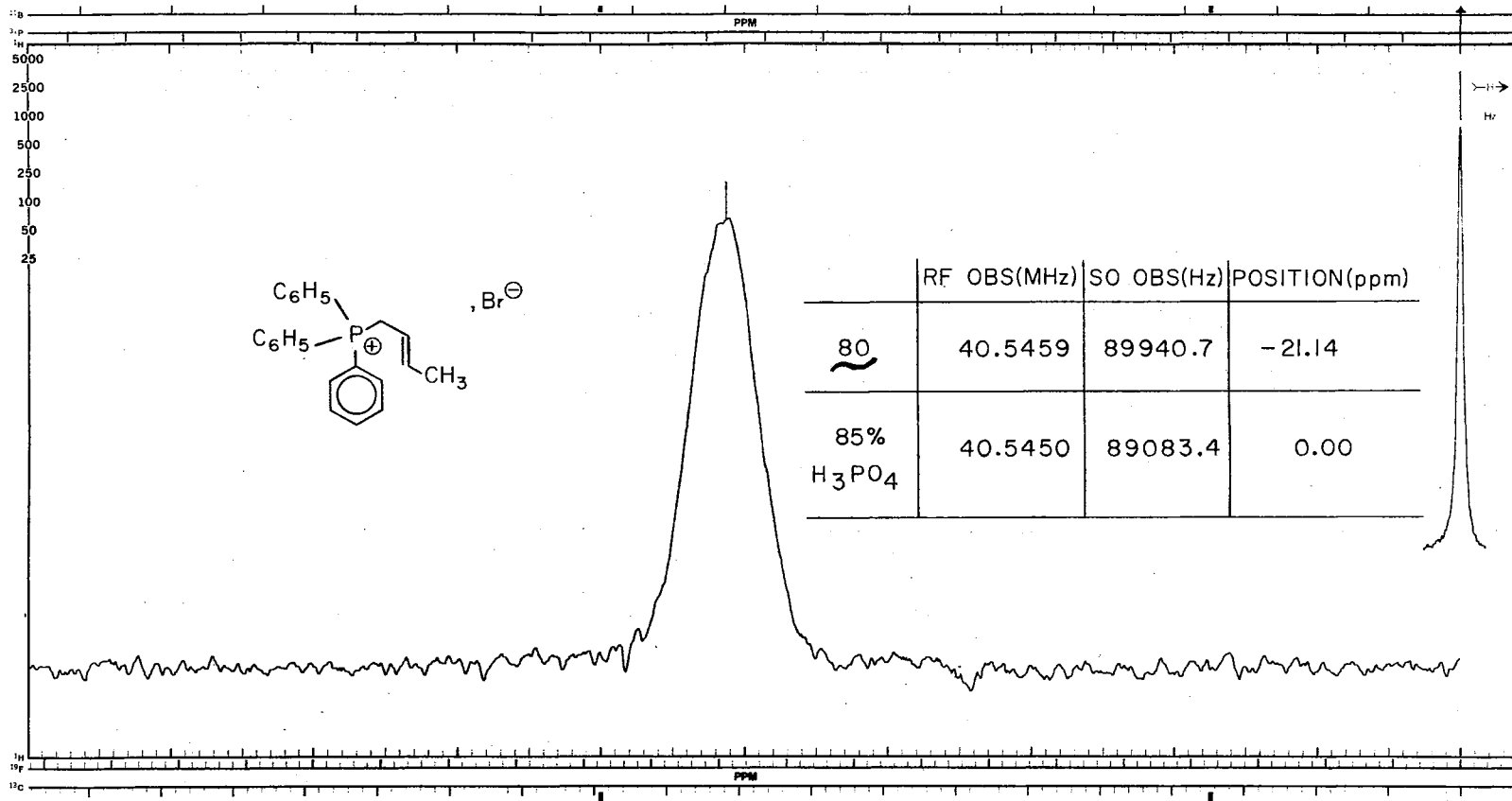
PLATE XI



2-Butenyltriphenylphosphonium Bromide (80)

Solvent. . . DCCL <sub>3</sub>	O.F. . . . 100.1 Hz	F.B. . . . .2 Hz	R.F. . . 65 db
S.W. . . . 1000 Hz	S.T. . . . 1000 sec	S.O. . . .83701 Hz	S.A. . . . 3.2 Lock. . .HOMO

PLATE XII

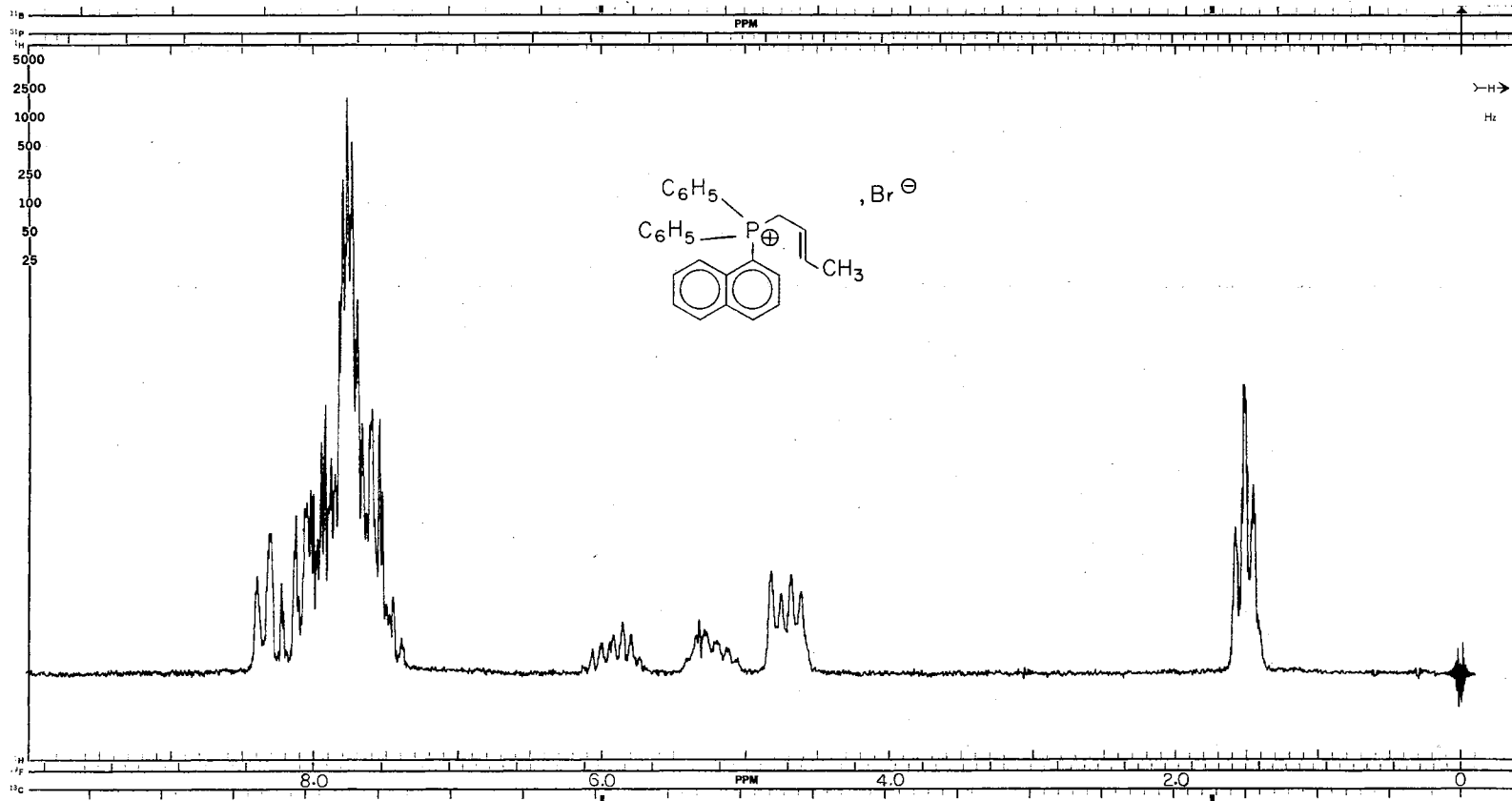


<sup>31</sup>P Spectrum of 2-Butenyltriphenylphosphonium Bromide (80)

Solvent . . . DCCl<sub>3</sub>      O.F. . . . 40.5 Hz      F.B. . . . .0.4 Hz      R.F. . . .86 db

S.W. . . . 1000 Hz      S.T. . . . 250 sec      S.O. . . . .89426 Hz      S.A. . . . . 25      Lock. . . . .<sup>1</sup>H

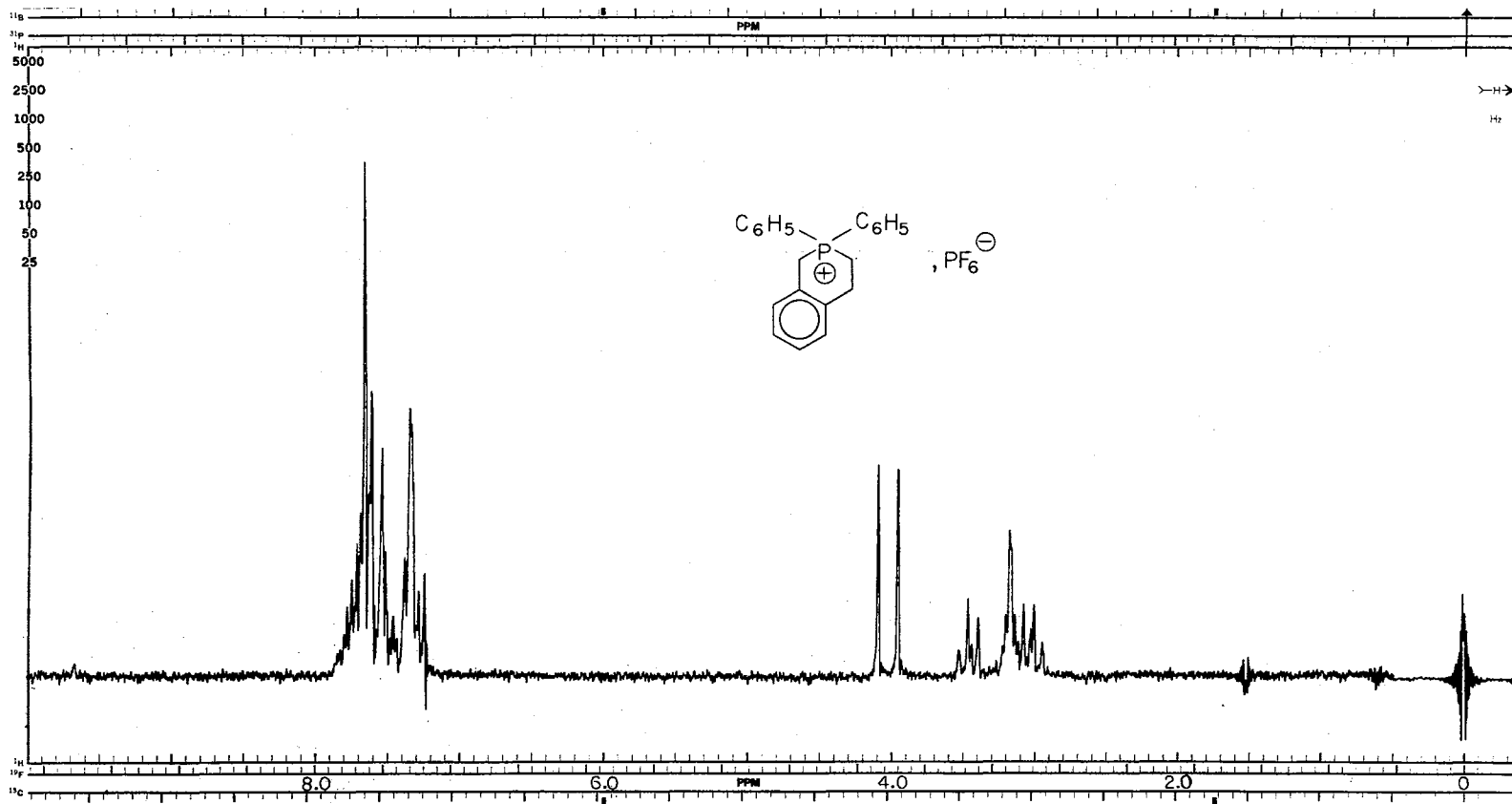
PLATE XIII



2-Butenyl-1-naphthyldiphenylphosphonium Bromide (81)

Solvent . . . DCCL <sub>3</sub>	O.F. . . . 100.1 Hz	F.B. . . . .2 Hz	R.F. . . .71 db
S.W. . . . .1000 Hz	S.T. . . . .500 sec	S.O. . . .83701 Hz	S.A. . . .5.0 Lock. . .HOMO

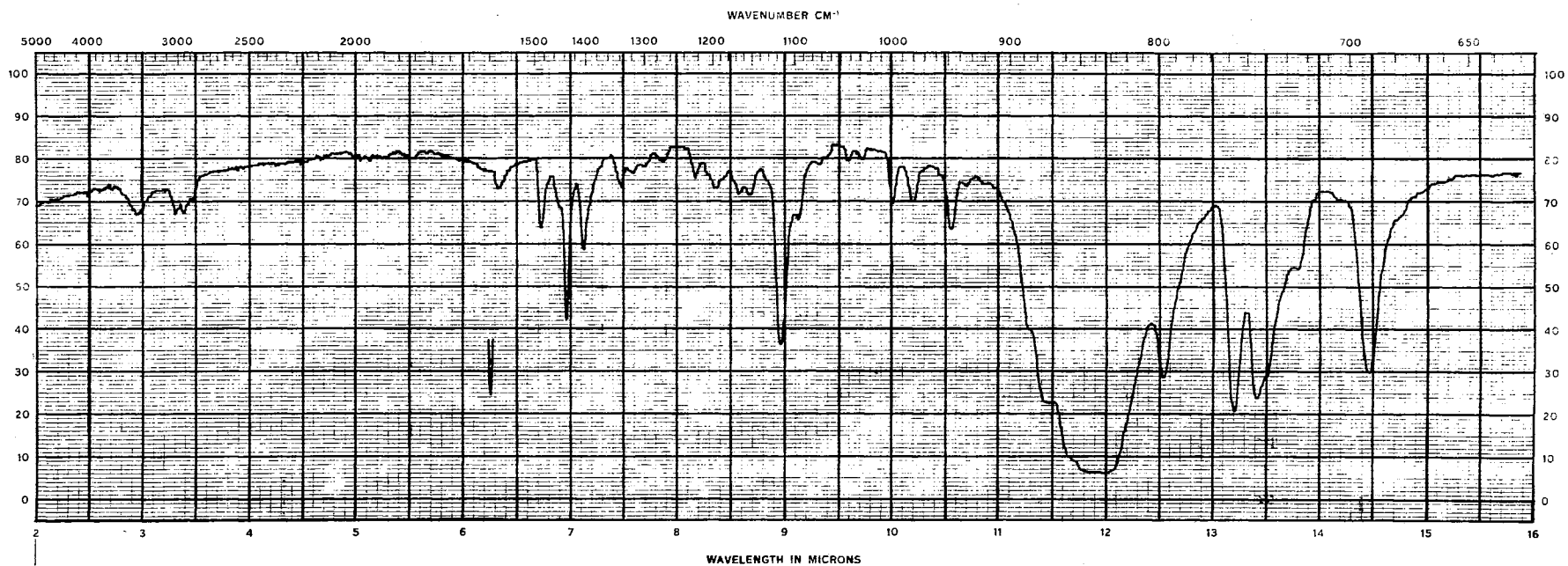
PLATE XIV



1,2,3,4-Tetrahydro-2,2-diphenylisophospholinium Hexafluorophosphate (82)

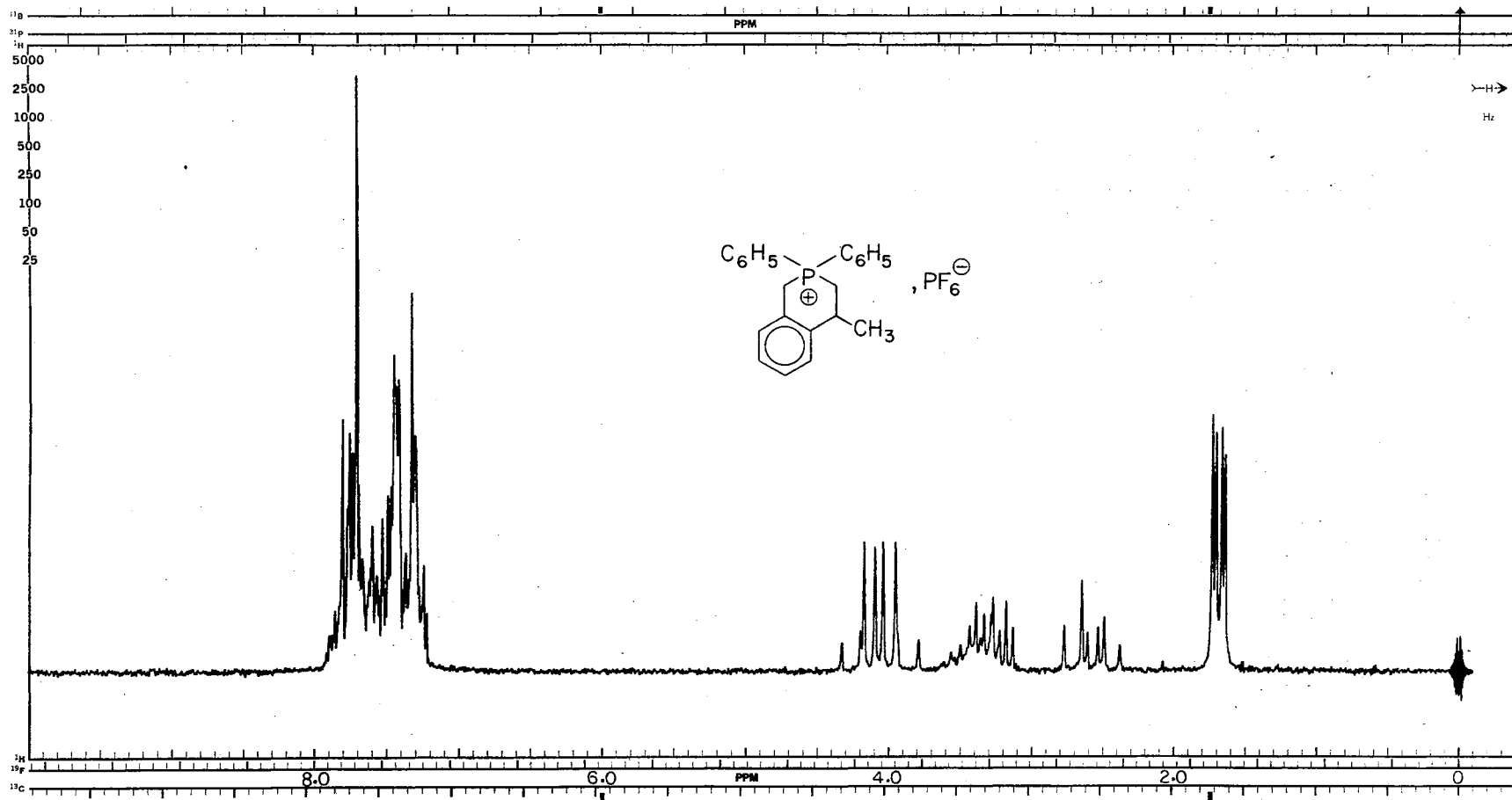
Solvent. .DCCl <sub>3</sub> /CF <sub>3</sub> CO <sub>2</sub> H	O.F. . . .100.1 MHz	F.B. . . . 2 Hz	R.F. . . .71 db
S.W. . . . . .1000 Hz	S.T. . . . .500 sec	S.O. . . 83701 Hz	S.A. . . .8.0 Lock. . .HOMO

PLATE XV



1,2,3,4-Tetrahydro-2,2-diphenylisophospholinium Hexafluorophosphate (82), KBr Pellets

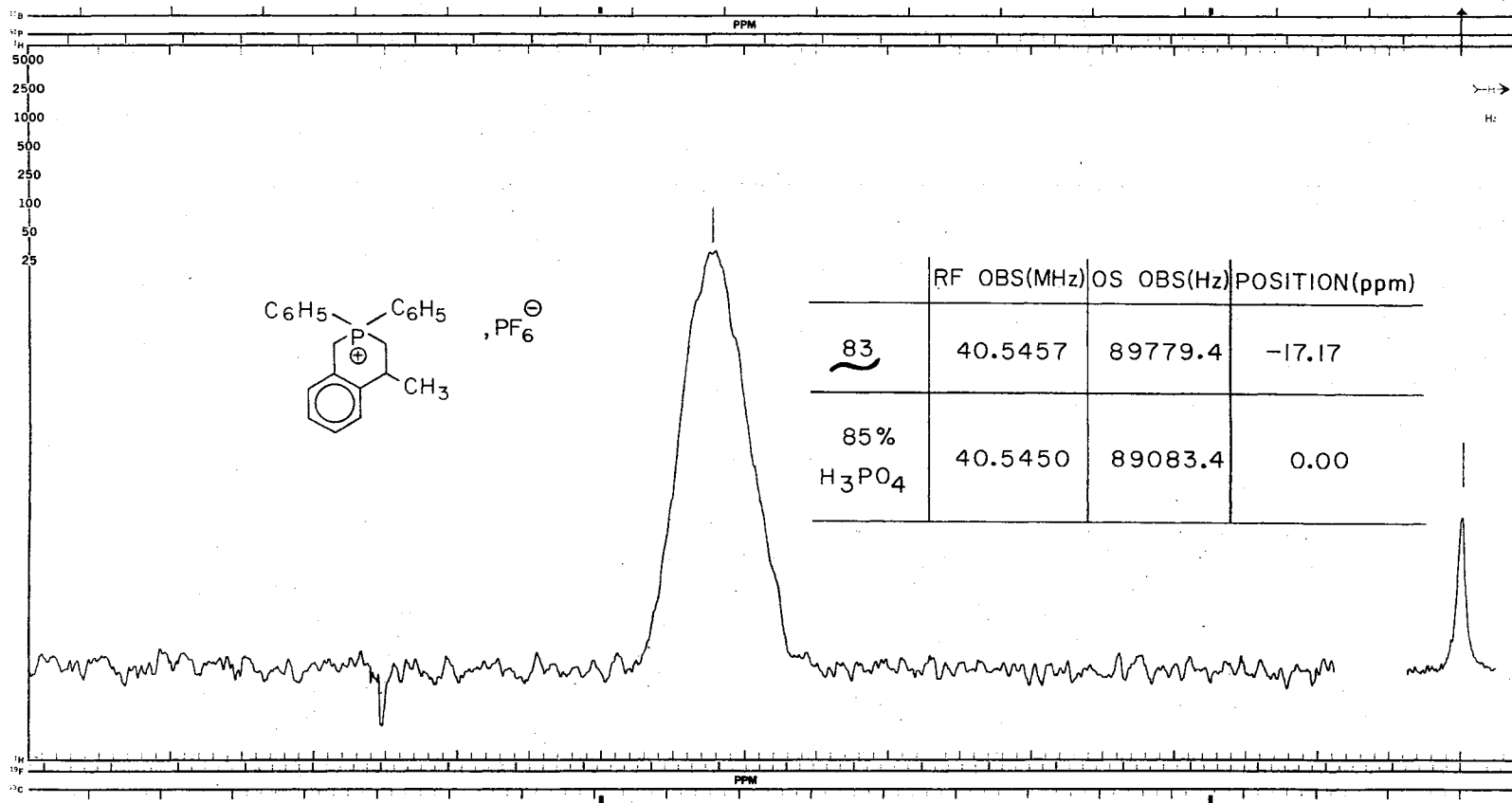
PLATE XVI



1,2,3,4-Tetrahydro-4-methyl-2,2-diphenylisophospholinium Hexafluorophosphate (83)

Solvent. .DCCl <sub>3</sub> /CF <sub>3</sub> CO <sub>2</sub> H	O.F. . . .100.1 MHz	F.B. . . .2 Hz	R.F. . . .60 db
S.W. . . . .1000 Hz	S.T. . . .1000 sec	S.O. .83701 Hz	S.A. . . .6.3      Lock. . . . .HOMO

PLATE XVII

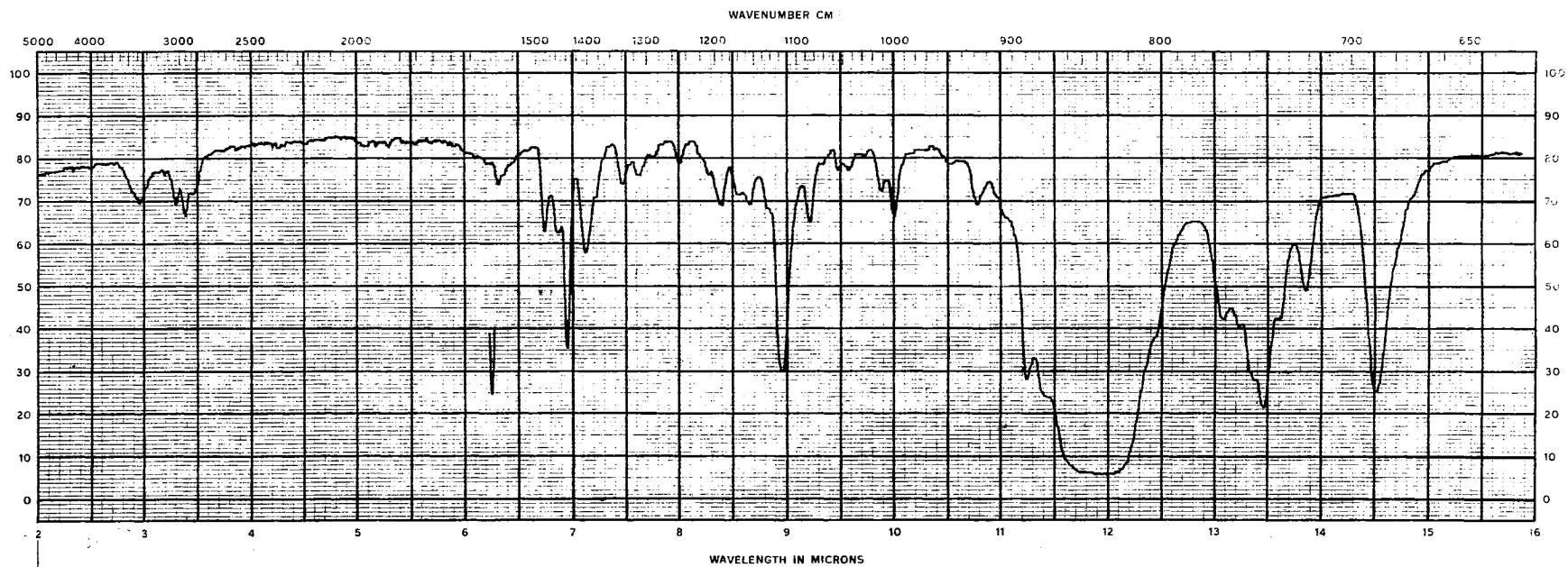


<sup>31</sup>P Spectrum of 1,2,3,4-Tetrahydro-4-methyl-2,2-diphenylisophosphinolinium Hexafluorophosphate(83)

Solvent. .DCCl<sub>3</sub>/CF<sub>3</sub>CO<sub>2</sub>H    O.F. . . .40.5 Hz    F.B. . . . .0.4 Hz    R.F. . . .86 db

S.W. . . . . .1000 Hz    S.T. . . . .250 sec    S.O. . . . .89256 Hz    S.A. . . . . 40    Lock. . . . .<sup>1</sup>H

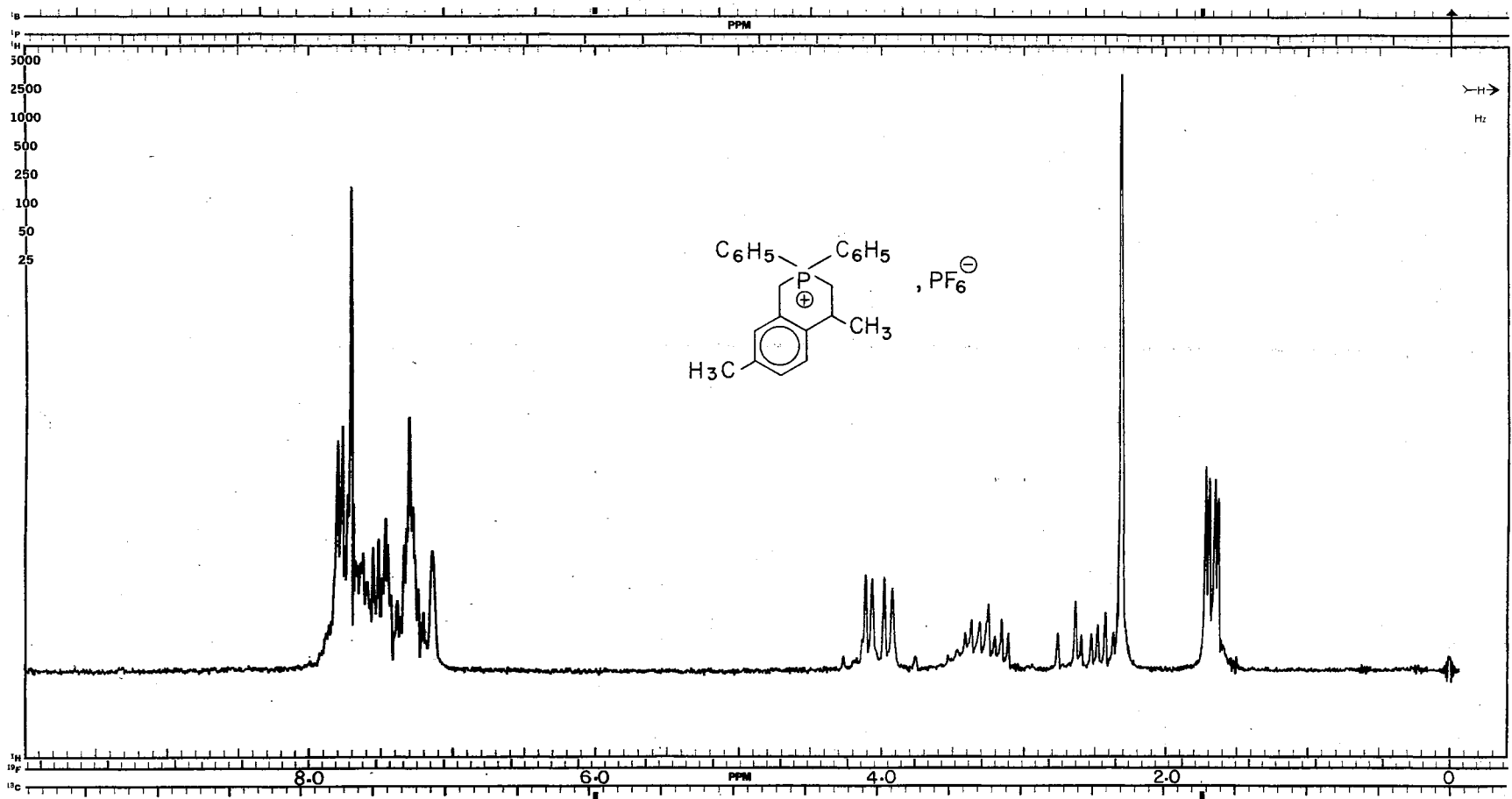
PLATE XVIII



1,2,3,4-Tetrahydro-4-methyl-2,2-diphenylisophospholinium Hexafluorophosphate (83), KBr Pellet



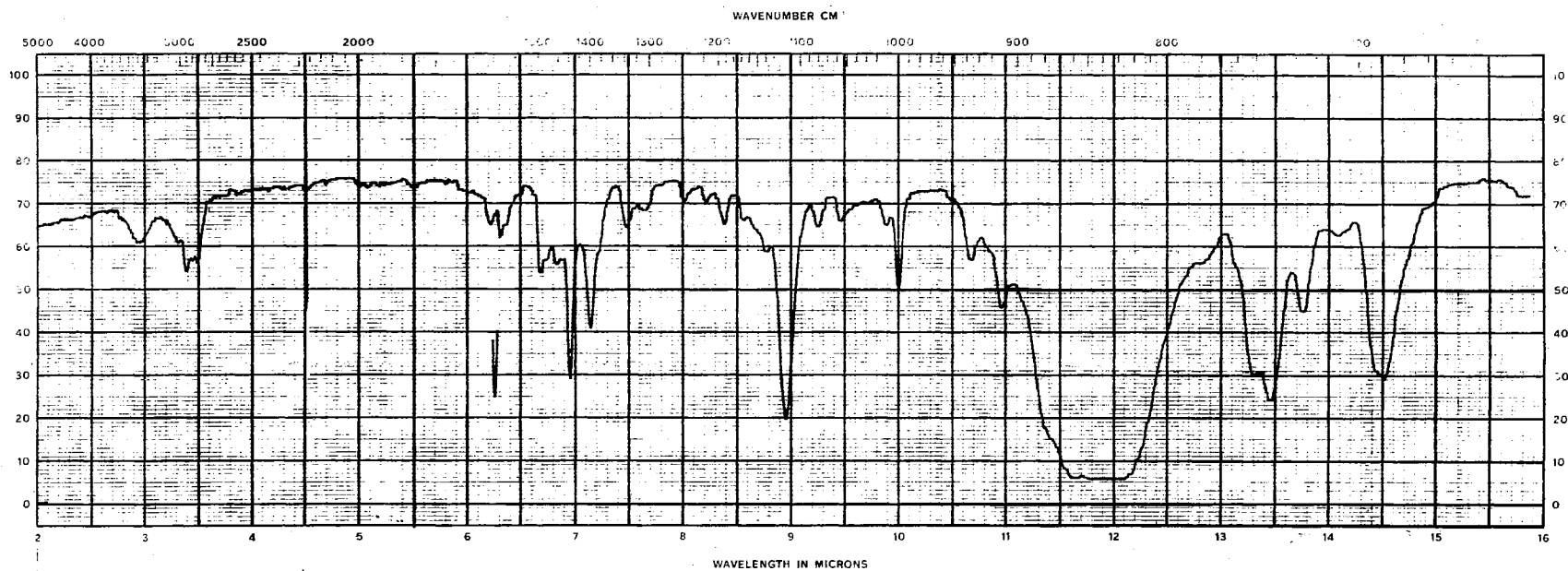
PLATE XIX



1,2,3,4-Tetrahydro-4,7-dimethyl-2,2-diphenylisosphinolinium Hexafluorophosphate (84)

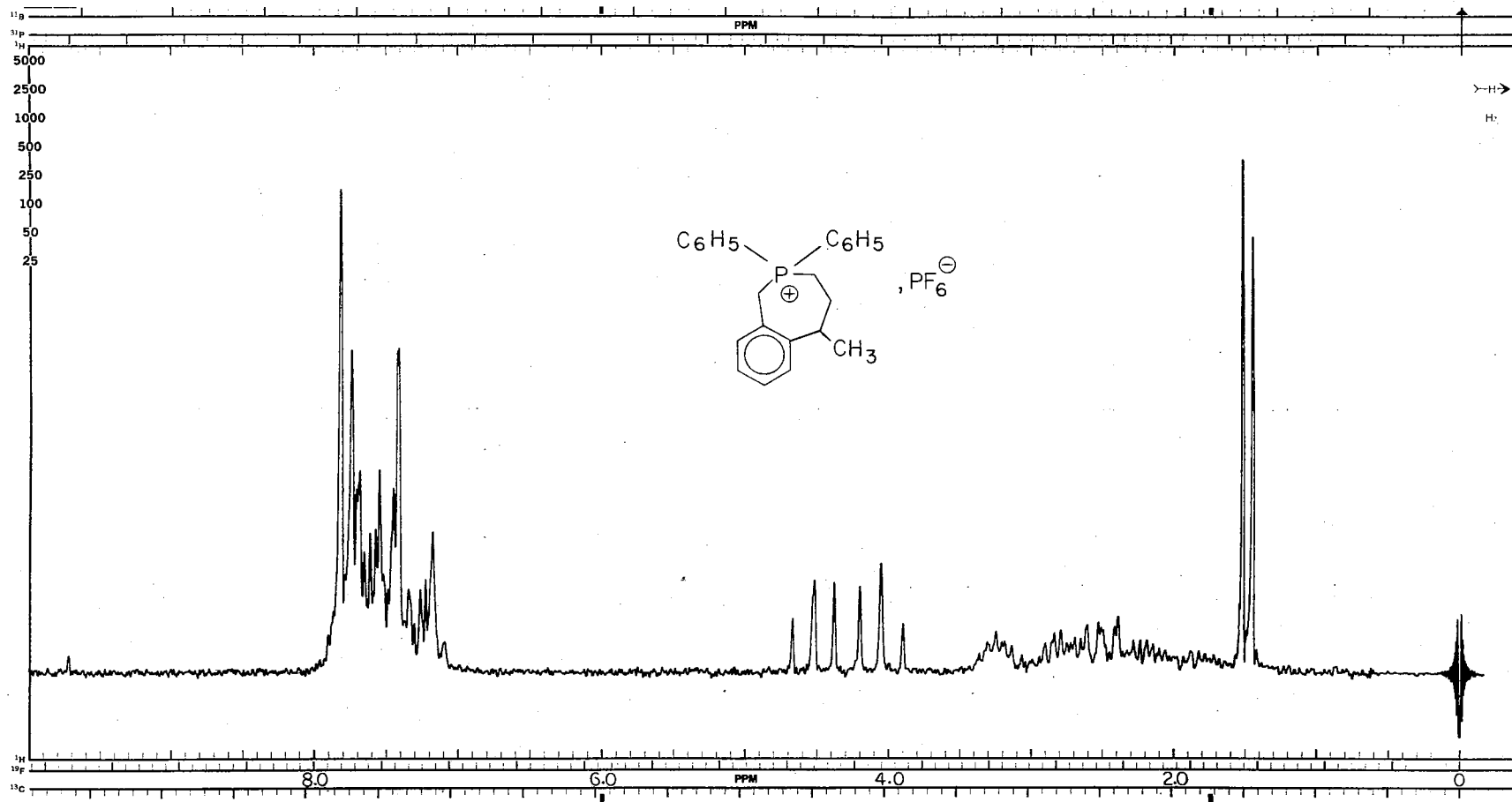
Solvent. .DCCl <sub>3</sub> /CF <sub>3</sub> CO <sub>2</sub> H	O.F. . . .100.1 MHz	F.B. . . . .2 Hz	R.F. . . .64 db
S.W. . . . .1000 Hz	S.T. . . . .500 sec	S.O. . . .83701 Hz	S.A. . . . .4.0
			Lock. . . . HOMO

PLATE XX



1,2,3,4-Tetrahydro-4,7-dimethyl-2,2-diphenylisophosphinolinium Hexafluorophosphate (84), KBr Pellet

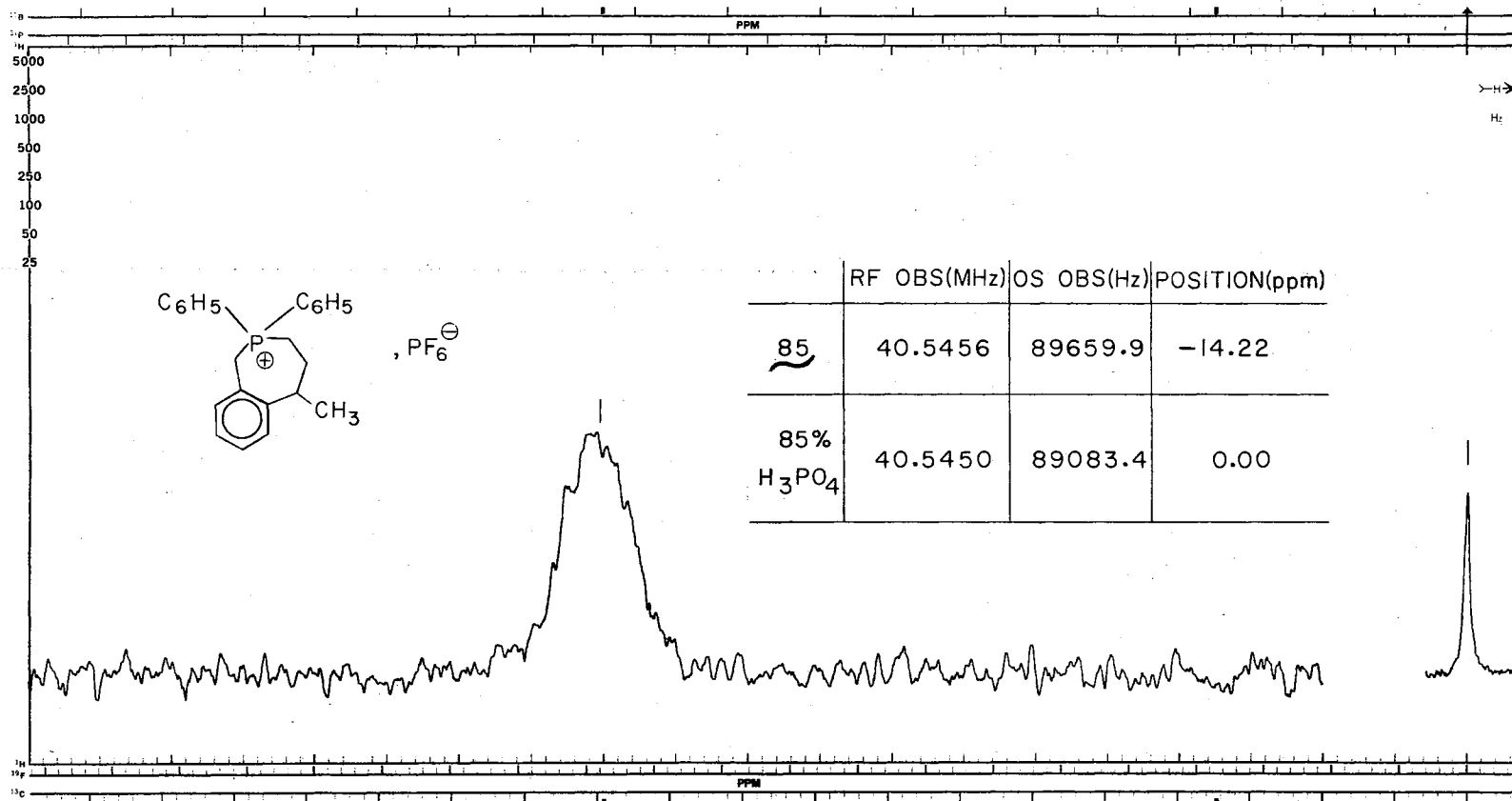
PLATE XXI



2,3,4,5-Tetrahydro-5-methyl-2,2-diphenyl-1H-benzo[c]phosphepinium Hexafluorophosphate (85)

Solvent. .DCCl<sub>3</sub>/CF<sub>3</sub>CO<sub>2</sub>H    O.F. . . .100.1 MHz    F.B. . . . 1 Hz    R.F. . . .69 db  
 S.W. . . . . .1000 Hz    S.T. . . . .500 sec    S.O. . 83701 Hz    S.A. . . 10.0    Lock. . . . . HOMO

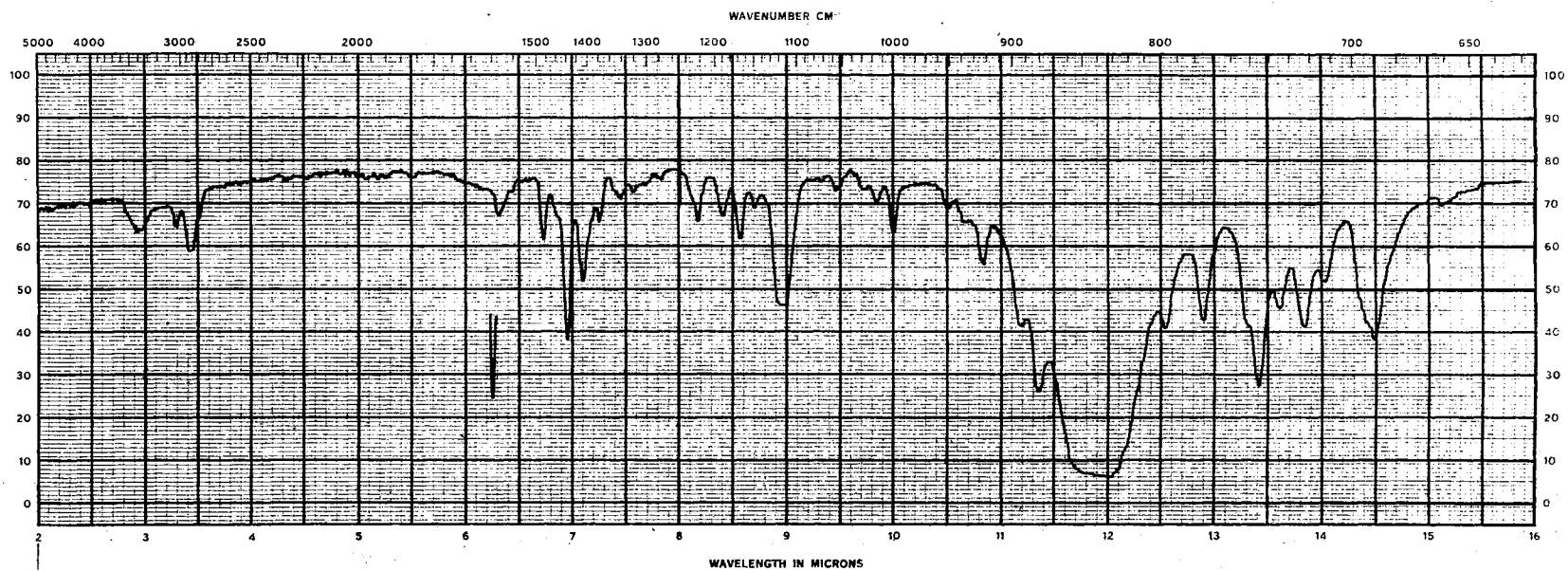
PLATE XXII



<sup>31</sup>P Spectrum of 2,3,4,5-Tetrahydro-5-methyl-2,2-diphenyl-1H-benzo[c]phosphepinium Hexafluorophosphate (85)

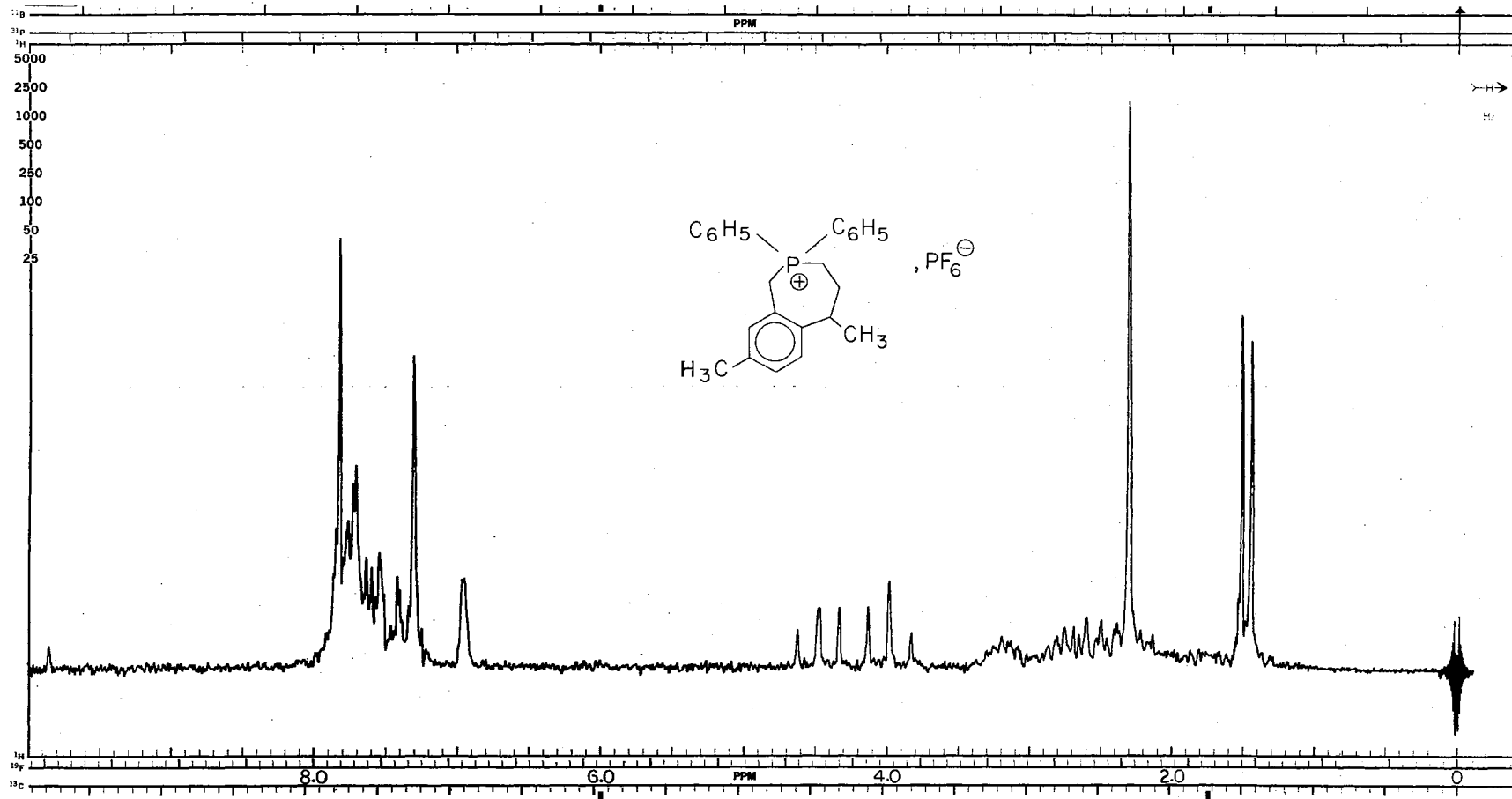
Solvent. .DCCl<sub>3</sub>/CF<sub>3</sub>CO<sub>2</sub>H    O.F. . . .40.5 Hz    F.B. . . . 0.04 Hz    R.F. . . .86 db  
 S.W. . . . .1000 Hz    S.T. . . .250 sec    S.O. . . .89055 Hz    S.A. . . . 50    Lock. . . .<sup>1</sup>H

PLATE XXIII



2,3,4,5-Tetrahydro-5-methyl-2,2-diphenyl-1H-benzo [c]phosphepinium Hexafluorophosphate (85), KBr Pellet

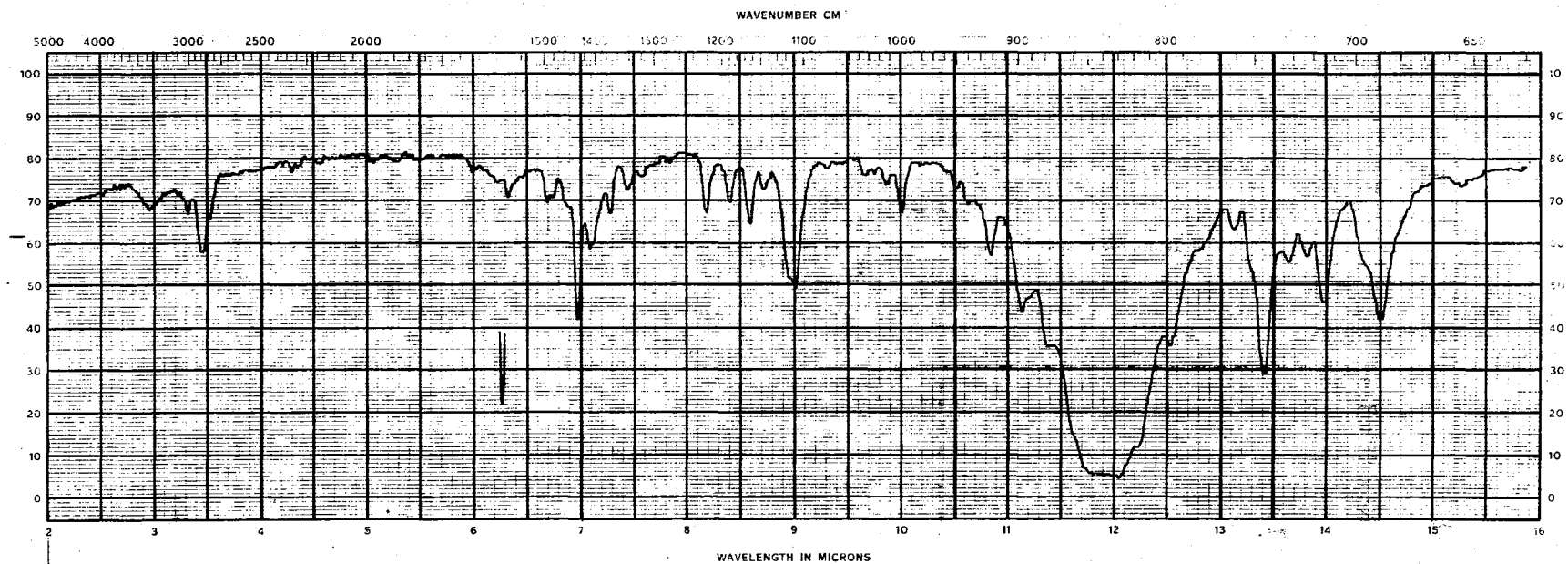
PLATE XXIV



2,3,4,5-Tetrahydro-5,8-dimethyl-2,2-diphenyl-1H-benzo[c]phosphepinium Hexafluorophosphate (86)

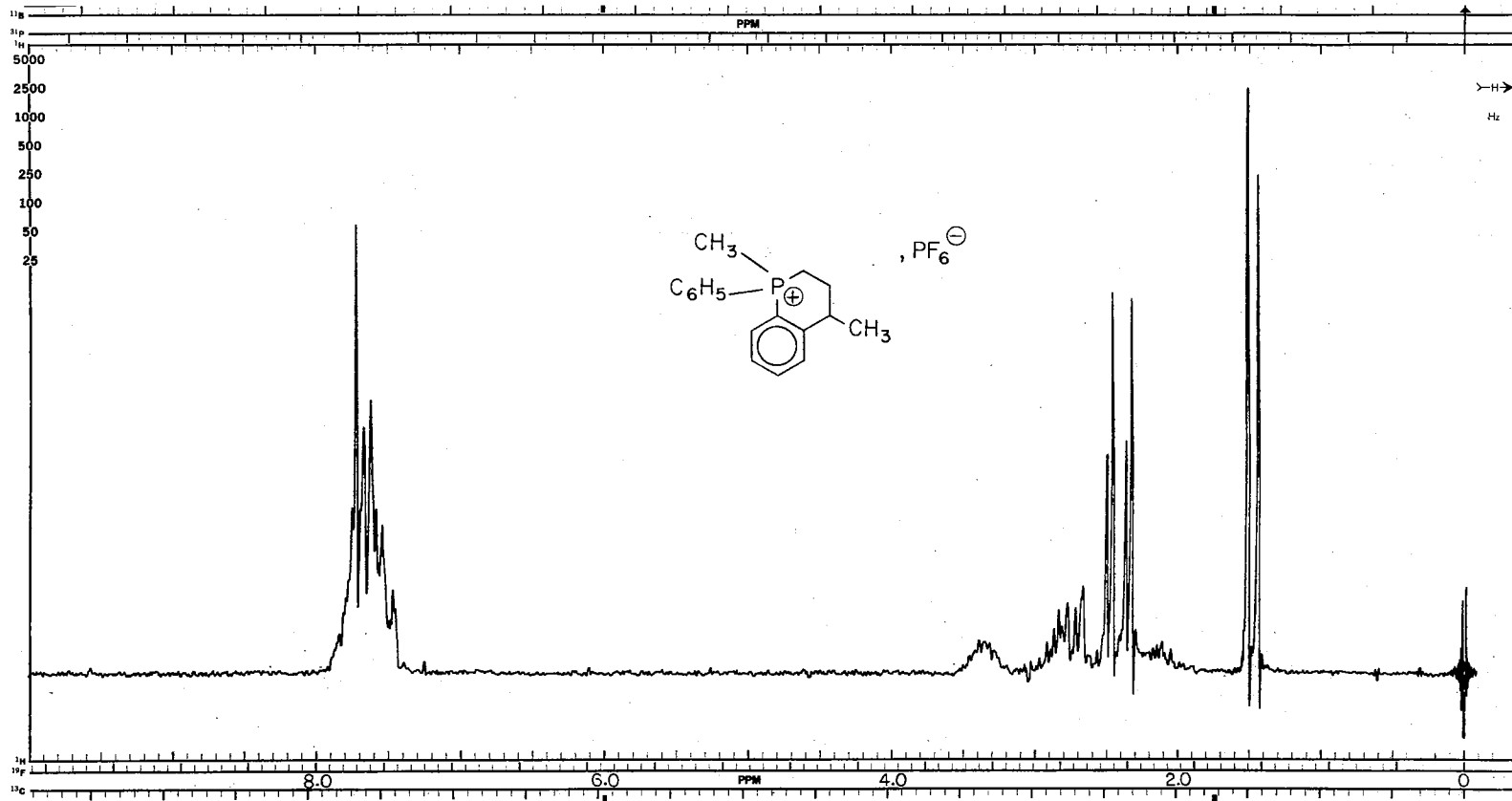
Solvent. . .DCCl<sub>3</sub>/CF<sub>3</sub>CO<sub>2</sub>H    O.F. . . .100.1 Hz    F.B. . . . 1 Hz    R.F. . . .69 db  
 S.W. . . . . .1000 Hz    S.T. . . . 500 sec    S.O. . 83701 Hz    S.A. . . . 12.5    Lock. . . .HOMO

PLATE XXV



2,3,4,5-Tetrahydro-5,8-dimethyl-2,2-diphenyl-1H-benzo[c]phosphepinium Hexafluorophosphate (86), KBr Pellet

PLATE XXVI

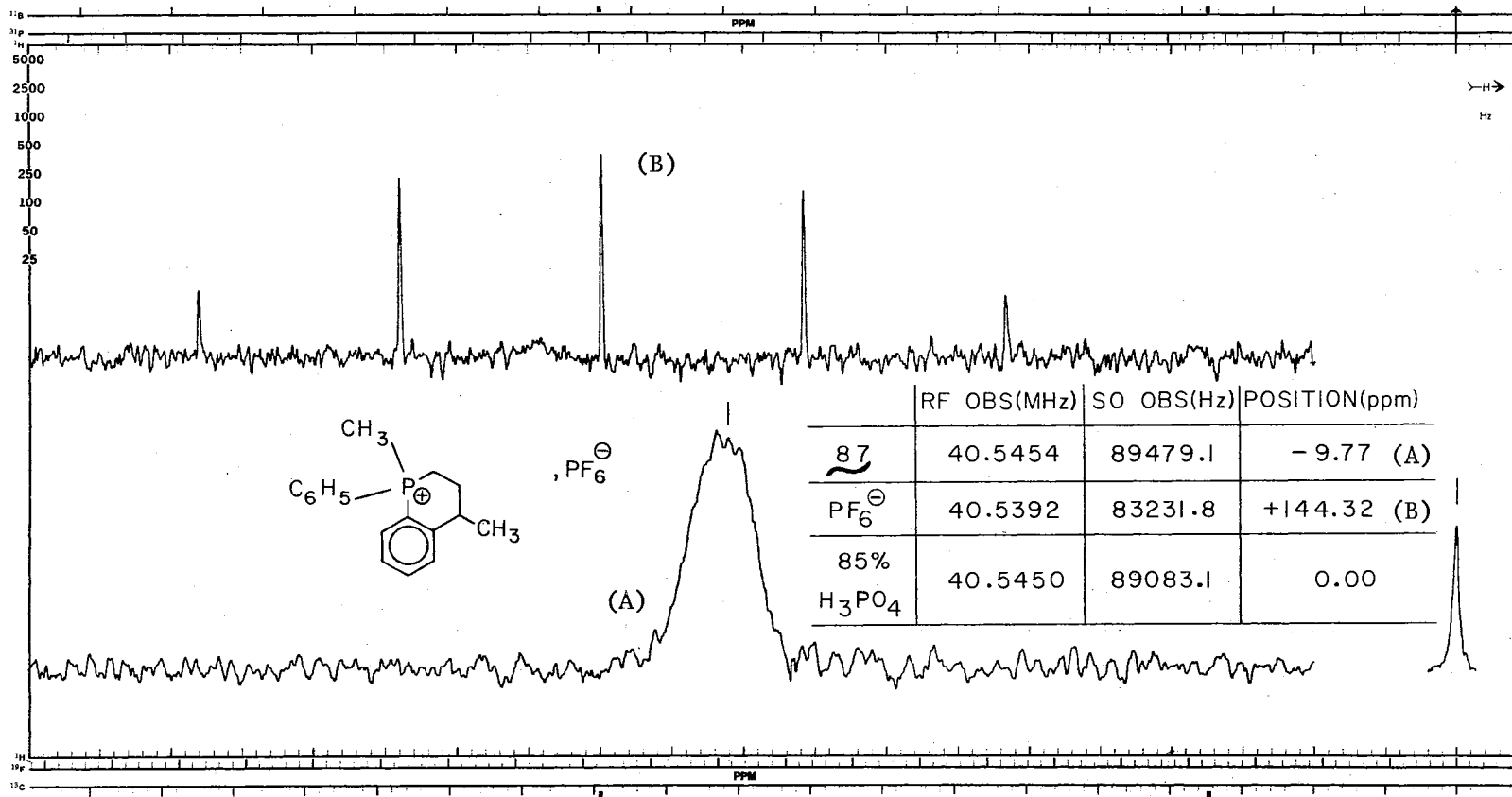


1,2,3,4-Tetrahydro-1,4-dimethyl-1-phenylphosphinolinium Hexafluorophosphate (87)

Solvent. . . . .	DCCl <sub>3</sub> /CF <sub>3</sub> CO <sub>2</sub> H	O.F. . . . .	100.1 Hz	F.B. . . . .	1 Hz	R.F. . . . .	.67 db
S.W. . . . .	.1000 Hz	S.T. . . . .	500 sec	S.O. . . . .	83701 Hz	S.A. . . . .	.6.3 Lock. . . . .
							HOMO



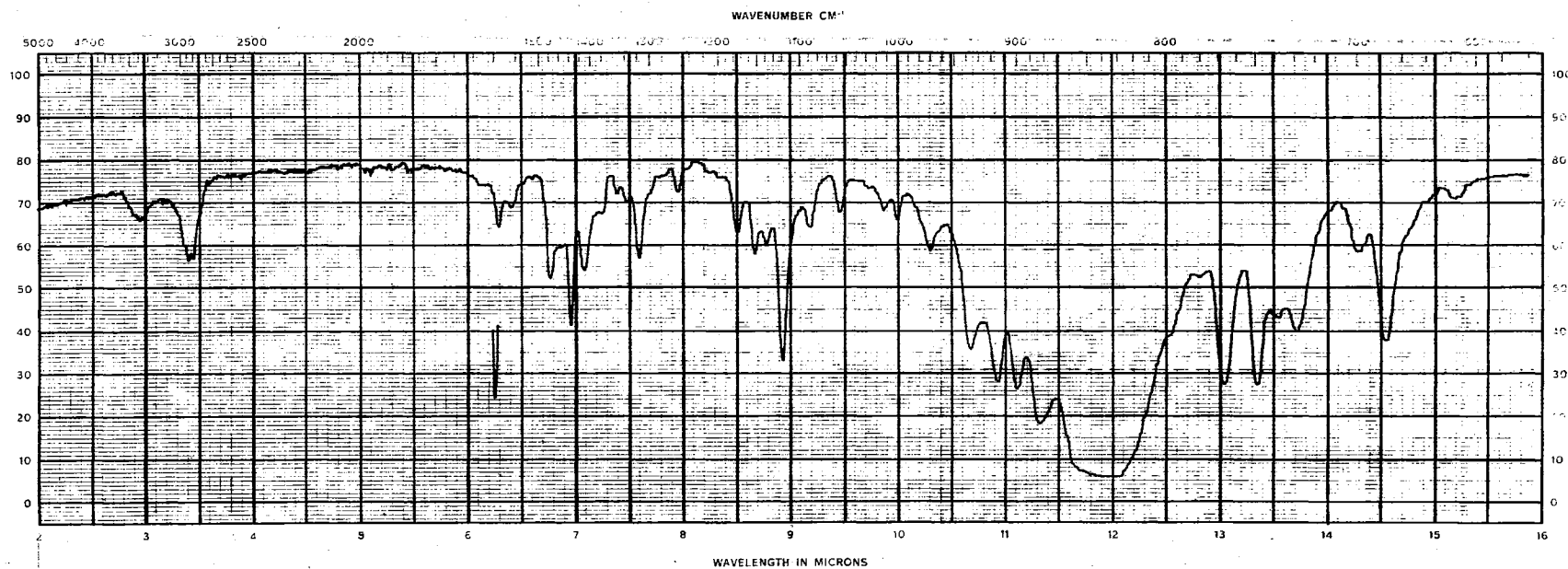
PLATE XXVII



<sup>31</sup>P Spectrum of 1,2,3,4-Tetrahydro-1,4-dimethyl-1-phenylphosphinolinium Hexafluorophosphate (87)

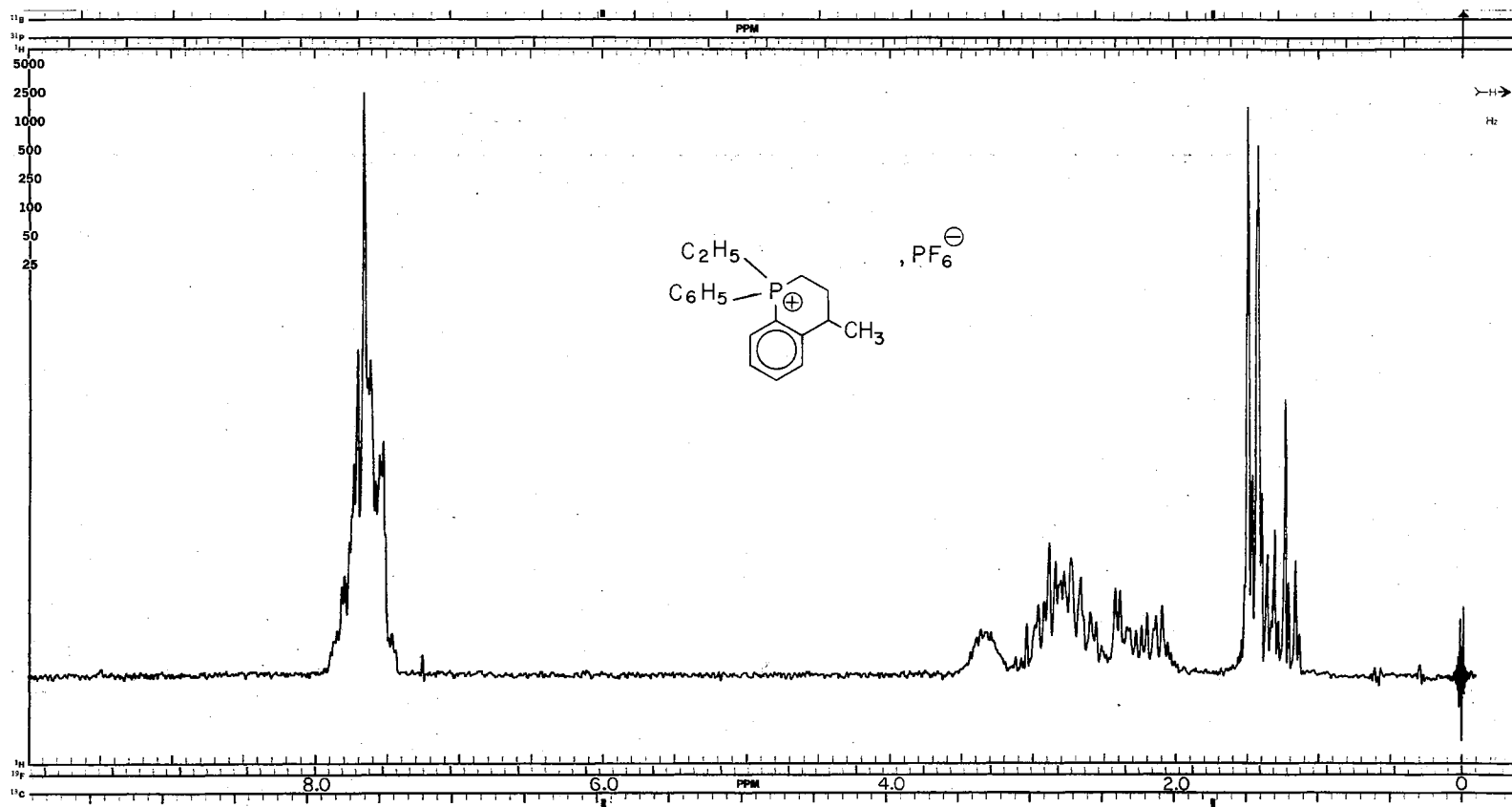
Solvent. .CH<sub>3</sub>CN/CF<sub>3</sub>CO<sub>2</sub>H (5 drops) O.F. . . 40.5 Hz F.B. . . .0.4 Hz R.F. . . .87 db  
 S.W. . . . . . 1000 Hz S.T. . . .250 sec S.O. . . .88986 Hz S.A. . . . 40 Lock. . . .<sup>1</sup>H

PLATE XXVIII



1,2,3,4-Tetrahydro-1,4-dimethyl-1-phenylphosphinolinium Hexafluorophosphate (87), KBr Pellet

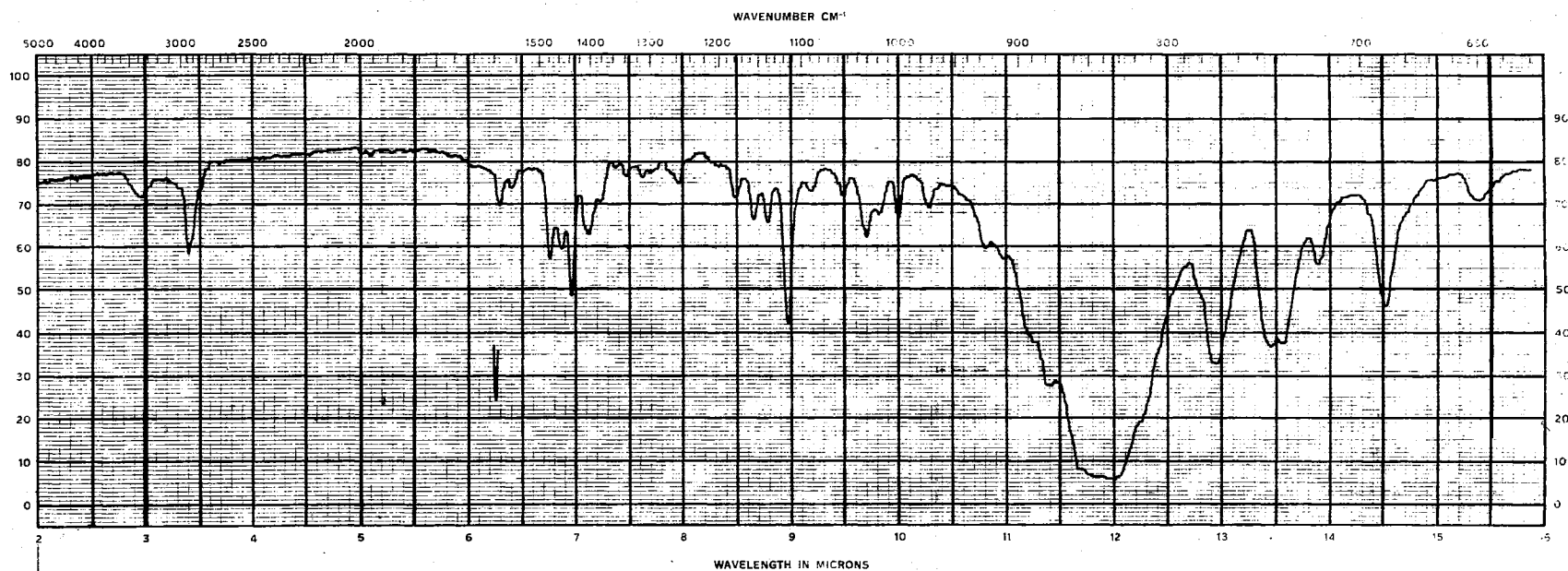
PLATE XXIX



1-Ethyl-1,2,3,4-tetrahydro-4-methyl-1-phenylphosphinolinium Hexafluorophosphate (88)

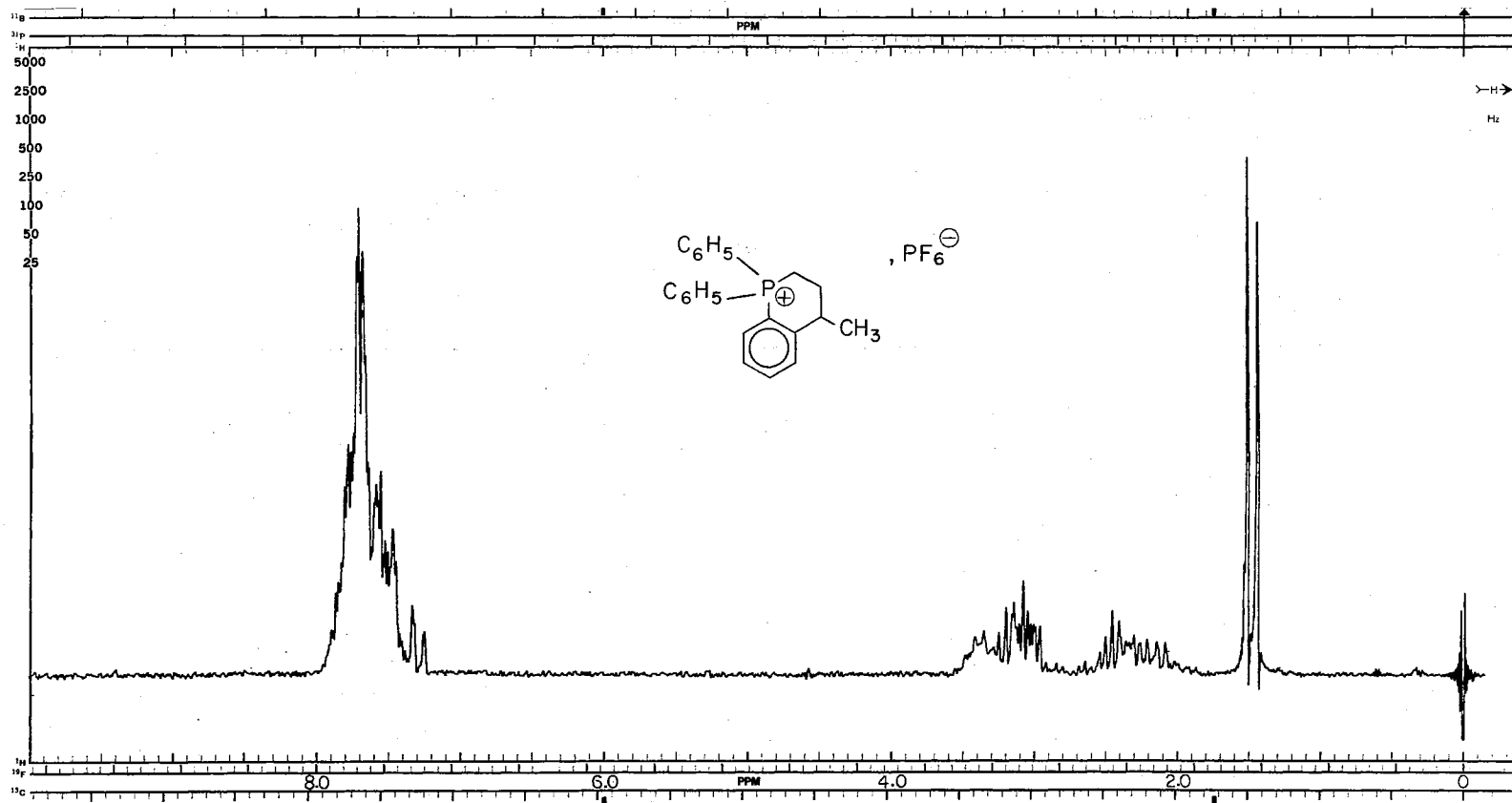
Solvent. .DCCl <sub>3</sub> /CF <sub>3</sub> CO <sub>2</sub> H	O.F. . . .100.1 Hz	F.B. . . .1 Hz	R.F. . . .69 db
S.W. . . . .1000 Hz	S.T. . . . 500 sec	S.O. .83701 Hz	S.A. . . .8.0 Lock. . . .HOMO

PLATE XXX



1-Ethyl-1,2,3,4-tetrahydro-4-methyl-1-phenylphosphinolinium Hexafluorophosphate (88), KBr Pellet

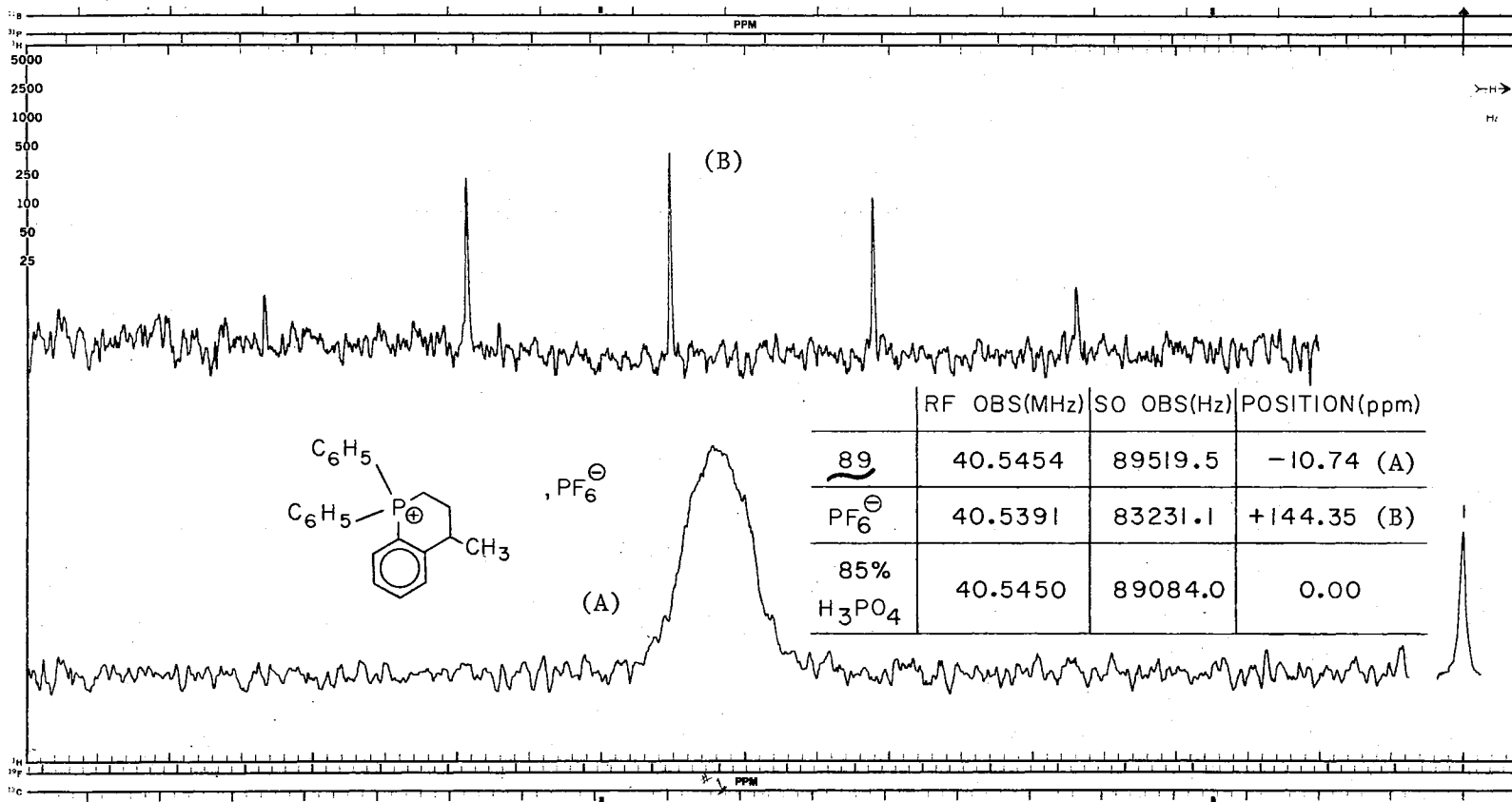
PLATE XXXI



1,2,3,4-Tetrahydro-4-methyl-1,1-diphenylphosphinolinium Hexafluorophosphate (89)

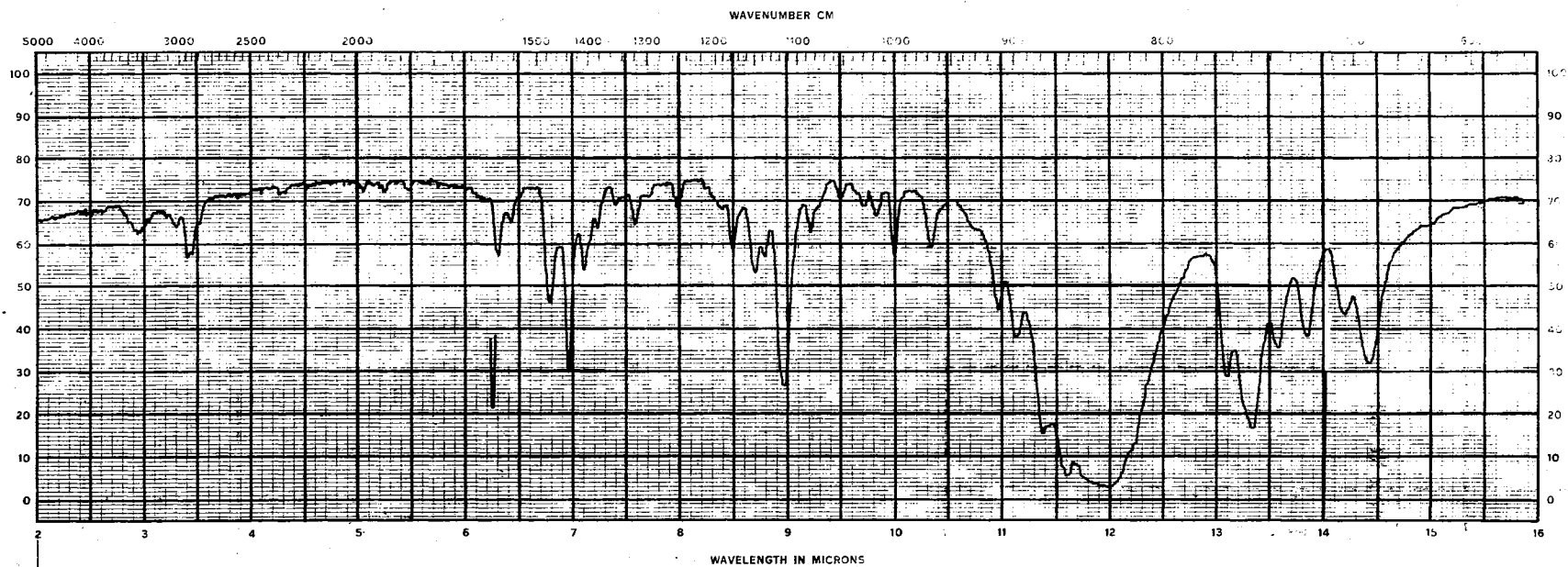
Solvent. .DCCl <sub>3</sub> /CF <sub>3</sub> CO <sub>2</sub> H	O.F. . . .100.1 Hz	F.B. . . .1 Hz	R.F. . . .68 db
S.W. . . . .1000 Hz	S.T. . . . 500 sec	S.O. .83701 Hz	S.A. . . .6.3 Lock. . . .HOMO

PLATE XXXII



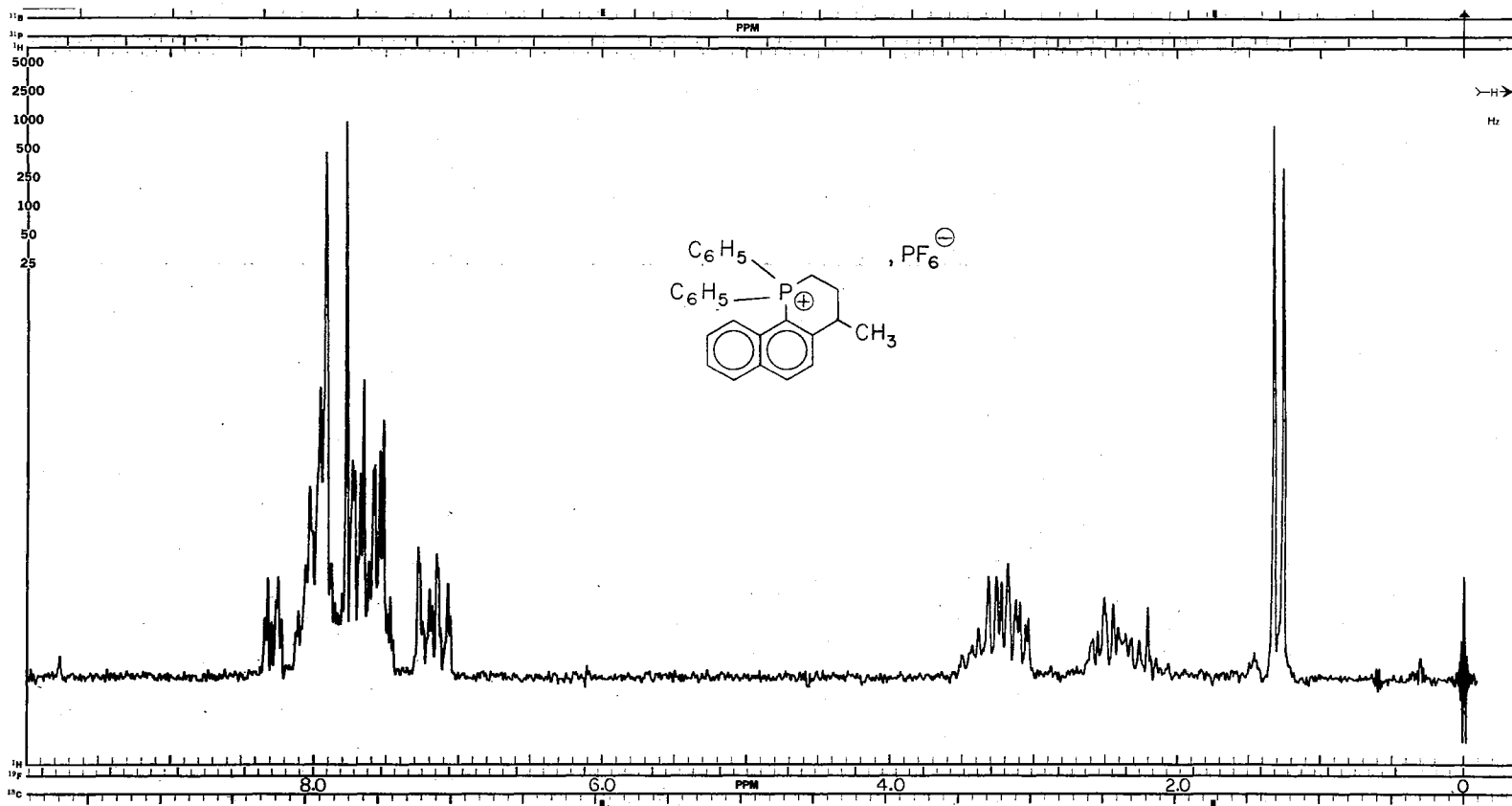
$^{31}\text{P}$  Spectrum of 1,2,3,4-Tetrahydro-4-methyl-1,1-diphenylphosphinolinium Hexafluorophosphate (89)  
 Solvent.  $\text{CH}_3\text{CN}/\text{CF}_3\text{CO}_2\text{H}$  (5 drops) O.F. . . 40.5 Hz F.B. . . 0.4 Hz R.F. . . 87 db  
 S.W. . . . . 1000 Hz S.T. . . 250 sec S.O. . 89005 Hz S.A. . . .40 Lock. . .  $^1\text{H}$

PLATE XXXIII



1,2,3,4-Tetrahydro-4-methyl-1,1-diphenylphosphinolinium Hexafluorophosphate (89), KBr Pellet

PLATE XXXIV

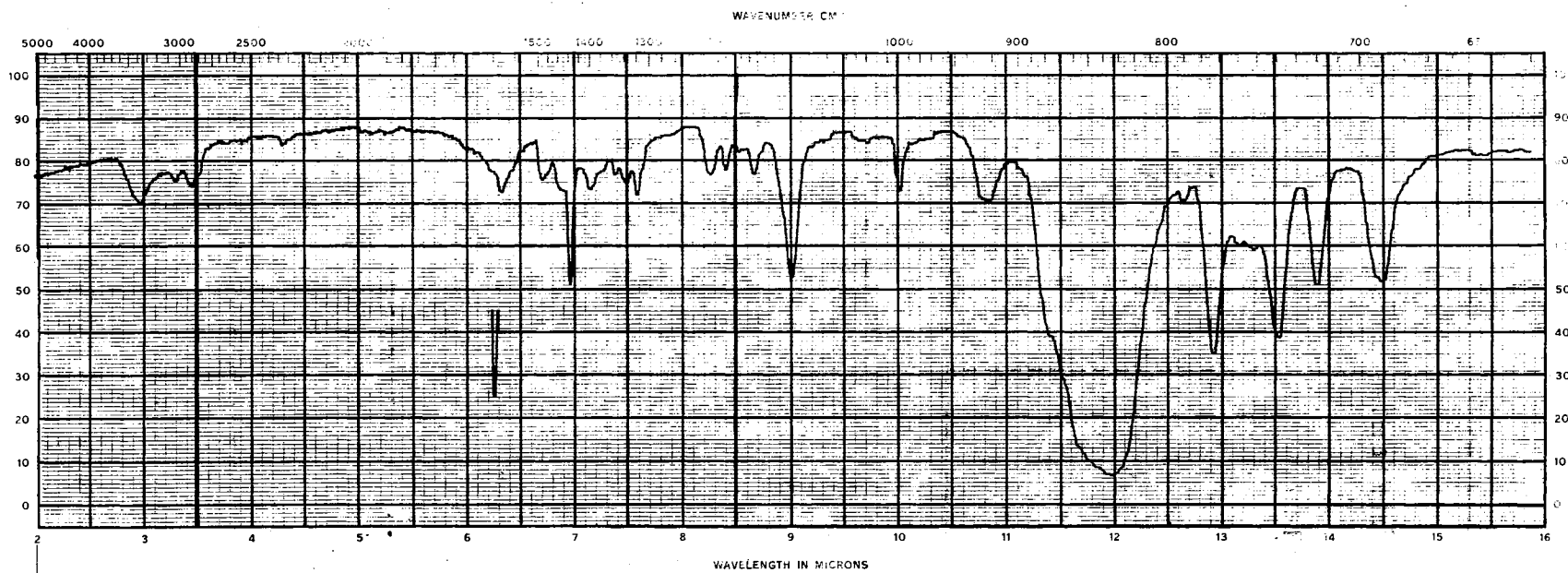


1,2,3,4-Tetrahydro-4-methyl-1,1-diphenylbenzo [h]phosphinolinium Hexafluorophosphate (90)

Solvent. .DCCl <sub>3</sub> /CF <sub>3</sub> CO <sub>2</sub> H	O.F. . . .100.1 Hz	F.B. . . . 1 Hz	R.F. . . . 69 db
S.W. . . . . .1000 Hz	S.T. . . . . 500 sec	S.O. 83701 Hz	S.A. . . . .12.5 Lock. . . HOMO



PLATE XXXV



1,2,3,4-Tetrahydro-4-methyl-1,1-diphenylbenzo [h]phosphinolinium Hexafluorophosphate (90), KBr Pellet

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