TABLE II

Name	Color	M.p., °C.	Yield, %	Formula	As analyses, %[8]	
					Calcd.	Found
4-Hydroxyquinoline-6-arsonic acid	White	>320	29.7	$C_9H_8O_4NAs$	27.84	27.97
4-Hydroxy-2-methylquinoline-6-arsonic acid	White	>320	31.6	$C_{10}H_{10}O_4NAs$	26.46	26.48
4-Hydroxyquinazoline-5-arsonic acid	White	>320	48.3	$C_8H_7O_4N_2As$	27.74	27.89
4-Hydroxyquinazoline-6-arsonic acid	White	>320	22.2	$C_8H_7O_4N_2As$	27.74	27.82
4-Hydroxyquinazoline-7-arsonic acid	White	>320	42.2	$C_8H_7O_4N_2As$	27.74	27.70
6-Arsenoso-4-hydroxyquinoline	White	317	53.2	$C_9H_6O_2NAs \cdot H_2O$	29.60	29.90
6-Arsenoso-4-hydroxy-2-methylquinoline	White	310	75.1	$C_{10}H_8O_2NAs \cdot H_2O$	27.97	27.80
7-Arsenoso-4-hydroxyquinazoline	White	295	69.1	$C_8H_5O_2N_2As \cdot H_2O$	29.49	29.41
4-(4′-Arsonoanilino)-8-nitroquinoline	Yellow	288	30.2	$C_{15}H_{12}O_5N_3As$	19.25	19.08
4-(4′-Arsonoanilino)-2-methylquinoline	Light gray	285	33.2	$C_{16}H_{14}O_3N_2As$	20.95	21.06
4-(4′-Arsonoanilino)-2-methyl-6-nitroquinoline	Yellow	288	50.1	$C_{16}H_{14}O_5N_3As$	18.58	18.39
4-(4′-Arsonoanilino)-quinazoline	Light gray	>320	58.0	$C_{14}H_{12}O_3N_3As$	21.71	21.66

fully neutralized with calcium carbonate. The mixture was then heated to boiling and filtered through a hot-water funnel. The undissolved portion was repeatedly extracted with boiling water. From the combined filtrate and washings the amino-4-hydroxyquinazoline crystallized in long white needles on cooling.

4-Hydroxyquinolinearsonic Acids and 4-Hydroxyquinazolinearsonic Acids.—A solution of 3.5 g. of the amine in 35 ml. of 2 *N* hydrochloric acid was cooled to a temperature below 5° and diazotized with sodium nitrite solution. The diazonium solution was poured with mechanical stirring into a water solution composed of sodium arsenite (5 g.), sodium hydroxide (3 g.) and a few crystals of copper sulfate. After being stirred for 2 hours and having stood overnight, the mixture was warmed at 80° for 10 minutes, and filtered to remove the dark tarry impurity. The filtrate was neutralized with hydrochloric acid, treated with charcoal, filtered and the filtrate was made acidic to congo red paper with hydrochloric acid. The crude arsonic acid separated as white needles and was purified by dissolving in 5% sodium bicarbonate solution and reprecipitating with the addition of 1 *N* hydrochloric acid until acid to congo red paper.

Arsenoso-4-hydroxyquinolines and Arsenoso-4-hydroxyquinazolines.—One gram of the pure arsonic acid was dissolved or suspended in 35 ml. of 1.5 *N* hydrochloric acid containing a trace of potassium iodide. The solution was cooled in an ice-bath and saturated with sulfur dioxide for two hours. After remaining in a refrigerator overnight, the solution was neutralized with concd. ammonium hydroxide. The white precipitate was filtered and dissolved in 1 *N* sodium hydroxide. The arsenoso derivative was isolated as white needles by passing carbon dioxide into the alkaline solution.

Condensation of 4-Chloroquinolines and 4-Chloroquinazolines with *p*-Arsanilic Acid.—The 4-chloroquinoline or the 4-chloroquinazoline (0.005 mole) and *p*-arsanilic acid (0.0045 mole) were dissolved in 5 ml. of dimethylformamide at 50°. The solution was heated at 80–90° for 3–4 hours. A solid product usually separated after 2–3 hours of heating. A less pure product could be recovered from the mother liquor by neutralizing with ammonium hydroxide. The crude product was purified by dissolving in hot 5% sodium bicarbonate solution and reprecipitating with the addition of 2 *N* hydrochloric acid. The condensation products are hygroscopic.

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(8) Cislak and Hamilton, THIS JOURNAL, **52**, 638 (1930).

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Attempted Preparation of Thorium(III) Fluoride[1a,b]

BY JAMES C. WARF[2]

An attempt to prepare a lower fluoride of thorium was undertaken to aid in clarifying the role of thorium as an actinide element. While the presence of an f electron in thorium is not essential to the general actinide hypothesis,[3] a trifluoride, isostructural with uranium(III) fluoride, would be predicted on the basis of an electron in the 5 f orbital, paralleling the cerium(III) ion with a 4 f electron.

The method employed involved the reduction of thorium(IV) fluoride by thorium metal, following a technique successful in the analogous synthesis of uranium(III) fluoride.[4] The thorium tetrafluoride, prepared by hydrofluorination of the oxide, was analyzed by pyrohydrolysis.[5] Calcd. for ThF_4: Th, 75.33; F, 24.67. Found: Th, 75.37; F, 24.60. Its freezing point was 1068 ± 2°. The thorium metal, prepared by bomb reduction, contained approximately 0.1% ThO_2 and 0.2% zinc.

Two attempts to carry out the reaction

$$Th + 3ThF_4 = 4ThF_3$$

were made using platinum boats. Thorium (1 g.) was converted to its hydride by heating to 750° in hydrogen (purified over uranium at 700°), and ground intimately with the stoichiometric quantity of thorium tetrafluoride. The mixture in a platinum boat was heated in a quartz tube by means of a platinum-wound resistance furnace. An atmosphere of helium purified over uranium powder at 800° was maintained at all times. A temperature of 1175° was reached in the first run, and 1280° in the second. In both cases the platinum boats were attacked, being reduced to metallic globules of a thorium–platinum alloy in the second case. The gray residues were examined by X-ray diffraction, and all the lines in both cases could be accounted for by the presence of Th, ThF_4 and ThH_2.

Another run was made as above using a boat fashioned from 1-mm. rolled thorium sheet. A temperature of 1290° was maintained 30 minutes. Practically all of the thorium tetrafluoride had volatilized away, and the boat had been etched. An X-ray diffraction pattern of the dark residue could be interpreted on the basis of the Th, ThF_4 and ThO_2.

Finally, two bombs were fabricated from thorium metal; each was tapped, and sealed with a threaded thorium plug. The first was charged with 10 g. of intimately ground stoichiometric Th–ThF_4 mixture, and heated to 1600° in vacuum in an induction furnace. The bomb was sawed open lengthwise, which revealed that the thorium powder had settled to the bottom, and that the inside wall was attacked. X-Ray analysis showed Th and ThF_4 only. The second bomb was filled with thorium tetrafluoride alone,

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(1) (a) Based on work done in 1946–1947, Ames Laboratory of the Atomic Energy Commission, declassified as AECD-2654 on July 14, 1949. (b) Presented at the Chicago, Illinois, Meeting of the American Chemical Society, September, 1950.

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(3) See G. T. Seaborg, "The Transuranium Elements," "NNES," Div. IV, Vol. 14 B, McGraw-Hill Book Co., Inc., New York, N. Y., 1949, pp. 1492–1524.

(4) J. Warf, Plutonium Project Report CC-1525 (March 14, 1944) (AECD-2523); also J. J. Katz and E. Rabinowitch, "The Chemistry of Uranium," "NNES," Div. VIII, Vol. 5, McGraw-Hill Book Co., Inc., New York, N. Y., 1951, p. 349 ff.

(5) J. Warf, "Analytical Chemistry of the Manhattan Project," "NNES," Div. VIII, Vol. 1, McGraw-Hill Book Co., Inc., New York, N. Y., 1950, p. 729 ff.

heated to 1600°, quenched in mercury, and sawed open. The walls had been attacked somewhat, and in the interior of the solidified thorium tetrafluoride a few gray areas of finely divided thorium metal were found.

No evidence for the existence of a lower fluoride of thorium was found. There was some indication however, that thorium dissolves slightly in its fluoride at high temperature, a behavior similar to that of uranium in its tribromide,[6] the alkaline earth metals in their halides,[7] or cerium in its chloride.[8]

Mention should be made of the preparation of thorium(III) and thorium(II) halides[9–11] prepared by reduction of the tetrahalides, especially the iodide, by the metal. These lower iodides were observed to parallel the corresponding halides of zirconium and hafnium in physical and chemical properties. Similarly a brown thorium(III) and silvery thorium(II) sulfide are known[12] whose properties indicate the presence of no f electrons.

[6] C. D. Thurmond, Plutonium Project Report CC-2522 (Dec. 20, 1944).

[7] D. D. Cubicciotti and C. D. Thurmond, THIS JOURNAL, **71**, 2149 (1949).

[8] D. D. Cubicciotti, *ibid.*, **71**, 4119 (1949).

[9] E. Hayek and Th. Rehner, *Experientia*, **5**, 114 (1949).

[10] E. Hayek, Th. Rehner, and A. Frank, *Monatsh.*, **82**, 575 (1951).

[11] J. S. Anderson and R. W. D'Eye, *J. Chem. Soc.*, (Suppl. Issue No. 2), S 244 (1949).

[12] E. D. Eastman, *et al.*, THIS JOURNAL, **72**, 4019 (1950).

CONTRIBUTION NO. 52 FROM THE
INSTITUTE FOR ATOMIC RESEARCH
IOWA STATE COLLEGE
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COMMUNICATIONS TO THE EDITOR

THE REACTION OF DI-ISOPROPYL FLUOROPHOSPHATE WITH TYROSINE

Sir:

We have been engaged for some time on a comparative study of the action of di-isopropyl fluorophosphate (DFP) and di-isopropyl chlorophosphate (DClP) on amino-acids under "physiological" conditions in the hope of finding some clear-cut difference which might parallel the marked difference between the biochemical activities of these two compounds[1] (DFP is toxic and inhibits cholinesterase and other enzymes whereas DClP is not markedly toxic). The appearance of the recent paper of Wagner-Jauregg, O'Neill and Summerson[2] on a similar subject prompts us to make this preliminary communication of our positive findings.

Wagner-Jauregg, O'Neill and Summerson[2] studied the action of non-polar DFP and DClP on a number of amino-acid esters and amines in that DClP is the more reactive solution and uniformly observed the latter to be the more reactive[3]; they were unable to phosphorylate amino-acids in slightly alkaline aqueous media with DFP although they observed, but do not describe in detail, reaction between DFP and phenol in aqueous potassium carbonate.

We have been more fortunate and have been able to demonstrate a marked difference in the reactivity of DFP and DClP toward tyrosine. Using 0.02 *M* halophosphate and 0.005 *M* tyrosine in 0.08 *M* sodium bicarbonate at 38° and following the disappearance of free phenolic hydroxyl by the colorimetric method of Thomas[4,5] we obtained the following results

Time hr.	3	4	9	24
% Reaction of (DFP)	43	49	52	56
phenolic OH. (DClP)	–	7	10	8

Clearly DFP reacts readily, under these conditions, with the phenolic hydroxyl group of tyrosine whereas DClP does not. The reaction product from DFP, O-di-isopropylphosphoryl-tyrosine (I), was isolated from the reaction mixture, by chromatography on deactivated charcoal,[6] as needles, m.p. 158–160° (dec.), from aqueous acetone (Found N, 4.1; $C_{15}H_{24}O_6NP$ requires N, 4.1), and, more easily, as its N-2,4-dinitrophenyl derivative, needles, m.p. 159–160°, from methanol (Found C, 49.4; H, 5.1; N, 7.9; $C_{21}H_{26}O_{11}N_3P$ requires C, 49.3; H, 5.1; N, 8.2). The structure of (I) was confirmed by its chromatographic recognition in the hydrogenation product of its amorphous *p*-bromocarbobenzoxy derivative (Found C, 49.7; H, 5.0; N, 2.8; $C_{23}H_{29}O_2NBrP$ requires C, 49.5; H, 5.2; N, 2.5), obtained by treating DFP similarly with N-*p*-bromocarbobenzoxytyrosine, m.p. 156–157° (Found: C, 51.7; H, 4.1; N, 3.4; $C_{11}H_{16}O_5NBr$ requires C, 51.8; H, 4.1; N, 3.55).

This marked difference in the chemical behavior of the two halophosphates suggests, although it does not prove, that the reaction of DFP with cholinesterase and other sensitive enzymes involves reaction at a tyrosine side-chain; it is of interest that chymotrypsin, which is sensitive to DFP, has been

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[1] E. C. Webb, *Biochem. Soc. Symp.*, **2**, 50 (1948); H. G. Cook, B. C. Saunders and F. E. Smith, *J. Chem. Soc.*, 635 (1949).

[2] T. Wagner-Jauregg, J. J. O'Neill and W. H. Summerson, THIS JOURNAL, **73**, 5202 (1951).

[3] *Cf.* B. C. Saunders and G. J. Stacey, *J. Chem. Soc.*, 695 (1948).

[4] L. E. Thomas, *Arch. Biochem.*, **5**, 175 (1944).

[5] The absorptiometer used was purchased with the aid of a grant from the Central Research Fund of the University of London for which we express our thanks.

[6] Schramm and J. Primosigh, *Ber.*, **76**, 373 (1943).