1.2×10^4 c./sec./mg., respectively; that of the ring-labeled compound was 235 c./sec./mg.[8]

Experimental

2,4-Dichlorophenoxyacetic Acid from Bromoacetic Acid.—From the reaction of 139 mg. of bromoacetic acid with a fifteen-fold excess of 2,4-dichlorophenol in sodium hydroxide solution, 210 mg. (95%) of 2,4-D, m.p. 138.5–139.5°, was isolated.

Conversion of Sodium Acetate to 2,4-D.—Thirty-seven and one-half milligrams (1 millimole) of anhydrous hydrogen chloride, 7.9 mg. (0.1 mM.) of freshly distilled acetyl chloride and 192 mg. (1.2 mM.) of bromine were distilled under high vacuum into a 25-ml. r.b. flask chilled in liquid nitrogen containing 82 mg. of sodium acetate and 1.5 mg. of red phosphorus. The flask, sealed in vacuum, was immersed in a boiling water-bath until the bromine color had nearly disappeared (1 to 5 hours). The product was dissolved in 1 cc. of water and converted to 2,4-D as already described. Consistent yields of 75–80% from sodium acetate were obtained. Omission of the hydrogen chloride and acetyl chloride from the bromination mixture lowered the over-all yield to 40–63%.

Aniline.—Ten grams of sodium azide was added over a period of 50 minutes to a rapidly stirred mixture of 12.2 g. of benzoic acid, 80 ml. of chloroform and 40 ml. of 100% sulfuric acid maintained at 40°. When the evolution of nitrogen had ceased, the reaction mixture was diluted with water and made alkaline; extraction with ether and treatment with hydrogen chloride afforded 11.8 (91%) of aniline hydrochloride; m.p. 194.5°.

Phenol.—Diazotization of 13.00 g. of aniline hydrochloride followed by hydrolysis of the diazonium salt gave 7.04 g. (75%) phenol, b.p. 95° (25 mm.).

Phenoxyacetic Acid.—Methyl phenoxyacetate, prepared from sodium phenoxide and methyl bromoacetate, was hydrolyzed in dilute sodium hydroxide solution, which on acidification yielded phenoxyacetic acid, m.p. 97–98°[9] in 90% yield.

2,4-Dichlorophenoxyacetic Acid.—The temperature of a mixture of 1.74 g. of phenoxyacetic acid, 0.39 g. of sulfuryl chloride and 7 ml. of glacial acetic acid was slowly raised from 0 to 75° and then maintained at the latter temperature until gas evolution ceased. Dilution of the reaction mixture with water and crystallization of the precipitate from benzene afforded 1.87 g. (74%) 2,4-D, m.p. 137–138°.

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[8] All samples were converted to barium carbonate and counted using the upper shelf of a Tracerlab lead pig and a Tracerlab TGC-2 Geiger–Müller tube with a 1.0 mg./cm.² mica window.

[9] R. Fusco and F. Mazzucchi, *Gazz. chim. ital.*, **71**, 406 (1941); *C. A.*, **37**, 121 (1943).

BOSTON 10, MASS.
RECEIVED JULY 18, 1951

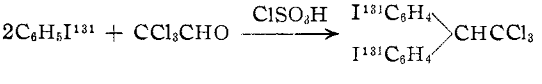
Synthesis of Radioactive Iodine[131] Analog of DDT[1]

BY JENS A. JENSEN AND GEORGE W. PEARCE

The iodine^{131} analog, 1,1,1-trichloro-2,2-bis-(*p*-iodo^{131}-phenyl)-ethane, of DDT has been prepared by the steps

$$C_6H_5NH_2 + HNO_2 \xrightarrow[NaNO_2]{HCl} C_6H_5N_2Cl \tag{1}$$

$$C_6H_5N_2Cl + NaI^{131} \longrightarrow C_6H_5I^{131} \tag{2}$$



$$2C_6H_5I^{131} + CCl_3CHO \xrightarrow{ClSO_3H} (I^{131}C_6H_4)_2{>}CHCCl_3 \tag{3}$$

The method of Lucas and Kennedy[2] was used for the first two steps. Twenty-two millimoles of aniline was converted to 15 millimoles of iodobenzene, using 22 millimoles of NaI in which 25 millicuries of NaI^{131} was incorporated. The steam distilled product plus 6 millimoles of inactive iodobenzene was condensed with 8 millimoles of chloral using chlorosulfonic acid as condensing agent. Recrystallization of the crude product from 1 to 1 acetone–alcohol gave 1.42 g. (2.6 millimoles) of DI*DT, m.p. 173–174°, 25% yield based on iodobenzene. Activity recovery was 22.4% corrected for decay, but not for inactive iodobenzene added. Specific activity was 2.5 microcuries per milligram. The synthesis can be completed in 2–3 days.[3]

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[1] From the Technical Development Branch, Communicable Disease Center, U. S. Public Health Service, Federal Security Agency, Savannah, Georgia.

[2] "Organic Syntheses," Coll. Vol. II, John Wiley and Sons, Inc., New York, N. Y., 1946, p. 351.

[3] For a detailed description order Document 3488 from American Documentation Institute, 1719 N Street, N. W., Washington 6, D. C., remitting $1.00 for microfilm (images 1 inch high on standard 35-mm. motion picture film) or $1.20 for photocopies (6 × 8 inches) readable without optical aid.

TECHNICAL DEVELOPMENT BRANCH
SAVANNAH, GEORGIA
RECEIVED AUGUST 16, 1951

A Preparation of C^{14} Labeled Isopropyl N-Phenylcarbamate[1,2]

BY ALBERT V. LOGAN AND JOSEPH MURRAY[2]

The preparation of C^{14} labeled isopropyl N-phenylcarbamate (IPC) was undertaken as the initial phase of a plan to study the mode of action of the compound upon many weedy annual grasses. The experimental procedures described here were adopted as the most economical and best suited for the preparation of the IPC. Plant studies are underway at the present time utilizing the radioactive compound.[3]

Experimental

Acetic acid labeled with C^{14} in the carbonyl group was prepared by a modification of the Grignard method used by Van Bruggen.[4] The yields on two separate runs were 69.1 and 77.3% based on the $BaC^{14}O_3$ used. The radioactive barium acetate (254 mg., 0.995 millimole) obtained from the neutralization of the acetic acid was placed in a combustion tube backed by an equal amount of inactive barium acetate in a separate boat. Pyrolysis was carried out under vacuum at 500°.[5] The resulting carbonyl labeled acetone was collected in a liquid nitrogen cooled trap. The acetone was redistilled and reduced by the action of lithium aluminum hydride[6] in ether solution. The labeled isopropyl alcohol was dried over recalcined calcium oxide and vacuum transferred to a dry reaction vessel.

The IPC was prepared by heating 0.3 ml. of phenyl isocyanate with the isopropyl alcohol at 80° for three hours. The product was crystallized from boiling heptane; 160 mg. of IPC, m.p. 84–85°, was obtained. A second crop of crystals 164 mg., m.p. 79–80°, was obtained from the mother liquor. The yield of pure compound was 38% based upon $BaC^{14}O_3$ used and barium acetate added. The over-all

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[1] Published with the approval of the Monograph Publications Committee, Oregon State College, as Research Paper No. 191, School of Science, Department of Chemistry.

[2] This note is based on a thesis submitted by Joseph Murray in partial fulfillment of the requirements for the degree of Master of Science at Oregon State College, June, 1950.

[3] For detailed experimental description order Document 3564 from American Documentation Institute, 1719 N Street, N. W., Washington 6, D. C., remitting $1.00 for microfilm (images 1 inch high on standard 35-mm. motion picture film) or $1.00 for photocopies (6 × 8 inches) readable without optical aid.

[4] J. T. Van Bruggen, C. K. Claycomb and T. T. Hutchens, *Nucleonics*, **7**, 45 (1950).

[5] A. V. Grosse and S. Weinhouse, *Science*, **104**, 402 (1946).

[6] R. F. Nystrom and W. G. Brown, THIS JOURNAL, **69**, 1197 (1947).

yield, including the less pure compound, was approximately 77% calculated on the same basis.

Both samples of IPC were counted as $BaCO_3$, corrected for self absorption. The first sample (m.p. 84–85°) showed an activity of 7.78 × 10^5 counts/min./mg. The second sample (m.p. 79–80°) showed an activity of 6.69 × 10^5 counts/min./mg.

Acknowledgment.—Funds for the purchase of the isotopes used were provided by the General Research Council, Oregon State College.

DEPARTMENT OF CHEMISTRY
OREGON STATE COLLEGE
CORVALLIS, OREGON

RECEIVED JANUARY 28, 1952

Synthesis of Carbon-14 Labeled Urea[1,2]

BY ALBERT L. MYERSON[3]

Carbon-14 labeled urea was conveniently synthesized in small quantities through the direct combination of carbon dioxide and ammonia at room temperature, to form ammonium carbamate. The latter compound was sealed in a capillary and heated to 135°, to form urea. The first reaction is quantitative, while the second reaches equilibrium at 40% conversion.

This synthesis constitutes one of the simplest operations by which radioactive carbon dioxide can be incorporated into an organic compound on a micro scale. The preparation of urea from carbon dioxide and ammonia was originally reported[4] using 10 to 20 g. quantities, where maximum conversion was obtained by heating 16 g. of carbamate in a volume of 37 cc. In the present work, two radioactive syntheses were carried out employing 30 and 300 mg. of barium carbonate, respectively, the total activity in each case being 0.35 mc. The m.p. of the white crystals of urea was 131.5° without recrystallization, compared to reported values of 132 to 133°.

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[1] For experimental details of this synthesis order Document 3493 from American Documentation Institute, 1719 N Street, N. W., Washington 6, D. C., remitting $1.00 for microfilm (images 1 inch high on standard 35-mm. motion picture film) or $1.00 for photocopies (6 × 8 inches) readable without optical aid.

[2] Reported at a symposium "Isotopes and Medicine," at the University of Wisconsin, Madison, Wis., in September, 1948.

[3] The Franklin Institute, Philadelphia, Pa.

[4] F. Fichter and B. Becker, *Ber.*, **44**, 3473 (1911).

DEPARTMENT OF CHEMISTRY
UNIVERSITY OF WISCONSIN
MADISON, WIS.

RECEIVED DECEMBER 22, 1951

A Synthesis of Formaldehyde-C^{14} [1]

BY A. R. JONES AND W. J. SKRABA

Methanol-C^{14} has been converted to formaldehyde-C^{14} by the chlorination of methyl-C^{14} acetate followed by hydrolysis of the chlorinated product. The reactions, first studied by Henry[2] and Michael[3] gave a 60% yield of product when isolated with the aid of inert formaldehyde.[4]

Since the hydrolysis of carefully purified chloromethyl acetate[5] gave a quantitative yield of formaldehyde, efforts to improve the over-all yield of formaldehyde from methanol were confined to the acetylation and chlorination steps. The over-all yield was not improved by conducting the acetylation at atmospheric pressure under reflux, and was considerably decreased when a mole proportion of pyridine was added before acetylation.

The chlorination yield was not affected by ultraviolet irradiation of the reaction mixture, nor by varying the reaction temperature from 20–60°. The over-all yields of formaldehyde were best when a slightly less than molar proportion of chlorine was used.

To avoid the competing chlorination of the methyl group of the acetate moiety, the methyl esters of chlorocarbonic, oxalic, chloroacetic, trichloroacetic, bromoacetic, benzoic and *p*-toluenesulfonic acids were chlorinated. Poor yields were obtained in all cases. A mixture of methyl bromoacetate and bromine was decolorized after two days at room temperature, but hydrolysis of the product yielded only a small amount of formaldehyde.[6]

Experimental

Acetylation.—Methanol-C^{14}, 332 mg., 10.4 mmoles, 21.43 microcuries (2.06 microcuries/mmole) and acetyl chloride, 816 mg., 10.4 mmoles, were consecutively high-vacuum distilled[7] into the liquid nitrogen cooled nipple of a one-liter bulb. The reaction vessel was isolated from the manifold and the frozen reagents were warmed to 40–50° for 45 minutes with a heat lamp. The contents were then frozen into the nipple by immersing the latter in liquid nitrogen. To remove a part of the hydrogen chloride, the nipple was warmed to −80° (Dry Ice and trichloroethylene) and the bulb was evacuated to 10^{-4} mm.

Chlorination.—The Dry Ice–trichloroethylene-bath was replaced by liquid nitrogen and 1400 ml. (27° and 12.9 cm. pressure), 9.6 mmoles, of commercial chlorine gas, from which impurities non-condensable with liquid nitrogen had been removed, was distilled into the reaction bulb. The pressure of chlorine was determined with a manometer in which the mercury was protected by a layer of sulfuric acid. The bulb was isolated from the manifold and the contents were allowed to warm to room temperature in subdued light. Loss of the chlorine color began while the reactants were still quite cold. The contents of the bulb were recondensed and allowed to return to room temperature several times to ensure thorough mixing. When all trace of chlorine color had disappeared, one to two hours, part of the hydrogen chloride was removed as described above.[8]

Hydrolysis.—A 25-ml. hydrolysis bulb containing 3 ml. of distilled water and equipped with a spring-loaded 4-mm. straight-bore stopcock was attached to the manifold, im-

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[1] This document is based upon work performed under Contract Number W-7405 eng. 26 for the Atomic Energy Commission at the Oak Ridge National Laboratory.

[2] L. Henry, *Ber.*, **6**, 739 (1873).

[3] A. Michael, *Am. Chem. J.*, **1**, 418 (1879).

[4] Since the preliminary report of this procedure (Jones and Skraba, *Science*, **110**, 332 (1949)), another synthesis has been proposed by A. Murray and A. R. Ronzio, AECU-991; LADC-778.

[5] M. Descude, *Compt. rend.*, **132**, 1567 (1901).

[6] Radioactive paraformaldehyde was prepared by treating chloromethyl-C^{14} acetate with sufficient commercial formalin solution to furnish the water for hydrolysis. This procedure produced a paste which left a residue of dry polymeric formaldehyde when the volatile material was removed under high vacuum.

In attempts to prepare an isolable solid derivative from which formaldehyde would be easily recoverable, formaldehyde oxime, hexamethylenetetramine and the methylol derivatives of saccharin and phthalimide were investigated. None gave sufficiently high yields ol derivative from reaction with aqueous formaldehyde.

Direct oxidation of dilute methanol to formaldehyde with potassium persulfate (P. D. Bartlett and J. D. Cotman, THIS JOURNAL, **71**, 1419 (1949)) was attempted as a preparative method, but was not found feasible because of the difficulty of recovering formaldehyde from the dilute aqueous solution necessary for reaction to take place.

[7] All joints and stopcocks were greased with Dow-Corning silicone vacuum grease.

[8] After a number of runs the reaction bulb contained a trace of white non-volatile material and the over-all yields of formaldehyde decreased. Replacement of the bulb corrected the matter.