minenickel(II) tetrafluoborate were treated with the stock solution of nitron acetate. Only with an aqueous solution of tetrapyridinecopper(II) tetrafluoborate did the test fail to give the grayish-white precipitate.

The above precipitate after being washed thoroughly, dried at 120° and analyzed by the usual microanalytical procedures was found to contain 60.02% carbon, 4.04% hydrogen and 14.39% nitrogen compared with the theoretical values for $C_{20}H_{16}N_4HBF_4$ of 59.97, 4.28 and 14.00, respectively.

The melting point of the grayish-white crystals was found to be 228–229° (uncor.) compared with values of 224.5°[4] and 227°[5] reported for the green needles.

Lange[5] observed that the light green needles were obtained only with nitron purchased from Kahlbaum prior to 1935 or from Eastman Kodak Company prior to 1940. After these dates, the nitron from each of these companies produced the grayish-white precipitate with the tetrafluoborate ion. Lange believes that the earlier samples of nitron must have contained an impurity which reacted with some material apparently always present in solutions containing tetrafluoborate ion (perhaps a product of hydrolysis) to give the green color. Crystals of nitron tetrafluoborate up to 2 cm. in length have been grown which are optically clear but possesses a light yellow to brown color.[5] The melting point observed for grayish-white solid is higher than that observed for the green needles, which supports this hypothesis.

It was of interest to learn if fused ammonium tetrafluoborate were an electrolyte. Since ammonium tetrafluoborate is reported to sublime between 230°[6] and 250°,[7] heating curves were investigated (with and without conductivity measurements) by placing about 90 g. of the purified salt in a polished copper cylindrical liner in a steel bomb. A copper thermocouple well containing a calibrated single-junction, iron-constantan thermocouple was buried in the sample and connected to a Leeds and Northrup Micromax recording potentiometer. A transition point was observed at 205 ± 3°. A transition from the rhombic to an isotropic crystalline state has been observed at 236° using a micro sample on a hot stage microscope.[8] The latter value is above the lower value reported for the sublimation temperature.[6] If the rate of heating were too fast, greater error in ascertaining the transition temperature would be encountered using a micro sample than one of 90 g.

The triple point of ammonium tetrafluoborate was observed at 487 ± 3°. There was an excellent correlation between the break in the heating curve and the sudden increase in conductivity.

A faint odor of ammonia was detected upon opening the bomb after the thermal data were obtained. The salt was a hard, fused, white mass which was tinged very slightly with a small amount of a very pale blue color at the interface of the salt and the copper liner. In the course of this investigation, it was observed also that fused ammonium tetrafluoborate attacks zirconia and Pyrex glass but not silver or platinum.

Saturated solutions of ammonium tetrafluoborate in purified acetone, benzene, chloroform, ethanol, pyridine and tetrachloroethane were prepared and allowed to stand in closed vessels at room temperature for two weeks. Fifty-milliliter samples of the supernatant solutions were allowed to evaporate in tared evaporating dishes and the weight of the ammonium tetrafluoborate residue ascertained. It was found that the solubility of ammonium tetrafluoborate in each of the above solvents (except ethanol) is less than 2 mg. per 100 ml. of solvent. In contradiction to the report of Berzelius[9] that ammonium tetrafluoborate is *freely* soluble in ethanol, it was found that the solubility is 0.7 g. per 100 g. of ethanol. Ethanol and aqueous solutions of ammonium tetrafluoborate are electrolytes.

---

(4) E. Wilke-Dörfurt and G. Balz, *Z. anorg. Chem.*, **159**, 197 (1927).

(5) W. Lange, Procter and Gamble Co., Ivorydale, Ohio, private communication.

(6) G. H. Curtis, *Iron Age*, **155**, 54 (1945).

(7) W. E. White, (to Aluminum Company of America), U. S. Patent 2,403,148 (July 2, 1946).

(8) D. Vörlander, J. Hollatz and J. Fischer, *Ber.*, **65B**, 535 (1932).

(9) J. J. Berzelius, *Ann. physik. Chem.*, **78**, 113 (1824); *Stockholm Acad. Handl.*, 284 (1823).

DEPARTMENT OF CHEMISTRY
UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

RECEIVED JUNE 25, 1951

The Reaction of Anilidophosphoric Chlorides with Aryl Grignard Reagents[1]

BY D. C. MORRISON

These reactions were studied as a possible approach to the synthesis of aromatic phosphonic acids, $ArPO(OH)_2$ from phosphorus oxychloride as starting material. The object of these preparations was to obtain the phosphonic acids in radioactive form from phosphorus oxychloride containing P^{32}.[2] It was then desired to observe the distribution of these compounds in rats, especially in animals bearing tumors in the hope that some localization in the latter would occur.

These syntheses are analogous to the phosphinic acid preparations of Michaelis and Wegner[3] and of Kosolapoff,[4] where a Grignard reagent is allowed to react with a substituted monoamidophosphoric chloride. The amide groups replace one chlorine atom of phosphorus oxychloride leaving the other two chlorines free to react with the reagent. The product is a substituted amide of a phosphinic acid and can be hydrolyzed to the free acid. These workers employed piperidine and diethylamine, respectively, as the amines used to form the amidochlorides.

In the present work, the amidochlorides were derived from aniline and the type reaction was extended to the use of a substituted diamidophosphoric monochloride. The action of arylmagnesium bromides on monoanilido phosphoric dichlorides gives very poor yields of diaryl phosphinic anilides while the interaction of the Grignards and dianilidophosphoric monochloride gives fair yields of aryl phosphonic dianilides. Hydrolysis of these anilides furnishes the corresponding phosphinic and phosphonic acids. The latter reaction enables phosphonic acids to be prepared from phosphorus oxychloride.

The reaction of dianilidophosphoric chloride with the reagent apparently proceeds according to the equation

$$(C_6H_5NH)_2POCl + ArMgX \longrightarrow ArPO(NHC_6H_5)_2 + MgXCl$$

An over-all yield of 40% of benzenephosphonic acid dianilide (based on $POCl_3$) in the two-step process was obtained with the phenyl Grignard. A considerable excess of the Grignard reagent is

---

(1) The work described in this paper was sponsored by the Atomic Energy Commission. It was supported in part by a grant from the Henry, Laura and Irene B. Dernham Fund of the American Cancer Society and the Christine Breon Fund.

(2) Axelrod, *J. Biol. Chem.*, **176**, 295 (1948).

(3) Michaelis and Wegner, *Ber.*, **48**, 316 (1915).

(4) Kosolapoff, THIS JOURNAL, **71**, 369 (1949).

necessary for success of the reaction. Proper treatment of the product gives a crystalline precipitate of the phosphonic dianilide. This could be hydrolyzed by refluxing with concentrated hydrochloric acid to the free phosphonic acid.

The analogous action of arylmagnesium halides on monoanilidophosphoric dichloride, C_6H_5NH-$POCl_2$, produces little of the desired product formed by Cl replacement, the phosphinic monoanilides, $Ar_2PONHC_6H_5$. Among the reaction products the previously mentioned phosphonic acid dianilides are usually found. These are believed to result by disproportionation of the monoanilidochloride forming the dianilidochloride and subsequent reaction with the arylmagnesium halides. The mixtures of phosphonic dianilides and phosphinic monoanilides are very difficult to separate and only the diphenylphosphinic acid anilide was obtained in pure condition. However, after hydrolysis with hydrochloric acid, the mixture of phosphonic and phosphinic acids can be more readily separated.

As a control experiment, the interaction of phenylmagnesium bromide with phosphoric acid trianilide was studied, but 85% of the latter was recovered unchanged after several hours of refluxing in ether solution.

Experimental

The dianilidophosphoric chloride was obtained by the method of Cook, *et al.*[5]

It was found, however, that if the ether solution of reactants is dilute enough, most of the product remains in solution and after filtration can be added directly to the Grignard solution.

Preparation of Benzenephosphonic Acid Dianilide.—The following preparation of benzenephosphonic dianilide illustrates the general method used for the phosphonic dianilides.

The reaction product from 18.2 ml. (0.2 mole) of aniline and 9.2 ml. (0.1 mole) of phosphorus oxychloride in 400 ml. of anhydrous ether, after 14 hours in the cold, was filtered and the filter residue washed with ether. The combined filtrates were added dropwise at room temperature to phenylmagnesium bromide from 30 ml. (0.285 mole) of bromobenzene and excess magnesium. A white transient precipitate forms during this addition but always dissolves if sufficient Grignard reagent is used. The solution was then refluxed for 1.5 hours, cooled and hydrolyzed by ice and hydrochloric acid. The ether layer (usually containing some suspended product) was washed with sodium hydroxide solution and with water. It was diluted with 250 ml. more ether and left in an ice-bath for several hours. The collected and washed product weighed 5.1 g. The filtrate gave 1.1 g. in two crops on further processing. The brown resinous residues, though no crystalline anilide can be obtained from them, will furnish some phosphonic acid on hydrolysis with hydrochloric acid. An exactly similar run employing 20 ml. (0.191 mole) instead of 30 ml. of bromobenzene gave a total yield of 3.8 g. of phosphonic dianilide.

Other preparations of aryl phosphonic dianilides were similar and likewise gave uncrystallizable residues, hydrolysis of which gave additional amounts of the desired aromatic phosphonic acid.

An alternative method of reaction consists of adding the powdered dianilidophosphoric monochloride in portions to the Grignard solution at room temperature and then refluxing and processing as before. Yields by this process are inferior to those obtained by the first process. Results are given in the table using the first method. The yield of *o*-tolylphosphonic dianilide (based on dianilidophosphoric chloride) by the second method was 36.7%.

No report of *p*-anisyl phosphonic dianilide was found in the literature. The compound was recrystallized from acetone–ether.

Anal. Calcd. for $C_{19}H_{19}N_2PO_2$: C, 67.45; H, 5.62. Found: C, 67.48; H, 5.85.

Hydrolysis of *p*-Tolylphosphonic Dianilide.—This is given as representative of the hydrolysis reactions. A mixture of 0.73 g. of the dianilide and 50 ml. of concentrated hydrochloric acid was refluxed for one hour and then left overnight on the steam-bath. The dry residue was repeatedly ground and extracted with boiling ether. Filtration and evaporation of the combined extracts left 0.349 g. of *p*-tolyl phosphonic acid; yield 89.5%. This was recrystallized from ether–benzene or benzene alone; m.p. 187.5–188.5°, lit. 189°.[6,7]

Preparation of Diphenylphosphinic Anilide.—The monoanilidophosphoric dichloride used in this experiment was produced by the method of Caven.[8]

The monoanilidophosphoric chloride in powdered form (2.5 g., 0.012 mole) was added gradually to the phenylmagnesium bromide from 8.5 ml. (0.081 mole) of bromobenzene and 1.8 g. (0.075 mole) of magnesium. This solution was refluxed 1.25 hours and then cooled and hydrolyzed. The washed ether layer was concentrated for crystallization; yield 0.32 g. of impure material, m.p. 199–206°. After four recrystallizations from benzene this had m.p. 231–233°. Much intractable residue was left. No simple anilides of diarylphosphinic acids appear to be described in the literature, though some diarylthiophosphinic anilides are known.

Anal. Calcd. for $C_{18}H_{16}PON$: C, 73.72; H, 5.46. Found: C, 73.31; H, 5.67.

Hydrolysis of Diphenylphosphinic Anilide.—This anilide was hydrolyzed by concentrated hydrochloric acid similarly to the phosphonic acid dianilide. The diphenyl phosphinic acid formed was recrystallized from water; m.p. 191–192°. With other aryl Grignards and the monoanilidophosphoric dichloride only mixtures were obtained. Some phosphinic acids could be obtained from these by concentrated hydrochloric acid hydrolysis. The phosphonic and phosphinic acids were best separated by taking advantage of the greater water solubility of the former or the greater benzene solubility of the latter.

With the appearance of the article by Kosolapoff[9] describing a method for phosphonic acids utilizing diethylamidophosphoric dichloride, $(C_2H_5)_2NPOCl_2$, a few runs by this process were tried using phenylmagnesium bromide. The process appears to give results comparable to the present method. Both benzenephosphonic and diphenylphosphinic acids were obtained, the relative amounts depending upon the reaction time and temperature.

TABLE I

PHOSPHONIC DIANILIDES $ArPO(NHC_6H_5)_2$

Ar radical	M.p., °C. lit.[a]	M.p., °C. uncor. found	Yield/$POCl_3$, %
Phenyl	211	211.5	40.3
o-Tolyl	234	230.5	..
p-Tolyl	209	207.5–208.5	21.7
p-Anisyl	...	210	18.1

[a] Michaelis, *Ann.*, **293**, 193 (1896).

Acknowledgment.—The author is grateful for advice received during the course of the work from Drs. J. G. Hamilton, K. G. Scott, E. Hoerger and W. D. Kumler

CROCKER LABORATORY, UNIVERSITY OF CALIFORNIA
DIVISION OF RADIOLOGY, UNIVERSITY OF CALIFORNIA
MEDICAL SCHOOL
BERKELEY AND SAN FRANCISCO, CALIFORNIA

RECEIVED JUNE 26, 1951

---

(5) H. G. Cook, J. D. Ilett, B. C. Saunders, G. J. Stacey, H. G. Watson, I. G. E. Wilding and S. J. Woodcock, *J. Chem. Soc.*, 2921 (1949).

(6) Michaelis and Panek, *Ber.*, **13**, 653 (1880).

(7) Preliminary work showed that aromatic phosphonic acids in the form of their diphenyl esters were formed to a moderate extent by rapidly adding (two to five min.) an aryl Grignard solution to ethereal diphenyl chlorophosphate, $(C_6H_5O)_2POCl$, cooled in an ice-bath. The mixture was poured at once into ice and hydrochloric acid, affording a mixture from which the phosphonic acids could be isolated by prolonged alkaline hydrolysis.

(8) Caven, *J. Chem. Soc.*, **81**, 1362 (1902).

(9) Kosolapoff, THIS JOURNAL, **72**, 5508 (1950).