40°. The yield was 91 g. (93%); m.p. 164–166°; $[\alpha]^{25}D$ −72.7° (*c* 1, 96% ethanol). The quinine salt titrated with base gave an equivalent weight of 665 (theory, 661.8).

L-(−)-N-Acetyl-3-(3,4-diacetoxyphenyl)-2-methylalanine.—The quinine salt of L-(−)-N-acetyl-3-(3,4-diacetoxyphenyl)-2-methylalanine (17.7 g., 0.0268 mole) was dissolved at 0–5° in 11.0 ml. of 2.5 *N* hydrochloric acid and 60 ml. of water. To the clear solution was added 10.6 ml. of 2.5 *N* hydrochloric acid which caused product to precipitate. After holding overnight at 0–5°, the product was filtered, washed with cold water, and dried under vacuum at 40°. The yield was 7.49 g. (83%); m.p. 181–183°; $[\alpha]^{25}D$ −74.5° (*c* 1, 96% ethanol). Base titration showed an equivalent weight of 336 (theory, 337.3).

L-(−)-3-(3,4-Dihydroxyphenyl)-2-methylalanine.—A solution of L-(−)-N-acetyl-3-(3,4-diacetoxyphenyl)-2-methylalanine (25.0 g., 0.074 mole) in 200 ml. of 6 *N* hydrochloric acid was refluxed for 2 hr. The solution was concentrated to dryness under vacuum and the residual yellow oil was concentrated to dryness three times with 50-ml. portions of *t*-butyl alcohol to remove hydrochloric acid. The gummy residue was dissolved in 45 ml. of water and the solution was filtered to remove a trace amount of insoluble material. The filtrate was adjusted to pH 7.0 with concentrated ammonia. After adding 1.0 g. of sulfur dioxide, the mixture was held at 0–5° overnight. The crystals were filtered, washed with cold water, and dried under vacuum at 50°. The product weighed 14.9 g., but contained 11.3% water by Karl Fischer titration (84.5% yield calculated for $C_{10}H_{13}NO_4 \cdot 1.5\ H_2O$).[19]

The L-(−)-α-methyldopa, m.p. 295° dec., $[\alpha]^{25}D$ −3° (*c* 2, 0.1 *N* hydrochloric acid) had an equivalent weight by base titration of 239 (theory, 238) and had an absorption maximum at 281 mμ (ε 2780). The dried product gave an infrared spectrum identical with material resolved through the 1-phenylethylamine salt.

(19) X-Ray analysis reveals that L-(−)-α-methyldopa exists in three crystalline forms. Normally, when isolated from aqueous solutions, a sesquihydrate is obtained. Vigorous drying of the sesquihydrate (100°, under vacuum) gives an anhydrous form which, when exposed to air, absorbs water and is transformed back to the hydrate. A second, nonhygroscopic, anhydrous form has been isolated from isopropyl alcohol solutions.

Condensation of Catechol with Phenylphosphonous Dichloride. A Novel Ring-Cleavage Reaction[1]

K. DARRELL BERLIN AND M. NAGABHUSHANAM[2]

Department of Chemistry, Oklahoma State University, Stillwater, Oklahoma

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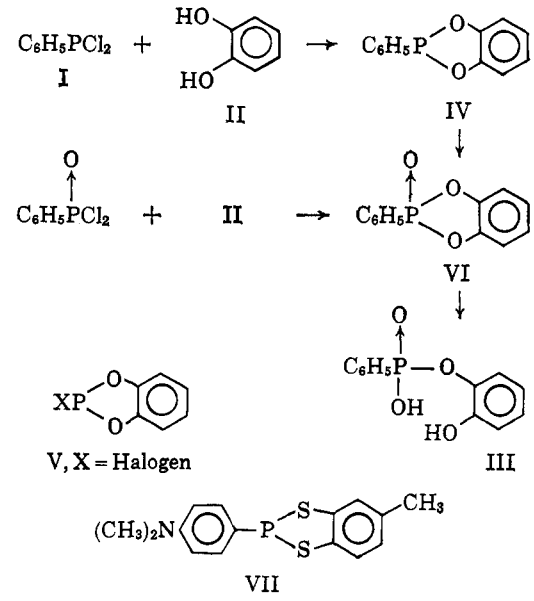
The chemistry of cyclic compounds derived from trivalent and pentavalent phosphorus has been investigated in some detail and an excellent review[3] has appeared recently which included data on the reaction of phosphorus trichloride with catechol (II). No detailed investigation on the synthesis of 2-aryl-substituted 1,3,2-benzodioxaphospholes has been described.

The reaction between catechol (II) and phenylphosphonous dichloride (I) is more complicated than might be anticipated. When the condensation was performed with equimolar quantities of I and II in the presence of pyridine or triethylamine in various solvents, the only isolable product was 2-phenyl-1,3,2-benzodioxaphosphole 2-oxide (VI) (Scheme I). In addition the phosphonate VI is exceedingly unstable since,

SCHEME I



upon standing for a short time (even in desiccator), it is converted quantitatively to a strong acid, *o*-hydroxyphenylhydrogen phenylphosphonate (III).[4] Reaction of I and II in bromobenzene at reflux led to the cyclic derivative IV.[5] From the cool solution, relatively pure 2-phenyl-1,3,2-benzodioxaphosphole (IV) was obtained in excellent yield. The structure of the product was tentatively established by the infrared spectral data. However, the spectrum changed rapidly when the impure ester IV was subjected to purification by recrystallization or upon storage in a desiccator. Structural confirmation of III was provided *via* hydrolysis with hydrochloric acid to yield phenylphosphonic acid and catechol. The P–O bond in III is readily cleaved by treatment with mineral acid as well as alkali. Thus, it appears that 2-phenyl-1,3,2-benzodioxaphosphole (IV) is formed initially but undergoes rapid oxidation followed by hydrolysis to III. The extreme sensitivity to oxidation of the heterocyclic ring in IV is somewhat surprising in view of the isolation of corresponding 2-halogen analogs (V),[3] although they are reported to be inherently sensitive to cleavage because of ring strain.[6] Although a related, stable sulfur compound (VII) was recorded recently, attempts to prepare other members in the series failed.[7]

Phenylphosphonic dichloride reacted with II in bromobenzene to give VI[8] (infrared analysis confirmed

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(2) Postdoctorate Fellow, 1963–1964.

(3) R. S. Edmundson, *Chem. Ind.* (London), 1770 (1962).

(4) This compound may have been obtained (no analytical data) from the reaction of phenylphosphonic dichloride and II, but it now seems the previous material (m.p. 115–118°) may not have been sufficiently pure [W. W. Coover, Jr., R. L. McConnell, and M. A. McCall, *Ind. Eng. Chem.*, **52**, 409 (1960)].

(5) The procedure is similar to that used for the preparation of dihydro-1,3,2-benzodiazaphosphole 2-oxides: see R. L. Dannley and D. Zazaris, Abstracts, 142nd National Meeting of the American Chemical Society, Atlantic City, N. J., Sept., 1962, p. 62-Q.

(6) The corresponding 2-alkoxy derivatives of this system were reported to be extremely sensitive at low temperature: see W. S. Reich, *Nature*, **157**, 133 (1946).

(7) I. G. M. Campbell and J. K. Way, *J. Chem. Soc.*, 5034 (1960).

(8) Actually, VI was claimed to have been prepared from phenylphosphonic dichloride and II, but the melting point was 124–125°, identical with the melting point found for III in our work [L. Anschütz and H. Walbrecht, *J. prakt. Chem.*, **133**, 65 (1932)].

its identity) which upon standing in air was converted to III quantitatively. In view of this facile cleavage of the heterocyclic ring, further work is being carried out with other aromatic dihydroxy compounds and will be reported later.

Experimental[9]

Reaction of Phenylphosphonous Dichloride with II.—A solution of phenylphosphonous dichloride (17.9 g., 0.10 mole) in 50 ml. of bromobenzene was added dropwise with vigorous stirring at room temperature under nitrogen to a solution of catechol (11.0 g., 0.10 mole) in 350 ml. of bromobenzene. The resultant clear solution was then heated to reflux at which temperature hydrogen chloride was evolved quantitatively (0.20 mole). The mixture was refluxed for 6 hr. and the evolved hydrogen chloride was passed into water and titrated with 1.0 *N* sodium hydroxide. The clear yellow solution was distilled until nearly 300 ml. of bromobenzene was removed. The solution when cooled to 0° (nitrogen atmosphere) yielded 16.1 g. of 2-phenyl-1,3,2-benzodioxaphosphole (IV), m.p. 140–145°. It was collected by suction filtration and washed with bromobenzene. The filtrate which was concentrated to 80 ml. gave 4.0 g. of IV (total 20.1 g., 93%) which was stored in vacuum desiccator; λ_{max}^{KBr} 6.23 and 6.7 (aromatic C=C), 6.92 μ (C_6H_5–P), besides other bands for substituted benzene rings.

In order to prepare the analytical sample, 2.09 g. of IV was subjected to repeated recrystallization from methylene chloride–petroleum ether (b.p. 40–60°). In spite of efforts to preserve anhydrous conditions (although nitrogen was used it was not rigorously deoxygenated and thus could cause oxidation of IV to VI) during this process, the ester IV was converted into *o*-hydroxyphenylhydrogen phenylphosphonate (III), m.p. 123.5–124.5°; λ_{max}^{KBr} 2.95 (OH), 6.92 (C_6H_5–P), 7.8 μ (P→O); pK_a 1.90 (methanol); neut. equiv. 253.2.

Anal. Calcd. for $C_{12}H_{11}O_4P$: C, 57.3; H, 4.4; P, 12.4. Found: C, 56.8; H, 4.43; P, 12.36.

In other experiments, dropwise addition of phenylphosphonous dichloride to a stirred solution of an equimolar quantity of catechol in ether, tetrahydrofuran, or benzene containing triethylamine or pyridine at 0° in an atmosphere of nitrogen resulted in the immediate precipitation of the corresponding hydrochloride salt of the amine. Filtration of the precipitate gave a clear solution which on evaporation left an oil. This was purified by distillation, b.p. 139–141° (0.3 mm.); λ_{max}^{film} 6.92 (C_6H_5–P), 7.8 (P→O), 8.2 μ (C–O–), besides other absorption bands. Immediate elemental analysis for carbon and hydrogen corresponded to VI.

Anal. Calcd. for $C_{12}H_9O_3P$: C, 62.08; H, 3.9. Found: C, 61.80; H, 3.79.

Reaction of Phenylphosphonic Dichloride with II.—A solution of phenylphosphonic dichloride (19.5 g., 0.10 mole) in 50 ml. of bromobenzene was added dropwise under nitrogen over a period of 30 min. to a well-stirred solution of catechol (11.0 g., 0.10 mole) in 350 ml. of anhydrous bromobenzene. The mixture was boiled 6 hr., and the evolved hydrogen chloride (quantitative) was titrated. Removal of the solvent left an oil and immediate infrared analysis showed that VI was formed. Upon standing it solidified, m.p. 118–121°. Recrystallization from methylene chloride–petroleum ether or from bromobenzene gave sufficiently pure acid III, m.p. 123–124°.

Hydrolysis of *o*-Hydroxyphenylhydrogen Phenylphosphonate (III).—A mixture of 6.25 g. of III and 25 ml. of hydrochloric acid was boiled 16 hr. during which period the color of the solution turned from brown to pink. After cooling, the solution was diluted with water, neutralized with sodium bicarbonate, and extracted with ether. Evaporation of solvent gave 2.3 g. of catechol, m.p. 103.5–104.5°. The aqueous layer was acidified with hydrochloric acid and extracted with ether. From the ether extract 0.4 g. of crystalline phenylphosphonic acid (m.p. 158–160.5°) was isolated.

(9) All melting points are corrected and all boiling points are uncorrected. The microanalyses were performed by Midwest Microlab, Inc., Indianapolis, Ind.

Reactions of Aryl Grignard Reagents with 2,2,4-Trimethyl-3-hydroxy-3-pentenoic Acid β-Lactone[1]

K. DARRELL BERLIN AND M. H. COOPER[2]

Department of Chemistry, Oklahoma State University, Stillwater, Oklahoma

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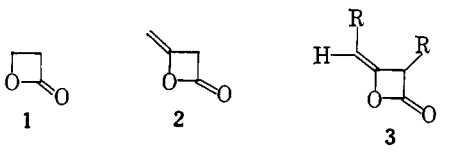
The course of reaction of β-lactone systems with organometallic reagents is not well understood and appears to depend markedly upon the β-lactone employed. β-Propiolactone (**1**) has been reported to react with phenyl Grignard reagent by acyl–oxygen ring-opening, to give phenyl vinyl ketone and 3-bromopropanoic acid.[3] Phenyllithium yields phenyl vinyl ketone and



1 **2** **3**

the diadduct, 1,1-diphenyl-1,3-propanediol.[4] However, benzyl and allyl Grignard reagents, as well as several organic cadmium reagents, have been reported[4] to produce alkyl–oxygen fission with concomitant ring opening to form the β-substituted carboxylic acids. Diketene (**2**) condenses with a variety of Grignard reagents,[5] adding 3 moles to give 1,1-disubstituted ethanol derivatives and methyl ketones. Aldoketene dimers (**3**) with Grignard reagents[6] give diadducts and the reverse aldol cleavage products of the diadducts. In all of these processes, yields of pure compounds were quite low and considerable polymeric material was reported.

We have investigated the reaction of the highly substituted β-lactone, 2,2,4-trimethyl-3-hydroxy-3-pentenoic acid β-lactone (**4**), with aryl Grignard reagents. In view of the geminal methyl groups on the α-carbon of the β-lactone **4**, we anticipated that the reaction might terminate after monoaddition to give a highly substituted β-diketone. If diaddition occurred, dehydration was not possible and a hydroxy ketone was a conceivable product, barring intervention of carbon–carbon cleavage in a retrograde aldol decomposition. The reactions were performed by normal addition of **4** in ether to the Grignard reagent followed by hydrolysis of the reaction mixture with ammonium chloride solution. Product analysis was completed by gas chromatography.

When excess phenyl Grignard reagent was allowed to react with **4** in ether, only benzophenone and diisopropyl ketone were obtained. This is analogous to the course of the same reaction with tetramethyl-1,2-cyclo-

(1) We gratefully acknowledge partial support of this research by the Research Foundation of the Oklahoma State University.

(2) Abstracted in part from the thesis of M. H. Cooper submitted in partial fulfullment of the requirements for the Master of Science degree of the Oklahoma State University, 1964.

(3) T. L. Gresham, J. E. Jansen, F. W. Shaver, and R. A. Bankert, *J. Am. Chem. Soc.*, **71**, 2807 (1949).

(4) C. G. Stuckwisch and J. V. Bailey, *J. Org. Chem.*, **28**, 2362 (1963).

(5) A. Gibaud and A. Willemart, *Bull. soc. chim. France*, 432 (1956).

(6) D. V. Nightingale and R. H. Turley, *J. Org. Chem.*, **26**, 2656 (1961).