[Contribution from the W. A. Noyes Laboratory of Chemistry of the University of Illinois]

# Nitrogen Compounds of the Phosphoric and Phosphonic Acids. II. Hydrazides of Phenylphosphonic and Phenylphosphonothionic Acids[1,2,3]

W. C. SMITH, RALPH GHER, Jr., and L. F. AUDRIETH

*Received September 26, 1955*

Phenylphosphonic dihydrazide has been prepared by hydrazinolysis of the dichloride and found to react with carbonyl compounds to yield the corresponding hydrazones [$N^2,N'^2$-dialkylidene(arylidene) phenylphosphonic dihydrazides]. Phenylphosphonothioic dihydrazide has also been obtained from the corresponding dichloride. It possesses some basic character as evidenced by formation of a monopicrate and a dihydrochloride; it reacts (a) with ketones to give the $N^2,N'^2$-dialkylidene(arylidene) phenylphosphonothioic dihydrazides and (b) with ethyl chloroformate to give an $N^2,N'^2$-dicarbethoxy derivative.

Only a limited number of N-substituted hydrazides of P-alkyl (or aryl) phosphonic acids have been described in the literature.[4] No unsubstituted hydrazides have been studied. The preparation and properties of the dihydrazides of phenylphosphonic and phenyl phosphonothionic acids are described in the present paper.

Phenylphosphonic dihydrazide (I), $C_6H_5PO(N_2H_3)_2$, was prepared by the reaction of the dichloride with an ether suspension of hydrazine and was characterized as a hydrazide by conversion into a number of aldehyde and ketone derivatives.

Phenylphosphonothioic dihydrazide (II), $C_6H_5PS(N_2H_3)_2$, may be prepared in good yield by the reaction of a chloroform solution of the acid chloride with 95% hydrazine. The product is readily soluble in chloroform, which facilitates its separation from the by-product hydrazine hydrochloride. It reacts with picric acid in ethanolic solution to form a monopicrate salt and with alcoholic hydrogen chloride to form a dihydrochloride. Presence of the hydrazide function was confirmed by preparation of a number of ketone derivatives [$N^2,N'^2$-dialkylidene(arylidene) phenylphosphonothioic dihydrazides] and by reaction with ethyl chloroformate to give the $N^2,N'^2$-dicarbethoxy derivative.

## EXPERIMENTAL[5]

*Phenylphosphonic dihydrazide* (I), $C_6H_5PO(N_2H_3)_2$. To a suspension of 22.2 g. of 95% hydrazine (0.66 mole; 10% excess) in 200 ml. of diethyl ether there was added dropwise with vigorous agitation 29.3 g. (0.15 mole) of phenylphosphonic dichloride[6] dissolved in 50 ml. of diethyl ether. The reaction flask was cooled in an ice-bath; the acid chloride was added at such a rate that the temperature did not rise above 15°. The ether layer was decanted from the semisolid reaction product and the latter was washed with three 50-ml. portions of ether. Twenty g. of the crude product then was treated with 50 ml. of hot absolute ethanol and the resulting mixture was filtered. The solid fraction obtained on cooling the ethanolic filtrate consisted entirely of hydrazine hydrochloride.[7] Initial concentration of the alcoholic solution resulted in the recovery of more $N_2H_4 \cdot HCl$. Further concentration and cooling yielded a second crop of crystals consisting largely of the desired compound, which was purified by recrystallization from absolute ethanol. The total recrystallized yield amounted to 6.6 g. (23.7%). The pure dihydrazide crystallizes as plates melting at 131°.

*Anal.* Calc'd for $C_6H_{11}N_4OP$: C, 38.70; H, 5.96; N, 30.10. Found: C, 38.78; H, 5.81; N, 30.37.

TABLE I

Aldehyde and Ketone Derivatives of Phenylphosphonic Dihydrazide

[$N^2,N'^2$-dialkylidene(arylidene) phenylphosphonic dihydrazides]
$PhPO(NHN{=}CR_2)_2$

| Carbonyl Compound | Empirical Formula | Crystallizing Solvent | M.P., °C. | Carbon Calc'd | Carbon Found | Hydrogen Calc'd | Hydrogen Found | Nitrogen Calc'd | Nitrogen Found |
|---|---|---|---|---|---|---|---|---|---|
| *p*-Methoxybenzaldehyde | $C_{22}H_{23}N_4O_3P$ | Chloroform | 171 | 62.52 | 62.13 | 5.49 | 5.42 | 13.26 | 13.09 |
| *p*-Chloroacetophenone | $C_{22}H_{21}Cl_2N_4OP$ | Absolute ethanol | 201 | 57.52 | 57.38 | 4.61 | 4.90 | 12.20 | 12.17 |
| Acetone | $C_{12}H_{19}N_4OP$ | Acetone | 170 | 54.12 | 53.57 | 7.19 | 7.03 | 21.04 | 20.52 |

---

[1] For the first article of this series see Audrieth, Gher, Jr., and Smith, *J. Org. Chem.*, **20**, 1288 (1955).

[2] Abstracted from doctoral dissertations submitted to the Graduate College of the University of Illinois by W. C. Smith (1954) and Ralph Gher, Jr. (1952).

[3] Support of these studies through research grants made available by the Victor Chemical Works, Chicago, Illinois, is gratefully acknowledged.

[4] Kosolapoff, *Organophosphorus Compounds*, John Wiley and Sons, Inc., New York, New York, 1950.

[5] Melting points are uncorrected.

[6] The acid chlorides used in the present investigation were kindly furnished by the Victor Chemical Works, Chicago, Illinois, and were redistilled before use.

[7] Attempts to find a more satisfactory solvent for separating the dihydrazide from $N_2H_4 \cdot HCl$ met with little success. Chloroform and a 10:1 ethanol-diethyl ether mixture were capable of giving somewhat better yield. No success was achieved in an effort to use either pyridine or triethylamine to remove the hydrogen chloride formed in the reaction between the acid chloride and hydrazine.

Phenylphosphonic dihydrazide is soluble in the lower alcohols but insoluble in ether. It is also readily soluble in water but cannot be recovered unchanged. The dihydrazide is not sufficiently basic to form a picrate salt in ethanolic solution. The only product that could be isolated was hydrazine monopicrate, indicating that solvolysis of (I) had taken place in alcoholic solution.

Several aldehyde and ketone derivatives [$N^2$,$N'^2$-dialkylidene(arylidene) phenylphosphonic dihydrazides] were prepared by adding the carbonyl compound dropwise to a warm ethanolic solution of (I). The properties of these compounds are summarized in Table I.

*Hydrazinium n-propyl phenylphosphonate* (III), $C_6H_5PO(OC_3H_7)OH{\cdot}N_2H_4$. The hydrazinolysis of di-*n*-propyl phenylphosphonate was investigated as a possible method for preparing (I). A two-hour reflux period led to isolation of III, melting sharply at 77°. The identity of III was confirmed by analysis and by formation of the corresponding azines when treated with benzaldehyde and *p*-chloroacetophenone. The isolation of III rather than the hydrazide suggests that the ester hydrazinolysis may have been unsuccessful because of hydrolysis resulting from the presence of 5% water in the hydrazine.

*Anal.* Calc'd for $C_9H_{17}N_2O_3P$ (III): C, 46.55; H, 7.37; N, 12.08. Found: C, 47.17; H, 7.61; N, 12.06.

*Phenylphosphonothioic dihydrazide* (II), $C_6H_5PS(N_2H_3)_2$. A solution of phenylphosphonothioic dichloride[6] (68.8 g., 0.326 mole) in 100 ml. of chloroform was added dropwise, with vigorous stirring, to a slurry of 96 g. of 95% hydrazine (2.85 moles; 118% excess) in 600 ml. of chloroform. The reaction flask was immersed in an ice-salt bath and the temperature was kept below 10° during the 75-minute addition period. The resulting mixture of solid, a small upper liquid layer of hydrazine hydrochloride in unreacted hydrazine, and the lower chloroform layer was warmed to bring the solid into solution to give two liquid layers. The bulk of the desired product was recovered from the chloroform layer on cooling. The balance of II was obtained by evaporation of the solvent and treatment of the residue with 100 ml. of hot water. The dihydrazide crystallized from the aqueous solution on cooling. A pure product melting at 115° was obtained on recrystallization from absolute ethanol. The yield was 54.1 g. (82%).

TABLE II

KETONE DERIVATIVES OF PHENYLPHOSPHONOTHIOIC DIHYDRAZIDE

[$N^2$,$N'^2$-dialkylidene(arylidene) phenylphosphonothioic dihydrazides]

$PhPS(NHN{=}CR_2)_2$

| Ketone | Empirical Formula | Crystallizing Solvent | M.P., °C. | Analyses Carbon Calc'd | Carbon Found | Hydrogen Calc'd | Hydrogen Found | Nitrogen Calc'd | Nitrogen Found |
|---|---|---|---|---|---|---|---|---|---|
| Acetone | $C_{12}H_{19}N_4PS$ | Ethanol | 155 | 51.1 | 51.31 | 6.74 | 6.56 | 19.85 | 19.73 |
| *p*-Chloroacetophenone | $C_{22}H_{21}Cl_2N_4PS$ | Absolute ethanol | 162 | 55.60 | 55.74 | 4.42 | 4.35 | 11.79 | 11.77 |
| Cyclohexanone | $C_{18}H_{27}N_4PS$ | Ethanol | 133 | 59.75 | 59.38 | 7.46 | 7.80 | 15.47 | 15.52 |

*Anal.* Calc'd for $C_6H_{11}N_4PS$: C, 35.6; H, 5.45; N, 27.7. Found: C, 35.86; H, 5.31; N, 27.98.

Quantitative solubilities of II in grams per 100 g. solvent at 25° were determined: water, 0.76; ethanol, 0.6; diethyl ether, 0.11; chloroform, 0.415; carbon tetrachloride, 0.01. Reference is made to the fact that II can be recovered unchanged from aqueous solutions, whereas I appears to decompose.

A *monopicrate* was obtained when an ethanolic solution of 5 g. (0.022 mole) of picric acid was added to 2.0 g. (0.010 mole) of II in 40 ml. of hot absolute ethanol. The yellow salt, which precipitated immediately, was purified for analysis by recrystallization from absolute ethanol. The salt melts at 165–166° with decomposition.

*Anal.* Calc'd for $C_{12}H_{14}N_7O_7PS$: C, 33.42; H, 3.25; N, 22.7. Found: C, 33.53; H, 3.40; N, 22.54.

A *dihydrochloride* of II was precipitated from ethanolic solution when the components were mixed in stoichiometric quantities. The salt melts with decomposition at 172°. Decomposition was found to occur when recrystallization from ethanol was attempted.

*Anal.* Calc'd for $C_6H_{13}Cl_2N_4PS$: C, 26.19; H, 4.73; N, 20.36. Found: C, 26.47; H, 5.45; N, 20.66.

The identity of II as a hydrazide was further confirmed by the preparation of several ketone derivatives [$N^2$,$N'^2$-dialkylidene(arylidene)phenylphosphonothioic dihydrazides]. Data are summarized in Table II. The isopropylidene derivative was obtained by the direct reaction of II with acetone; the other compounds were prepared by adding the ketone to an ethanolic solution of II.

Interaction of a solution of 2.0 g. (0.01 mole) of II in 20 ml. of 1 *N* NaOH with 2.2 ml. (0.023 mole, 15% excess) of ethyl chloroformate yielded 1.6 g. (46%) of a crystalline product when the reaction mixture was subsequently cooled in an ice-bath. The compound was found by analysis to be $N^2$,$N'^2$-dicarbethoxyphenylphosphonothioic dihydrazide, melting at 133°. The derivative is very soluble in acetone, chloroform, and dioxane and exhibits somewhat less but still appreciable solubility in hot absolute ethanol, water and ether.

*Anal.* Calc'd for $C_{12}H_{19}N_4O_4PS$: C, 41.65; H, 5.49; N, 16.19. Found: C, 41.13; H, 7.03; N, 16.06.

URBANA, ILLINOIS