Experiments 1, 4, 5, 6 and 7 were carried out as follows: On the vacuum line, the alkali metalloporphin desired was prepared from PH_2 and the corresponding alkali methylate in a manner analogous to the preparation of PNa_2 given in the preceding section. It was collected in pyridine solution in a cuvette which had a side tube containing the dried alkali iodide which was to be used in the attempted replacement. The cuvette was sealed off the line, and a quantitative curve was run on the Beckman from 7000 to 4500 Å. for the original alkali metalloporphin. The solution was then poured over into the side tube and allowed to mix with the alkali iodide. It was then poured back into the cuvette and the spectral curve run again.

Experiments 2, 3, 8, 10 through 14, and 16 through 18 were run in the open air by treating a dry pyridine solution of the metalloporphin with the appropriate inorganic salt. The reaction mixture was spectrally compared with solutions of the original metalloporphin and the metalloporphin that could have been formed to determine if replacement took place. The comparison was made on a Bausch and Lomb visual spectrophotometer. All metalloporphins were prepared by heating PH_2 with the acetate of the appropriate metal in either pyridine or glacial acetic acid. Benzene was then added, and the excess inorganic salt and the pyridine or acetic acid washed out by repeated extractions with water. The benzene solution was dried over anhydrous sodium sulfate, and the solution taken to dryness under vacuum. The metalloporphin was then taken up in dry pyridine for the replacement experiment.

Experiments 9 and 15 were conducted in the open air. The lithium salt was prepared by the addition of excess lithium methylate to a pyridine solution of free base. Such a solution is stable toward hydrolysis on a dry day for considerable periods of time if the lithium methylate is in appreciable excess. Dry zinc or mercuric acetate was then added, and complete replacement was observed as noted in Table I.

Summary

1. The metalloporphins derived from the smaller divalent metals are in general quite resistant to hydrolysis, show marked similarities in spectra, and undergo no known exchange reactions with isotopes of the same metal. Replacement reactions are possible, however; this has been demonstrated by the conversion of zinc tetraphenylporphin to copper tetraphenylporphin by prolonged heating with copper acetate.

2. The metalloporphins derived from the large divalent metals such as lead or mercury are less resistant to hydrolysis, differ in spectra from those of the smaller divalent metals, and undergo replacement reactions as follows: Lead or mercury in a metalloporphin is replaced quantitatively by a smaller divalent metal such as zinc or copper, and the larger lead ion in a metalloporphin is replaced by the smaller mercuric ion. Even with a large excess of inorganic metal ion, none of these replacements proceed in the reverse direction.

3. The porphin salts of the alkali metals are readily hydrolyzed by water, exhibit spectra in the case of $\alpha,\beta,\gamma,\delta$-tetraphenylporphin somewhat similar to lead and mercury, and undergo replacement reactions as follows: The alkali metal ions in an alkali metalloporphin are rapidly and completely replaced by a small divalent, a large divalent, or a smaller alkali metal ion. Even with a large excess of inorganic metal ion, none of these replacements proceed in the reverse direction.

4. Complete equilibration of the activity in a pyridine solution of sodium iodide and disodium[22] tetraphenylporphin is observed at room temperature in less than six minutes.

ST. LOUIS, MISSOURI RECEIVED NOVEMBER 9, 1949

CONTRIBUTION FROM THE DIVISION OF PLANT NUTRITION, COLLEGE OF AGRICULTURE, UNIVERSITY OF CALIFORNIA, BERKELEY]

The Quantitative Recovery of Carbon Dioxide in Lead Tetraacetate Oxidations of Sugars and Sugar Derivatives

BY SAMUEL ABRAHAM[1]

The selective cleavage of the weakened connecting bond of a 1,2 glycol can be accomplished with the use of either lead tetraacetate in glacial acetic acid[2a] or of periodate in aqueous solution[2b] The action of these two oxidizing agents on such glycols, by breaking the bond between the two hydroxyl-carrying carbon atoms and removing the hydroxyl hydrogens, produces the same carbonyl products.

Criegee,[2] in his original investigation, emphasized the use of dry organic solvents when lead tetraacetate is employed. However, Fischer[3] showed that the rate of hydrolysis of the oxidizing agent in water is much slower than the rate of oxidation of certain glycol compounds and that it is therefore possible to oxidize these substances with lead tetraacetate in the presence of water.

In the case of compounds which contain three adjacent hydroxyl groups, the reaction with two moles of periodate or two moles of lead tetraacetate will yield the corresponding aldehyde or ketone with the middle carbon splitting out as formic acid. Upon treatment with a third mole of lead tetraacetate in aqueous media, the formic acid formed is further oxidized to carbon dioxide.[4] No such reaction has been reported in the case of periodate oxidations.

Rate studies made on this oxidation by lead tetraacetate have shown that all the glycosides

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[1] Department of Physiology, University of California, Berkeley, California.

[2] (a) R. Criegee, *Ann.*, **481**, 275 (1939); *Ber.*, **64**, 260 (1931); *Agew. Chem.*, **50**, 153 (1937); (b) L. Malaprade, *Compt. rend.*, **186**, 382 (1927).

[3] E. Baer, J. M. Grosheintz and H. O. L. Fischer, THIS JOURNAL, **61**, 2607 (1939).

[4] J. M. Grosheintz, *ibid.*, **61**, 3379 (1939).

which contain a *cis* glycol structure consume the first mole of tetraacetate much more rapidly than those having only *trans* structures, suggesting that the initial attack upon the glycoside is at the *cis* configuration.[5] The oxidation of α- and β-methyl-L-arabinoside by Grosheintz[4] with lead tetraacetate has led to formation of 1-methoxy-diglycolic aldehyde in which the carboxyl groups could be estimated quantitatively by the method of Willstätter and Schudel[6] to demonstrate the elimination of carbon atom number three in the oxidation. Other investigators have used this method[7] as well as the oxidation by periodate,[8] in the determination of the structures of the sugars and the preparation of new sugar derivatives.[7]

In the present investigation D-glucose, methyl-D-glucoside, D-arabinose, methyl-D-arabinoside and D-glucose phenylosatriazole were oxidized with lead tetraacetate in acetic acid and water, with the quantitative recovery of the carbon dioxide produced from the reaction. Since D-glucose has five bonds to be broken, it was found necessary to oxidize it for a longer period of time than the D-arabinose which only has four bonds to be split. Methyl-D-glucoside, having two bonds cleaved at a *trans,trans* linkage was found to require more time for reaction than the arabinoside. The phenylosotriazole, not being soluble in water, was dissolved in pyridine. A small amount of water was added to this solution. It was then oxidized for a still longer period than either of the glycosides since three bonds had to be broken. According to the rates and quantitative recoveries of carbon dioxide produced in the reaction, the following series shows the times required for the oxidation (Fig. 1).

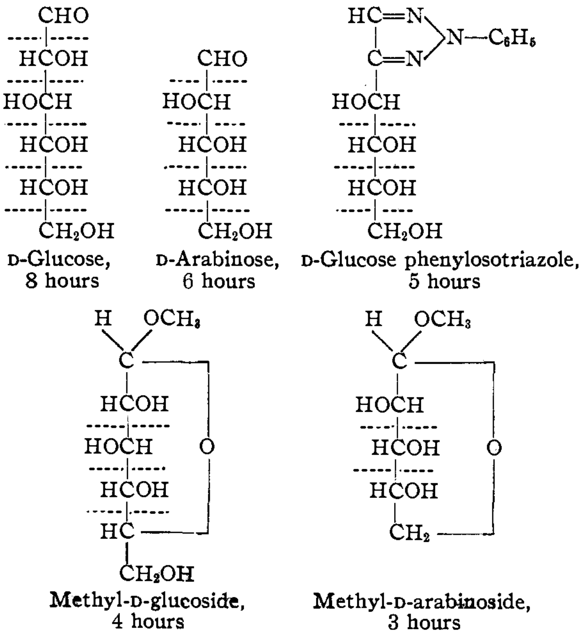
D-Glucose, 8 hours
D-Arabinose, 6 hours
D-Glucose phenylosotriazole, 5 hours
Methyl-D-glucoside, 4 hours
Methyl-D-arabinoside, 3 hours

Fig. 1.

The present work deals with the quantitative recovery of the carbon dioxide produced from these compounds by lead tetraacetate. The reactions were carried out at 40–42° and the carbon dioxide liberated was trapped in a sodium hydroxide solution. The carbon dioxide was then precipitated as barium carbonate using a solution of barium chloride.

These reactions are useful in the determination of the activity of the individual carbon atoms of radioactive glucose, prepared by the photosynthetic method from radioactive $C^{14}O_2$.[8a]

Apparatus

The apparatus is shown in Fig. 2. A column (at G) is filled with ascarite and serves to obtain carbon dioxide-free air. The reaction tube (A) is of 2 cm. diameter and is 17 cm. long. The inlet which is placed 1.5 mm. from the bottom of tube (A) has a diameter of 4 mm. (drawn down to 2 mm. at the bottom) and emerges from tube (A)

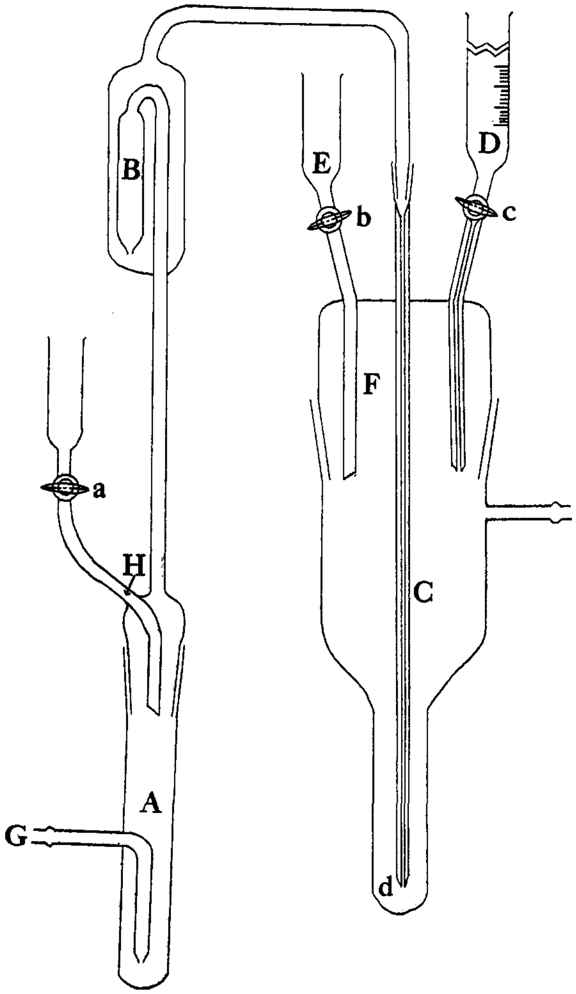

Fig. 2.

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[5] R. C. Hockett, *et al.*, THIS JOURNAL, 61, 1669 (1939).

[6] Willstätter and Schudel, *Ber.*, 51, 780 (1918).

[7] W. S. McClenahan and R. C. Hockett, THIS JOURNAL, 60, 2061 (1938).

[8] E. L. Jackson and C. S. Hudson, *ibid.*, 59, 994 (1937).

[8a] E. W. Putnam, W. Z. Hassid, G. Krotkov and H. A. Barker, *J. Biol. Chem.*, 176, 785 (1948).

about 8 cm. from the bottom. A 24/40 standard taper glass joint connects the reaction tube (A) with the gas washing tube (B). Buret inlet at (H) has 5 ml. capacity and a stopcock (a) with a 2 mm. bore. The tip of this buret should extend below the glass joint 24/40. The bulb on tube (B) has a diameter of 3 cm. and is 15 cm. long. Connected to the gas washing tube (B) with a 10/30 standard taper glass joint are burets (D) and (E) ring-sealed on a 50/50 standard taper glass joint (F). Buret (D) has 35 ml. capacity which is graduated into tenths, while buret (E) has a capacity of 5 ml. Both stopcocks (b) and (c) have a 2 mm. bore. The tips of both burets should go below the 50/50 joint. Buret (E) has a drip-tip with 4 mm. diameter, while (D) has a regular drawn out buret tip made from standard 2 mm. capillary. The 50/50 glass joint (F) is now connected to the receiver (C). The top 7 cm. of (C) has a diameter of 4.5 cm. and is drawn down to 2 cm. for the bottom 9 cm. The gas bubbling tube (d) which has the 10/30 joint is made from standard 1 mm. capillary and reaches through the ring-seal (F) to within 1 cm. of the bottom of the receiver (C). The outlet tube which is of 4 mm. diameter is about 1 cm. down from the bottom of the 50/50 joint. The suction is applied at this point when the apparatus is all assembled.

Experimental

It was found necessary to use a gas washing tube (B) to catch some of the acetic acid used in the reaction which was coming over with the carbon dioxide. Water was used in the trap (B) for this purpose. After each determination, the water in the trap was found to be sufficiently acidic so that none of the carbon dioxide bubbling through was dissolved in it. Furthermore, it was also found necessary to titrate the solution in receiver (C) in a closed system as shown in Fig. 2, as a significant amount of carbon dioxide was absorbed from the air to interfere with the results.

The water in the gas washing tube (B) was not effective enough to trap all the acetic acid, so that the titration to the phenolphthalein end-point was not a reliable method for determining the amount of carbon dioxide absorbed by the alkali in the receiver (C). Once the excess sodium hydroxide was titrated with dilute hydrochloric acid from the buret (D), 0.5 ml. of 0.1 *N* sodium thiosulfate was added to the receiver (C) before introducing the methyl orange indicator. This reagent took care of the unknown substance which destroyed the methyl orange indicator. Titration of the barium carbonate, which was formed when the barium chloride solution was added through buret (E) to the receiver (C), proved to be an accurate method for the quantitative estimation of the carbon dioxide liberated from the oxidation of the D-glucose, D-arabinose and the sugar derivatives employed.

Blanks were run before each reaction to determine the contaminating carbon dioxide. An alkali absorption column (ascarite) was used to obtain carbon dioxide-free air which was sucked through the whole apparatus. The blanks thus obtained were negligible.

Preparation of Methyl-D-glucopyranoside.—The methyl-D-glucopyranoside was prepared according to E. Fischer.[9] Since Hockett[5] has shown that the type of glycoside does not affect significantly the rate of oxidation when using lead tetraacetate, no attempt to separate the α- and β-isomers was made.

Preparation of D-Glucose Phenylosotriazole.—The preparation of the triazole, m. p. 195–196°, which was used in this investigation, has been described by Hudson and Hann.[10] In the amounts used this material was readily soluble in pyridine.

Preparation of D-Arabinose and Methyl-D-arabinopyranoside.—D-Arabinose was prepared from D-glucose by first converting it to calcium gluconate, using a slight modification of Goebel's method,[11] and subsequently to D-arabinose by the method of Hockett and Hudson.[12] Some of this sugar was finally treated according to Hudson[13] to yield methyl-D-arabinopyranoside. Reducing values using the ceric sulfate method of Hassid,[14] showed very little contaminating D-arabinose, which amounted to not more than 0.6%.

Preparation of Lead Tetraacetate.—The oxidizing agent, lead tetraacetate, was made according to McClenahan and Hockett, and stored in a desiccator over phosphorus pentoxide. When needed, it was weighed out and put into 2 ml. of glacial acetic acid in the reaction tube (A). Two additional ml. of the reagent was used to wash down the sides of the tube. The slight brown color, due to decomposition of the reagent, has no effect on the reaction as a large excess of the oxidizing agent is used in the reactions.

Oxidation of Formaldehyde.—In order to determine whether or not formaldehyde is attacked by the lead tetraacetate, a large excess of the oxidizing agent was allowed to react with it for four hours under the same experimental conditions as used on the sugars. No carbon dioxide was produced.

Determination.—The reaction tube (A, see Fig. 2) containing 1.42 g. of lead tetraacetate and 4 ml. of glacial acetic acid is connected to the gas washing tube (B), which is $^2/_3$ filled with water. The buret (D) is filled with 0.1 *N* hydrochloric acid. Twenty ml. of 0.1 *N* sodium hydroxide (carbon dioxide free) is pipetted into the receiver (C) and connected to the buret (D). A solution of the sample, sufficient to produce about $^1/_3$ mmol. of CO_2 introduced in 1 ml. of aqueous solution, is now put into the reaction tube (A) through a buret (a) followed by an additional 2 ml. of glacial acetic acid to wash the sugar solution down. At a moderate rate carbon dioxide free air is sucked through the system, the temperature of which is maintained at 40–42° by use of a water-bath on the reaction tube (A). The reaction is allowed to proceed for eight hours.

After the required time has elapsed, the water-bath is removed and 1 ml. of a 1 *M* barium chloride solution, to which several drops of phenolphthalein has been added, is sucked into the receiver (C) through buret (c). A precipitate of barium carbonate is formed in the receiver (C). After increasing the rate of bubbling, the excess sodium hydroxide is titrated to the phenolphthalein end-point, with care to avoid local concentration of acid. The yield of carbon dioxide is then determined by titration of the precipitated barium carbonate with 0.1 *N* hydrochloric acid to the methyl orange end-point. When the sample was 0.0120 g. of glucose, the carbon dioxide yield as determined by this method was 95.3% of the theoretical.

In the case of the osotriazole, 0.5 ml. of water is added to the reaction tube at the beginning of the oxidation, since water is needed to produce the carbon dioxide.

TABLE I

RECOVERY OF CARBON DIOXIDE[a]

Compound	Amounts used, g.	Time, hr.	CO_2 calcd., %
D-Glucose	0.012	3.5	65
D-Glucose	.012	4.5	77
D-Glucose	.012	6.0	84.5
D-Glucose	.012	8.0	95.3
D-Arabinose	.025	6.0	99
Methyl-D-glucoside	.068	4.0	97.7 and 97.6
Methyl-D-arabinoside	.0125	3.0	99.5
D-Glucose phenylosotriazole	.044	5.0	98.7
Formaldehyde	.060	4.0	0.0

[a] The temperature was maintained at 40–42° throughout these reactions.

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(9) E. Fischer, *Ber.*, **26**, 2400 (1893).

(10) R. M. Hann and C. S. Hudson, THIS JOURNAL, **66**, 735 (1944).

(11) W. F. Goebel, *J. Biol. Chem.*, **72**, 809 (1927).

(12) R. C. Hockett and C. S. Hudson, THIS JOURNAL, **56**, 1632 (1934).

(13) C. S. Hudson, *ibid.*, **47**, 265 (1925).

(14) W. Z. Hassid, *Ind. Eng. Chem.. Anal. Ed.*, **9**, 228 (1937).

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Summary

A simple method for the quantitative recovery of the carbon dioxide produced by the oxidation of certain glycosides and polyhydroxy compounds through the use of lead tetraacetate is described. This reaction is very useful and is now being used in the degradation of radioactive glucose, prepared photosynthetically.

BERKELEY 4, CALIFORNIA RECEIVED DECEMBER 5, 1949

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY AND THE PURDUE RESEARCH FOUNDATION, PURDUE UNIVERSITY]

Preparation and Polymerization of Trifluoromethyl- and Chloro-(trifluoromethyl)-substituted Styrenes

BY EARL T. MCBEE AND ROBERT A. SANFORD[1]

In a study of the properties of chloro-(trifluoromethyl)-benzene and bis-(trifluoromethyl)-benzene, a number of bromo derivatives of these substances have been prepared.[2] The substitution of the bromine atom in these compounds by a vinyl group was accomplished and the resulting products were polymerized.

Some trifluoromethyl-substituted styrenes have been reported previously.[3,4] The synthesis of the monomers comprised the dehydration of substituted α-methylbenzyl alcohols which were prepared by means of the Grignard reagent. The Grignard reaction was conducted with bromo, bromochloro and bromodichloro derivatives of (trifluoromethyl)-benzene and bis-(trifluoromethyl)-benzenes. In each instance in which an organometallic compound was formed, the magnesium reacted with the bromine substituent. No reaction between magnesium and chlorine or fluorine was observed.

A trifluoromethyl group ortho to the bromine atom may slightly retard the formation of the Grignard reagent. Otherwise, the trifluoromethyl group seemed to have little, if any, effect on the Grignard reaction. However, in no instance was a Grignard reagent formed from compounds in which a chlorine atom was ortho to the bromine. The compounds which failed to react with magnesium as well as those which did react are listed in Table I.

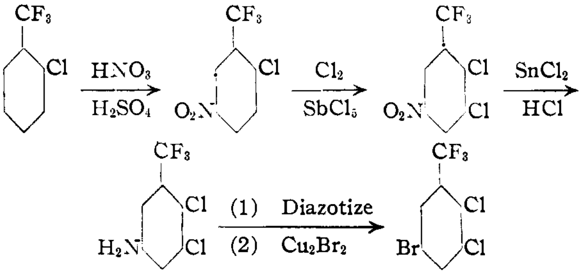
The Grignard reagents were condensed with acetaldehyde and the product hydrolyzed to the substituted α-methylbenzyl alcohols. These alcohols are listed in Table II. The dehydration of these alcohols was accomplished with a suspension of phosphorus(V) oxide in dry benzene at room temperature. The substituted styrene monomers were polymerized by an emulsion technique and the average molecular weights of the resulting polymers determined by the viscosity method. The monomers are listed in Table III.

TABLE I

REACTION OF SUBSTITUTED BROMOBENZENES WITH MAGNESIUM IN ETHER

(Trifluoromethyl)-benzene reacted	(Trifluoromethyl)-benzene failed to react
5-Bromo-2-chloro-	3-Bromo-4-chloro-
2-Bromo-5-chloro-	4-Bromo-3-chloro-
5-Bromo-2,3-dichloro-	5-Bromo-2,4-dichloro-
2-Bromo-1,4-bis-	5-Bromo-3,4-dichloro-
5-Bromo-1,3-bis-	5-Bromo-4-chloro-1,3-bis-
4-Bromo-1,2-bis-	2-Bromo-3,4-dichloro-1,5-bis-
2-Bromo-5-chloro-1,4-bis-	
5-Bromo-2-chloro-1,3-bis-	

Since the bromination of 2,3-dichloro-(trifluoromethyl)-benzene did not produce 5-bromo-2,3-dichloro-(trifluoromethyl)-benzene, this compound was prepared by



Acknowledgment.—The authors are indebted to the Ethyl Corporation and to the Westinghouse Electric Company for financial support which made this investigation possible.

Experimental

Preparation of Starting Materials

5-Bromo-2-chloro-(trifluoromethyl)-benzene, 3-bromo-4-chloro-(trifluoromethyl)-benzene, 2-bromo-5-chloro-(trifluoromethyl)-benzene, 4-bromo-3-chloro-(trifluoromethyl)-benzene, 5-bromo-2,4-dichloro-(trifluoromethyl)-benzene, 5-bromo-3,4-dichloro-(trifluoromethyl)-benzene, 2-bromo-1,4-bis-(trifluoromethyl)-benzene, 5-bromo-1,3-bis-(trifluoromethyl)-benzene, 4-bromo-1,2-bis-(trifluoromethyl)-benzene, 2-bromo-5-chloro-1,4-bis-(trifluoromethyl)-benzene, 5-bromo-2-chloro-1,3-bis-(trifluoromethyl)-benzene, 5-bromo-4-chloro-1,3-bis-(trifluoromethyl)-benzene and 2-bromo-3,4-dichloro-1,5-bis-(trifluoromethyl)-benzene were prepared by the bro-

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[1] Abstracted from the doctoral thesis of Robert A. Sanford.

[2] E. T. McBee, R. A. Sanford and P. J. Graham, THIS JOURNAL, **72**, 1651 (1950).

[3] M. W. Renoll, *ibid.*, **68**, 1159 (1946).

[4] G. B. Bachman and L. L. Lewis, *ibid.*, **69**, 2022 (1947).