methane from methylnitrosourea. The solutions in the receivers were combined and diluted to a volume of 250 cc. with anhydrous ether. A 10-cc. aliquot was used in the determination of the yield of diazomethane by the use of benzoic acid as described by Marshall and Acree.[4] The total yield was 4.15 g. or 72.6%.

Characterization of Diazomethane.—To 498 mg. (0.0017 mole) of stearic acid (m. p. 69 ± 0.1°) dissolved in 30 cc. of ether was added 331 mg. (0.0078 mole) of diazomethane in 20 cc. of ether. The ethereal solution was allowed to stand at room temperature for twenty minutes after the evolution of nitrogen had ceased. The excess diazomethane was decomposed with dilute hydrochloric acid solution and the ether fraction separated. After washing the ether solution with water (3 × 40 cc.), it was dried over anhydrous sodium sulfate and evaporated. The colorless residue crystallized on cooling. These crystals melted at 39-39.5° (capillary method) alone and on admixture with an authentic sample of methyl stearate. The yield was 514 mg. or 98.4% by theory.

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[4] E. K. Marshall and S. F. Acree, *Ber.*, **43**, 2323 (1910).

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Volatile Decomposition Products of Sugars in Aqueous Solution

BY LOUIS SATTLER AND F. W. ZERBAN

Enders and his co-workers[1] have published a series of papers purporting to show that methylglyoxal is found in the distillate not only when alkaline solutions of glucose and xylose are distilled at constant volume, but that methylglyoxal is found in distillates of neutral and acid solutions of these sugars as well. They also report the finding of methylglyoxal in the distillates from acid solutions of sucrose, maltose, dextrin and soluble starch.

Their conclusion that methylglyoxal is indeed the volatile material in the distillate, is based upon the following observations: the iodoform reaction, the color reaction with pyrrole, the color test of Denigès,[2] as for example with codeine phosphate, the Ariyama reaction[3] with arsenophosphotungstic acid and the characterization of methylglyoxal as its phenyl and 2,4-dinitrophenylosazones.

These color reactions for methylglyoxal are not specific and the reaction with sodium nitroprusside[4] has its limitations. The isolation of the osazones is not conclusive because acetol also yields the same derivatives. Acetol makes the Ariyama test ambiguous because, as with methylglyoxal, there is a great intensification of the blue color upon the addition of sodium cyanide (1 g.). Unfortunately, the conversion of acetol into 4(5)-methylimidazole[5] does not lend itself to micro quantities.

Baudisch and Deuel[6] have shown that sugars when distilled from a 5% sodium bicarbonate solution, yield acetol. The acetol can be specifically identified[7] by its reaction with *o*-aminobenzaldehyde to form 3-hydroxyquinaldine which can be isolated. This compound crystallizes from acetone and water in the form of colorless needles melting at 260°,[8] and possesses a beautiful blue fluorescence when it is illuminated in very dilute aqueous solution with invisible ultraviolet light.

In view of Enders' claim that methylglyoxal is obtained in the distillates when maltose solutions are distilled ranging over a wide *p*H, from strongly acid to strongly alkaline,[1b] it was deemed desirable to test for acetol because of the obvious conflict of these findings with the observations of Baudisch and Deuel. Pure 20% aqueous solutions of glucose and of maltose were distilled at constant volume. The distillates gave a positive test with Ariyama's reagent, and they yielded the reported osazones. However, with *o*-aminobenzaldehyde, under the conditions described by Baudisch and Deuel,[6] the distillates gave strong positive tests for acetol as observed by fluorescence. Baudisch and Deuel found that 1 g. of methylglyoxal gives only a faint acetol test, as observed by the intensity of the fluorescence, whereas 5 mg. of glucose when distilled with a sodium bicarbonate solution, yields a relatively large amount of acetol.

Pinkus[9] obtained the osazone of methylglyoxal when glucose was treated with strong alkali in the presence of phenylhydrazine. While Nef,[10] Wohl,[11] and Neuberg[12] have expressed beliefs that in alkaline solution methylglyoxal is the initial product formed in the rupture of the sugar molecule, Baudisch and Deuel are of the opinion that acetol is the primary compound which is produced because under their experimental conditions the Cannizzaro reaction is apparently negligible. Thymine, which on treatment with ferrous sulfate and sodium bicarbonate in the presence of air, is oxidized to urea, pyruvic acid and acetol, can be detected in the presence of sugar.[6]

Our finding of acetol in the distillates of aqueous sugar solutions does not rule out the simultaneous presence of methylglyoxal. It does point up the conclusion that Enders' quantitative method for the estimation of methylglyoxal is erroneous and that his opinions regarding the formation of methylglyoxal are open to modification. Of further interest to us is the darkening of these triose solutions when they are distilled from a 5% so-

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[1] (a) Enders and Marquardt, *Naturwissenschaften*, **29**, 46 (1941); (b) Enders, *Biochem. Z.*, **312**, 349 (1942); (c) Enders and Sigurdsson, *Biochem. Z.*, **317**, 26 (1944).

[2] Denigès, *Bull. soc. chim.*, **5**, 649 (1910).

[3] Ariyama, *J. Biol. Chem.*, **77**, 395 (1928).

[4] Neuberg, *Biochem. Z.*, **71**, 150 (1915).

[5] Weidenhagen and Wegener, *Z. Wirtschaftsgruppe Zuckerind.*, **88**, 927 (1938).

[6] Baudisch and Deuel, THIS JOURNAL, **44**, 1585 (1922).

[7] Baudisch, *Biochem. Z.*, **89**, 279 (1918).

[8] Königs and Stockhausen, *Ber.*, **35**, 2556 (1902).

[9] Pinkus, *ibid.*, **31**, 31 (1898).

[10] Nef, *ibid.*, **335**, 247 (1904).

[11] Wohl, *Biochem. Z.*, **5**, 57 (1907).

[12] Neuberg and Oertel, *ibid.*, **55**, 494 (1913); Neuberg and Rewald, *ibid.*, **71**, 144 (1915).

dium bicarbonate solution because there seems to be a connection with the "browning reaction" observed in food products which contain both sugars and amino derivatives.

Work is in progress on the formation of acetol in sugar solutions, and the quantitative determinations of acetol and methylglyoxal in mixtures of both.

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2-Aryl- and 2-Alkoxycyclohexanols[1]

BY B. C. MCKUSICK[2]

As part of a program to find improved insect-repellents, a number of 2-aryl- and 2-alkoxycyclohexanols were prepared from cyclohexene oxide.

The 2-arylcyclohexanols were obtained by condensing cyclohexene oxide with appropriate aryllithiums[3]; Grignard reagents were not used because the products would have been the isomeric arylcyclopentylcarbinols.[3] The postulated cyclohexanol structure was confirmed for one product, 2-(*p*-tolyl)-cyclohexanol, by oxidizing it to the known δ-*p*-toluylvaleric acid. Yields of cyclohexanols were good except in the case of 2-(*p*-methoxyphenyl)-cyclohexanol, where the low yield is understandable in view of the ease with which the side-reaction of *p*-methoxyphenyllithium with *p*-bromoanisole to give anisole and 5-bromo-2-methoxyphenyllithium is known to occur.[4] Since 2-phenylcyclohexanol prepared from cyclohexene oxide and phenyllithium[3] has been shown to have a *trans*-configuration,[5] it is probable that the present 2-arylcyclohexanols are also *trans*.

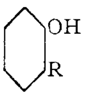
The 2-alkoxycyclohexanols were obtained by heating cyclohexene oxide with an excess of the appropriate alcohol in which a trace of sodium had been dissolved.[6] *trans*-1,2-Cyclohexanediol was a by-product of the preparation of 2-(β-phenethoxy)-cyclohexanol and may have been a by-product in other cases.

Experimental

2-Arylcyclohexanols.—The preparation of 2-(*m*-tolyl)-cyclohexanol can be used to illustrate the general procedure. In a 12-liter three-necked flask, 69 g. (20% excess) of lithium in the form of small strips[7] was stirred vigorously in 3 liters of anhydrous ether under nitrogen while 711 g. of *m*-bromotoluene was added at a rate to maintain gentle refluxing of ether. Once reaction set in, the flask was kept immersed in an ice-bath in order to shorten the time necessary for the addition (about one hour). The mixture was heated under reflux for an hour and 408 g. of cyclohexene oxide[8] was added in the same manner. The mixture was cooled in ice and decomposed by the gradual addition of 3 liters of water with stirring. The ether layer was separated, washed with water, dried over magnesium sulfate, and distilled; 655 g. (71% yield) of 2-(*m*-tolyl)-cyclohexanol was collected at 113–114° (1.0 mm.).

The acetate and propionate were obtained by heating 2-(*m*-tolyl)-cyclohexanol at 100° for two hours with 1.5 molar equivalents of acid anhydride and 2 molar equivalents of pyridine and distilling the reaction mixtures under reduced pressure.

TABLE I

2-SUBSTITUTED CYCLOHEXANOLS 

R	Boiling point[a] °C.	Mm.	M. p. or n^{25}_D	Yield, %	Formula	Analyses, % Calcd. C	H	Found C	H
m-Tolyl	113–114	1.0	1.5396	71	$C_{13}H_{18}O$	82.1	9.5	82.0	9.9
m-Tolyl[b]	85– 86	0.2	1.5113	93	$C_{15}H_{20}O_2$	77.6	8.7	77.4	8.4
m-Tolyl[c]	96–100	0.3	1.5067	97	$C_{16}H_{22}O_2$	78.0	9.0	78.6	9.2
p-Tolyl	109–113	1	72–73°[d]	84	$C_{13}H_{18}O$	82.1	9.5	82.5	9.9
2,5-Xylyl	114–115	2	1.5377	69	$C_{14}H_{20}O$	82.3	9.9	82.7	10.1
p-Methoxyphenyl	135–140	1.5	71–72°[d]	15	$C_{13}H_{18}O_2$	75.7	8.8	75.8	9.0
n-Propoxy[e]	82– 83	9	1.4538	67	$C_9H_{18}O_2$	..	..	..	..
n-Amyloxy	110–113	11	1.4559	77	$C_{11}H_{22}O_2$	70.9	11.9	70.3	11.6
2-Ethylhexyloxy	134–136	8	1.4576	49	$C_{14}H_{22}O_2$	73.6	12.4	73.1	12.5
Benzyloxy	110–112	0.3	1.5290	55	$C_{13}H_{18}O_2$	75.7	8.8	75.6	9.0
β-Phenethoxy	159–162	9	1.5221	48	$C_{14}H_{20}O_2$	76.3	9.2	75.5	9.1
β-Hydroxyethoxy[f,6]	108–110	0.4	1.4797	54	$C_8H_{16}O_3$	..	..	..	..

[a] Fractionations were through a five-inch indented Claisen distillation head. [b] Acetate. [c] Propionate. [d] Recrystallized from hexane. [e] Mousseron and Granger, *Compt. rend.*, **205**, 327 (1937). [f] Miscible with water.

Oxidation of 2-(*p*-Tolyl)-cyclohexanol.—A solution of 23 g. of chromic anhydride in 80 ml. of 80% acetic acid was added to 55 g. of 2-(*p*-tolyl)-cyclohexanol in 80 ml. of acetic acid, the temperature not being allowed to exceed 50°. After twenty-four hours at 25°, the mixture was poured into water and the products were taken up in ether. The ether solution was extracted with a 10%

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[1] This work was performed under Contract NDCrc 136 between Harvard University and the Office of Scientific Research and Development, with Paul D. Bartlett as official investigator.

[2] Present address: Chemical Department, Experimental Station, E. I. du Pont de Nemours & Company, Wilmington, Delaware.

[3] Cook, Hewitt and Lawrence, *J. Chem. Soc.*, 71 (1936).

[4] Wittig, Pockels and Droge, *Ber.*, **71**, 1903 (1938).

[5] Price and Karabinos, THIS JOURNAL, **62**, 1159 (1940).

[6] Holt (assigned to E. I. du Pont de Nemours & Co.), U. S. Patent 2,197,105 (1940).

[7] Gilman, Langham and Moore, THIS JOURNAL, **62**, 2327 (1940).

[8] The cyclohexene oxide was kindly furnished by Dr. A. P. Tanberg of the Chemical Department, Experimental Station, E. I. du Pont de Nemours & Company, Wilmington, Delaware.