

NOTES

Identification of the Products of Thermal Exchange between Alkyl Iodides and Molecular Iodine by the "Wash Out" Carrier Technique¹

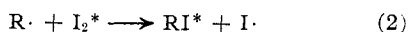
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RECEIVED JANUARY 16, 1953

Exchange between molecular iodine and the alkyl iodides has previously been observed to be induced both by light in the visible region² and thermally.³ The thermal reaction proceeds at a very low rate at temperatures of approximately 75° and is readily measurable only at low iodine concentrations. Preliminary evidence points to the mechanism as probably being due to a rate controlling reaction of the type



followed by a quenching of the radicals with molecular radioiodine.⁴



Isolation of the alkyl iodides formed provides identification of the radicals produced and the use of radioiodine together with suitable carriers makes this identification feasible. Radioiodine has previously been employed for free radical detection in the photolysis of the alkyl iodides,⁵ the radiolysis of alkyl iodides and hydrocarbons,⁶ in the photo-

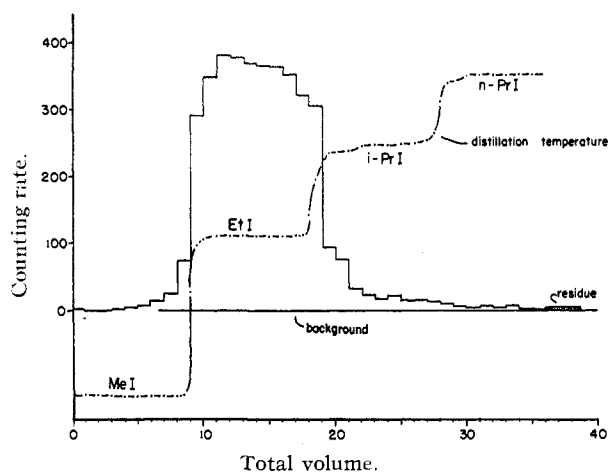


Fig. 1.—Fractional distillation of the exchange product of ethyl iodide and iodine after the addition of alkyl iodide carrier.

(1) Supported, in part, by a Frederick Gardner Cottrell grant from the Research Corporation of New York.

(2) R. M. Noyes, *THIS JOURNAL*, **70**, 2614 (1948).

(3) (a) J. Strachan, M. S. dissertation, Canisius College, 1950.

(b) C. T. Chmiel, M. S. dissertation, Canisius College, 1951.

(4) C. T. Chmiel and R. H. Schuler, Abstracts of Papers, 119th Meeting of the American Chemical Society, Cleveland, Ohio, April 9, 1951.

(5) W. H. Hamill and R. H. Schuler, *THIS JOURNAL*, **73**, 3466 (1951).

(6) (a) R. R. Williams, Jr., and W. H. Hamill, *ibid.*, **72**, 1857 (1950);

(b) L. H. Gevantman and R. R. Williams, Jr., *J. Phys. Chem.*, **56**, 569 (1952).

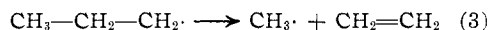
decomposition of methyl ethyl ketone and in studies of the decomposition of propyl radicals produced by the sodium flame reaction with propyl bromide.⁷ The purpose of this investigation is to ascertain the nature of the products of thermal exchange between alkyl iodides and molecular iodine and to determine the extent of radical rupture and isomerization under the conditions in which they are formed in these exchange experiments.

Preliminary investigations employed a fractionation procedure similar to that of Williams and Hamill.^{6a} Ethyl iodide and iodine⁸ were exchanged at 65°. The free iodine was extracted from the sample and 10 ml. each of methyl, *n*-propyl and isopropyl iodide carriers were added to 10 ml. of the exchange product. The mixture was fractionated using a 30-cm. Podbielniak heligrad packed column with one-cm. cuts of the distillate being taken. These were diluted to five ml. and counted. The activity, together with the boiling point, of each fraction is plotted in Fig. 1 as a function of the total volume distilled; with account being taken for any variation in the volume of the individual cuts. It is seen that the majority of the activity appears in the ethyl iodide fraction. No activity (< 1%) is observed in the methyl iodide and the small amounts of activity (< 4%) which do appear in the high boiling fractions probably result from contamination by incomplete fractionation or by physical hold-up in the column head. Three other experiments of this type gave similar results. This technique is extremely tedious to operate manually and somewhat less reliable if set up for automatic operation.^{6b} It also suffers in that the alkyl iodides can only be recovered with difficulty should further work on any of the fractions be desirable.

A modified technique has been developed in which the major fraction of each cut is collected as a unit, counted, and contaminating activity washed out by the addition of suitable carriers followed by fractionation. This "Wash Out" technique essentially involves the preparation of a sample which is radiochemically pure although not necessarily pure in the chemical aspect. Small amounts of impurities in the separated samples, as long as they do not contain activity, will not affect the results to an appreciable extent.

Ethyl iodide (b.p. 71.8° (750 mm.), *n*_D²⁰ 1.5102), *n*-propyl iodide (b.p. 42.8° (100 mm.), *n*_D²⁰ 1.5030), and isopropyl iodide (b.p. 47.0° (178 mm.), *n*_D²⁰ 1.4961) were allowed to thermally exchange with added iodine after the samples had been degassed and sealed on a vacuum line. The iodine was extracted, the samples washed, carriers added and the mixture separated on the Podbielniak column. Where there was possibility of contamination, the sample obtained from the first distillation was refractionated after the addition of inactive material identical to that of the supposed contaminant (*e.g.*, in the case of isopropyl iodide following a highly active ethyl iodide fraction, ethyl iodide was added to carry any contamination).

The results of these latter investigations, given in Table I, indicate that thermal exchange of the alkyl iodides with molecular iodine results almost entirely in the formation of a radiochemical species chemically identical to the parent substance. The propyl radical appears to have a sufficient lifetime in the liquid phase to be able to diffuse, without appreciable decomposition or isomerization, to the iodine present (at a mole fraction of 10⁻⁴). While a very small amount of decomposition to methyl radical does appear to take place at 95° in the case of the *n*-propyl radical, the isopropyl radical gives entirely negative results in this regard. It is possible for the propyl radical to decompose by reaction 3



(7) R. W. Durham, G. R. Martin and H. C. Sutton, *Nature*, **164**, 1052 (1949).

(8) Radioiodine (I¹³¹) prepared from samples obtained from the U. S. Atomic Energy Commission, Oak Ridge, Tennessee.

while no analogous reaction path is open to the isopropyl radical. Although they give no data in regard to the lifetime of the radicals, Durham, Martin and Sutton⁷ indicate a partial decomposition of propyl radical in the vapor phase at 400°.

TABLE I
PRODUCTS OF THE THERMAL EXCHANGE OF IODINE AND THE
ALKYL IODIDES

Ex- change, %	Total org. activ- ity, c./m.	CH ₃ I	C ₂ H ₅ I	Per cent. activity as		CH ₂ I ₂
				i-C ₃ H ₇ I	n-C ₃ H ₇ I	
Ethyl iodide (75°, 0.024 M in I ₂)						
71	885	0 ^b	>98	0 ^b	0 ^b	0 ^b
<i>n</i> -Propyl iodide (75°, 0.024 M in I ₂)						
64	660	0 ^b	0 ^b	0 ^c	>98	.. ^a
<i>n</i> -Propyl iodide (95°, 0.0008 M in I ₂)						
71	5730	0.5	0.2	0.3	98.5	0.5
Isopropyl iodide (95°, 0.0023 M in I ₂)						
98	14100	0.0 ^d	0.4	98.6	0.7	0.3

^a No carrier methylene iodide added. ^b < 0.5%. ^c < 1%. ^d < 0.1%.

The results of Table I represent an upper limit to systematic errors that can affect the validity of the present separation methods. It is indicated that the reliability of results obtained by this method is better than a fraction of one per cent., or the limit of the activity measurements should this be higher. Detection of the formation of small amounts of radicals appears to be quite practicable especially in the case of methyl since methyl iodide is easily separated from the higher boiling components.

Further investigations are in progress utilizing the technique described above in studies of alkyl iodide systems.

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A New Synthesis of Aminomalonic Acid¹

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RECEIVED NOVEMBER 26, 1952

Aminomalonic acid was first described in 1864, by Baeyer who prepared it by reduction of potassium oximinomalonate with sodium amalgam and water.² Ruhemann and Orton³ synthesized aminomalonic acid from nitromalonamide by reducing the nitro group with sodium amalgam and water, and removing the amido groups by hydrolysis. Lütz,⁴ in 1902, found that he could obtain aminomalonic acid by treating halogenated malonic acid with ammonia. Finally, in 1904, Piloty and Finckh⁵ obtained aminomalonic acid by alkaline hydrolysis of uramil, 5-aminobarbituric acid.

In view of the known instability of malonic acids, it is doubtful that any of these methods yields aminomalonic acid in pure form. In most cases the reagents used are quite destructive and the decomposition products, mainly glycine, may be expected to contaminate the product.

The present synthesis employs diethyl carbobenzyloxyaminomalonic acid, an intermediate in the

(1) No. 13 in amino acid series. For No. 12 see J. H. R. Beaujon, W. R. Straughn, Jr., and W. H. Hartung, *J. Am. Pharm. Assoc.*, **41**, 581 (1952).

(2) A. Baeyer, *Ann.*, **181**, 291 (1864).

(3) S. Ruhemann and K. J. P. Orton, *J. Chem. Soc.*, **67**, 1002 (1895).

(4) O. Lütz, *Ber.*, **35**, 2549 (1902).

(5) O. Piloty and C. Finckh, *Ann.*, **333**, 71 (1904).

preparation of malonic acid analogs of α -amino acids.⁶ The unsubstituted ester, hydrolyzed under conditions previously described,⁶ gives good yields of the alkali salt of carbobenzyloxyaminomalonic acid, which, on catalytic hydrogenolysis in aqueous solution, gives the salts of aminomalonic acid.

Experimental

Potassium Carbobenzyloxyaminomalonic Acid.—This compound was prepared by hydrolysis of 12.4 g. (0.04 mole) of diethyl carbobenzyloxyaminomalonic acid⁶ in 50 ml. of a 20% solution of potassium hydroxide in 95% ethanol. A gummy precipitate, weighing more than 12.5 g. (calcd. for pure dipotassium salt, 12.6 g.), was formed on standing overnight. This precipitate, on attempted recrystallization from 80–90% ethanol, formed a slightly yellowish, oily material. On washing with 95% ethanol it became almost colorless, and after drying over phosphorus pentoxide it turned into a white, hygroscopic solid. *Anal.* Calcd. for C₁₁H₉O₆NK₂: N, 4.26. Found: N, 4.31, 4.43.

Potassium carbobenzyloxyaminomalonic acid could be acidified to produce carbobenzyloxyaminomalonic acid, m.p. 147–148° (uncor.), with evolution of gas. *Anal.* Calcd. for C₁₁H₁₁O₆N: N, 5.54. Found: N, 5.56, 5.51.

Monodecarboxylation of carbobenzyloxyaminomalonic acid by boiling with dilute hydrochloric acid yielded N-carbobenzyloxyglycine, m.p. 119–120° (uncor.), m.p. reported, 120°.⁷ Although the analysis for the free acid is satisfactory, the visible evolution of gas on its formation suggests that it is more stable as a salt.

Monopotassium Carbobenzyloxyaminomalonic Acid.—To a solution of 2.4 g. of KOH (0.041 mole) in 10 ml. of water was added with constant stirring 10.2 g. of carbobenzyloxyaminomalonic acid (0.04 mole). To the resulting clear solution was added with stirring commercial absolute ethanol until no further precipitate formed. The solid was removed, washed with 95% alcohol and recrystallized three times from 80–90% alcohol; obtained 7.1 g. of pure white crystals, 61.1%. *Anal.* Calcd. for C₁₁H₁₀O₆NK: N, 4.82. Found: N, 4.82, 4.85.

Monopotassium Aminomalonic Acid.—A solution of 5.8 g. of monopotassium carbobenzyloxyaminomalonic acid (0.02 mole) in 50 ml. of distilled water was hydrogenated in the Parr apparatus in the presence of 2 g. of palladium-charcoal catalyst at an initial pressure of 4 atm. hydrogen; shaking was continued for an hour after the gage pressure became constant. The catalyst was removed and the solution concentrated under reduced pressure to 25 ml. and then poured into 150 ml. of boiling absolute ethanol and filtered. The solution, after standing for about a week, yielded large crystals, which were removed and recrystallized twice from 80–90% alcohol; yield 1.0 g., 32%. *Anal.* Calcd. for C₈H₉O₄NK: N, 8.91. Found: N, 8.92, 8.86.

Hydrogenation of dipotassium carbobenzyloxyaminomalonic acid under similar conditions, and isolation of the product as described above, also leads to the monopotassium aminomalonic acid, the carbon dioxide liberated during hydrogenolysis of the carbobenzyloxy group accounting for the other potassium ion.

(6) J. H. R. Beaujon and W. H. Hartung, *J. Am. Pharm. Assoc.*, **41**, 578 (1952).

(7) H. D. Carter, R. L. Frank and H. W. Johnston, *Org. Syntheses*, **23**, 13 (1943).

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4-Nitrophthalimides. I. Derivatives of Alkyl Halides Giving a Saponification Equivalent¹

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RECEIVED NOVEMBER 8, 1952

Among the many derivatives suggested for the identification of alkyl halides are the N-alkyl-

(1) From the Ph.D. Thesis of R. Vincent Cash, Indiana University, September, 1951.