The Preparation of the Isomeric Ethylphenylphosphonic Acids[1]

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Numerous papers[2] have described a wide variety of arylphosphonic acids prepared by the reaction between diazonium salts and phosphorus trihalides. In this Laboratory the reaction has failed to produce the expected arylphosphonic acid only in the case of *o*-nitrobenzenediazonium fluoborate.[2a] The failure may be due to steric effects or to the replacement of the nitro group in *o*-nitrobenzenediazonium fluoborate by a halogen atom.[2b] Recently, Ashby and Kosolapoff[2d] have reported that they were unable to prepare *o*-tolyl-, *o*-ethylphenyl- and *m*-ethylphenylphosphonic acids from the corresponding diazonium fluoborates. It seemed of interest to reëxamine these cases, since we could see no obvious reasons for these failures of the diazo reaction. We have now found that *o*-ethyl- and *m*-ethylphenylphosphonic acids can be obtained in low yields from the corresponding diazonium fluoborates. When *o*-toluenediazonium fluoborate reacted with phosphorus trichloride in ethyl acetate in the presence of cuprous bromide, we were unable to isolate any of the expected phosphonic acid either through the *p*-toluidine salt[2c] or through the magnesium salt or by the methods successfully used for isolating the ethylphenylphosphonic acids. We are unable to explain this failure.

The previously described procedures[2a] for isolating phosphonic acids are not applicable in the case of *o*-ethylphenylphosphonic acid. However, this compound can be isolated from the reaction mixture by procedures described in the Experimental section. The instability of *m*-ethylbenzenediazonium fluoborate[2d,3] requires that the compound be used immediately after it is prepared; the isolation and purification of the acid present no special problems. *p*-Ethylphenylphosphonic acid also can be prepared from the corresponding diazonium fluoborate. Table I lists the analyses, yields and m.p.'s of the isomeric ethylphenylphosphonic acids.

The *o*- and *m*-isomers of ethylphenylphosphonic acid have not previously been described. The *p*-isomer has been prepared[4] by means of a Friedel–Crafts reaction between ethylbenzene and phosphorus trichloride. Kosolapoff[4] also isolated from this reaction a small amount of another phosphonic acid, m.p. 116–117°. He suggested that this acid was probably the *m*-isomer. However, the m.p.'s of all three isomers reported here are significantly higher than 117°. It seems probable, therefore, that the low melting phosphonic acid reported by Kosolapoff[4] was a mixture of isomers.

Experimental Part

***o*-Ethylphenylphosphonic Acid.**—*o*-Ethylaniline[5] was redistilled and the fraction boiling at 99–100° at 20 mm. was used to prepare the corresponding diazonium fluoborate by the method designated by Roe as IIA.[6] The diazonium salt, after being dried in a vacuum desiccator, was suspended in dry ethyl acetate and treated with phosphorus trichloride and cuprous bromide in the usual manner.[2] After the reaction mixture was steam distilled, the phosphonic acid was isolated from the residual liquid in the distilling flask by one of two procedures.

Isolation Procedure 1.—The liquid was treated with hydrogen sulfide to precipitate the copper as copper sulfide, which was removed by filtration. The filtrate was then evaporated to a small volume (25 ml. for preparations on a 0.1-mole scale) and cooled in the deep-freeze at −25° whereupon the crude phosphonic acid crystallized from solution. The acid was then readily purified by procedure A as previously described.[2a]

Isolation Procedure 2.—The liquid was extracted with ether (three 25-ml. portions for preparations on a 0.1-mole scale), the ethereal extracts were combined, and the ether was removed by evaporation. The residue consisted largely of crude phosphonic acid which was purified by procedure A.[2a]

***m*-Ethylphenylphosphonic Acid.**—The preparation of *m*-ethylaniline from *m*-nitroacetophenone (Eastman 2243) by the procedure described in the literature[7] could not be accomplished. However, when we used toluene[8] (100 ml. of toluene per 10 g. of ketone) rather than alcohol as the solvent for the *m*-nitroacetophenone, we obtained a 44% yield of *m*-ethylaniline, b.p. 90–99° at 11 mm. We also found that a 75% yield of *m*-ethylaniline could be obtained by reducing *m*-aminoacetophenone (Eastman P 3598) in a similar manner.

m-Ethylbenzenediazonium fluoborate was prepared by method IIA[6]; it was immediately suspended in dry ethyl acetate and treated with phosphorus trichloride and cuprous bromide. After the reaction mixture was steam distilled, the residual liquid was filtered. The filtrate was evaporated to 25 ml. (for the preparations on a 0.1-mole scale) and cooled in deep-freeze at −25° whereupon the crude phosphonic acid crystallized from solution. The acid was then purified by recrystallization from dilute hydrochloric acid.

TABLE I

THE ISOMERIC ETHYLPHENYLPHOSPHONIC ACIDS

$RC_6H_4PO_3H_2$ R =	Yield, %	M.p.,[a] °C.	Formula	Phosphorus, %[b] Calcd.	Found	Neut. equiv.[c] Calcd.	Found
o-C_2H_5	11,[d] 12[e]	145.5–147	$C_8H_{11}O_3P$	16.64	16.42	93.1	94.9
m-C_2H_5	11[f]	128–129.5	$C_8H_{11}O_3P$	16.64	16.58	93.1	94.2
p-C_2H_5[g]	18[f]	176–177.5	$C_8H_{11}O_3P$	16.64	16.54	93.1	94.2

[a] Melting points were taken as previously described; *cf.* ref. 2a. [b] Phosphorus was determined by a modification of the method of M. D. Bachofer and E. C. Wagner, *Ind. Eng. Chem., Anal. Ed.*, **15**, 601 (1943). [c] The indicator used was thymolphthalein. [d] This yield was obtained when isolation procedure 1 was used. [e] This yield was obtained when isolation procedure 2 was used. [f] Based on *m*(or *p*)-ethylaniline. [g] Previously prepared by A. Michaelis and by G. M. Kosolapoff, ref. 4; highest previously reported m.p. 174.5–175°.

(1) The organophosphorus nomenclature in this paper is that proposed by the Organic Division's Advisory Committee on the Nomenclature of Organic Phosphorus Compounds; *cf. Chem. Eng. News*, **30**, 4515 (1952).

(2) See, for example, (a) G. O. Doak and L. D. Freedman, THIS JOURNAL, **73**, 5658 (1951); (b) L. D. Freedman, H. Tauber, G. O. Doak and H. J. Magnuson, *ibid.*, **75**, 1379 (1953); (c) R. W. Bost and L. D. Quin, *J. Org. Chem.*, **18**, 358 (1953); (d) E. C. Ashby and G. M. Kosolapoff, THIS JOURNAL, **75**, 4903 (1953).

(3) E. S. Lewis and E. B. Miller, *ibid.*, **75**, 429 (1953).

(4) A. Michaelis, *Ann.*, **293**, 193 (1896); G. M. Kosolapoff, THIS JOURNAL, **74**, 4119 (1952).

(5) Kindly furnished by the Monsanto Chemical Company.

(6) A. Roe in "Organic Reactions," Vol. V, John Wiley and Sons, Inc., New York, N. Y., 1949, p. 204.

(7) D. Papa, E. Schwenk and B. Whitman, *J. Org. Chem.*, **7**, 587 (1942).

(8) The use of toluene was suggested by Dr. Papa in a personal communication.

p-**Ethylphenylphosphonic Acid.**—1-Ethyl-4-nitrobenzene (Eastman P 2996) was redistilled and the fraction boiling at 139–143 at 25 mm. was collected. It was readily reduced with Raney nickel and hydrogen at 40 lb. pressure to *p*-ethylaniline, b.p. 115–120° at 29 mm. *p*-Ethylbenzenediazonium fluoborate was obtained from the amine by method IIA[6] and used immediately for the preparation of *p*-ethylphenylphosphonic acid by the general method previously described.[2] The phosphonic acid was purified by Procedure A.[2a]

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Condensation of 1,4-Diaroylbutanes with Benzaldehyde

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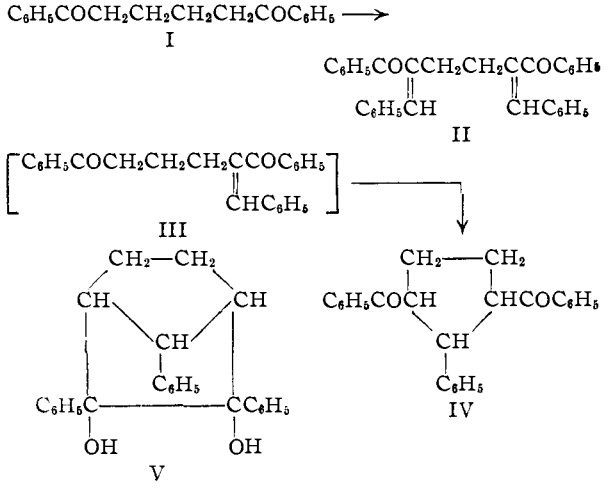
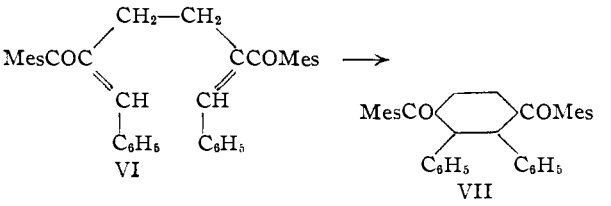
In the base-catalyzed condensation of 1,4-dibenzoylbutane (I) with benzaldehyde it was discovered that the dibenzal derivative II can be made successfully only by using a large excess of the aldehyde. Smaller amounts of benzaldehyde gave instead 1,3-dibenzoyl-2-phenylcyclopentane (IV), formed presumably by cyclization of the monobenzal derivative III by an internal Michael reaction.

In the cyclopentane derivative the two benzoyl groups appear to lie on the same side of the ring because the compound yields a pinacol V when reduced by the binary mixture Mg–MgI_2.[1] The reduction is analogous to that involved in the formation of satene glycol from 1,3-diacetylcyclohexane.[2] Oxidation with potassium permanganate reconverted the 2,3-dihydroxy-2,3,7-triphenylbicyclo[2,2,1]heptane (V) to the original diketone IV.



As was reported earlier,[3] the dibenzal derivative VI of 1,4-dimesitoylbutane is formed in satisfactory yield when the diketone and the aldehyde are taken in the theoretical amounts. Reduction of this compound with the binary mixture appears to occur in the conjugate manner to bring about cyclization. Although a satisfactory proof of structure was not worked out, the product is believed to be 1,4-dimesitoyl-2,3-diphenylcyclohexane (VII).



Experimental

1,4-Dibenzal-1,4-dibenzoylbutane (II).—A solution of 10 g. (0.0375 mole) of 1,4-dibenzoylbutane, 6.0 g. of sodium methoxide and 200 ml. of absolute ethanol was heated under reflux, with stirring, for 1.5 hours. The solution was cooled to 0°, the rate of stirring being increased to prevent clumping of the crystals which separated. To the cold mixture was added, with rapid stirring, 10 g. (0.094 mole) of benzaldehyde. After 10 minutes the ice-bath was removed and stirring continued for an additional hour at room temperature. The mixture was poured into iced acetic acid and, after the resulting mixture had been allowed to stand for an hour, it was extracted with benzene and with ether. The product, a dark yellow oil, crystallized from ethanol. The first two crops of crystals (1.5 g.) proved to be unchanged 1,4-dibenzoylbutane.

The residue from the second filtration was distilled *in vacuo*, and the oil which remained was distilled through a short-path still. Three fractions were collected; a low-boiling liquid which was found to be benzaldehyde, a middle fraction (144–159° (0.5 mm.)) which was the dibenzal derivative and a high-boiling fraction (159–220° (0.5 mm.)) which was a mixture of the dibenzal derivative with unchanged dibenzoylbutane. The pure dibenzal derivative boils at 166° (0.5 mm.); it crystallizes from an ethanol–water solution to give long, colorless needles, m.p. 39–40°.

Anal.[4] Calcd. for $C_{32}H_{26}O_2$: C, 86.83; H, 5.92. Found: C, 86.89; H, 6.45.

The infrared spectrum[5] shows no evidence of a hydroxyl group, but does indicate the presence of monosubstituted benzene; aromatic stretching vibrational band splitting at 1600 $cm.^{-1}$ indicates there is conjugation with the benzene ring. Absorption at 1647 $cm.^{-1}$ indicates the presence of a highly conjugated carbonyl group, and a band at 1629 $cm.^{-1}$ may be assigned to a conjugated carbon–carbon double bond.

1,3-Dibenzoyl-2-phenylcyclopentane (IV).—A solution of 10 g. of 1,4-dibenzoylbutane in 100 ml. of 95% ethanol was heated under reflux for 30 minutes, with stirring, with 4.2 g. of potassium hydroxide. To this mixture 5.74 g. of benzaldehyde was added rapidly, and heating was continued for one hour. The mixture was poured into iced hydrochloric acid, and the resulting mixture was treated with benzene. A high-melting solid (m.p. 238°), which was insoluble in most organic solvents, was not identified. From the filtrate 3.5 g. of a colorless crystalline solid, m.p. 158–159°, was obtained. Two more recrystallizations from benzene gave the pure compound, m.p. 162.5–163°. All the mother liquors were combined and the solvent was distilled under diminished pressure. The residual viscous, dark-brown oil was distilled *in vacuo* through a short-path still, two fractions being collected in approximately equal amounts. The first (b.p. 144° (0.3 mm.)) was the dibenzal derivative. The second (b.p. 214–225° (0.3 mm.)) was dissolved in ethanol; the solution, when allowed to stand, deposited colorless crystals of the cyclopentane derivative IV.

Anal. Calcd. for $C_{25}H_{22}O_2$: C, 84.72; H, 6.26. Found: C, 84.80; H, 6.23.

(1) M. Gomberg and W. E. Bachmann, THIS JOURNAL, **49**, 236 (1927).

(2) L. M. Mohunta and J. N. Ray, *J. Chem. Soc.*, 1328 (1934).

(3) R. C. Fuson and R. W. Hill, *J. Org. Chem.*, **19**, 1575 (1954).

(4) Microanalyses by Miss L. Chang and Mr. Josef Nemeth.

(5) The infrared spectra mentioned in this paper were recorded and interpreted by Miss Helen Miklas.