ester. Another possibility, that the deposited hydrogen reduces the double bond catalytically, is ruled out since only one-half the required amount of hydrogen would be produced in this way.

The behavior of the derivatives of the *cis* and *trans* acids in neutral solution is normal. All are reduced first at the double bond, for they show two final waves, characteristic of the ketone group. The *trans* form is reduced at more positive potentials than the *cis* form in all instances. This difference suggests the possibility of using the polarographic method to distinguish between such isomers when both forms are available. Values obtained for the *cis* N-dimethylamide confirm the open structure proposed by Lutz.[3c]

The cyclic methyl ester and cyclic N-methylanilide which have a furanone structure, show an entirely different behavior from the corresponding *cis* and *trans* compounds. Both are reduced to a dihydrofuranone since only one wave of two electrons is obtained. The appearance of additional waves at -1.50 and -1.79 v. for the cyclic N-methylanilide in alkaline solution points to a partial hydrolysis of this compound to the *cis* acid.

The anilide in the furanone series behaves differently from the cyclic methyl ester and N-methylanilide in neutral solution. It resembles the anil in the 2-benzoylbenzoic acid series,[1] giving two waves of approximately equal diffusion current constant, 0.91 and 0.97, at -0.99 and -1.63 v., respectively. These waves represent a reduction to a nitrogen-free compound since a third wave, identical to that found for the *trans* acid in neutral solution, is obtained at -2.34 v. This behavior is of interest since the anilide is converted by hydrochloric acid to the *trans* acid.[3c]

The remaining *cis* normal amides have a hydroxypyrrolinone structure, for they are reduced at slightly more negative potentials than their cyclic methyl ethers. Both of these derivatives in all instances are reduced to the corresponding 5 - (*p* - bromophenyl) - 4 - methyl - 2,5 - dihydropyrrolone-2. In each case where the individual half-wave potentials can be measured, the last two waves are identical with the waves obtained for the dihydropyrrolone.

Experimental

The current–voltage curves were determined in a manner similar to that described in the first paper in this series.[2] All measurements were made in a water thermostat at 25 ± 0.1°.

The dropping mercury electrode had the following characteristics. At a pressure of 46.5 cm. of mercury, the drop time in the solvent used was 3.34 seconds (open circuit). The value of m was 2.05 mg. sec.$^{-1}$ with a calculated value of $m^{2/3}t^{1/6}$ of 1.973 mg.$^{2/3}$ sec.$^{-1/2}$.

Materials.—The solutions used had the following compositions and anode potentials: 0.1 *M* tetrabutylammonium iodide, 50% dioxane, anode potential, -0.400 v.; 0.1 *M* tetrabutylammonium iodide, 0.052 *M* tetrabutylammonium hydroxide, 50% dioxane, anode potential, -0.393 v.

The compounds used in this work were prepared by methods given by Lutz and co-workers.[3]

Summary

The polarographic method is a suitable means of distinguishing between the *cis*, *trans* and cyclic derivatives of a typical α,β-unsaturated γ-ketonic acid, 3-(*p*-bromobenzoyl)-3-methylacrylic acid.

An explanation is offered for the anomalous behaviors of the *cis* and *trans* acids in neutral solution.

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Studies on the N-Acetyl-*d*-glucosylamine of Hockett and Chandler[1]

BY CARL NIEMANN AND JOHN T. HAYS[2]

In 1940 Hockett and Chandler[3a] announced the discovery of a second N-acetyl-*d*-glucosylamine $(\alpha)_D$ 87°, and in a recent communication[3b] suggested that this compound, which is isomeric with the previously described N-acetyl-*d*-glucosylamine $(\alpha)_D$ $-22°$,[4] is a N-acetyl-*d*-glucofuranosylamine. Hockett and Chandler obtained this new N-acetyl-d-glucosylamine $(\alpha)_D$ 87° by the reaction of either *aldehydo-d*-glucose pentaacetate or hexaacetyl-*d*-glucoheptonic nitrile with aqueous ammonia, the yield being approximately 56% in the first instance and 26% in the second.[5] We have found that this new N-acetyl-*d*-glucosylamine $(\alpha)_D$ 87° can also be prepared by the reaction of β-*d*-glucose pentaacetate with methanolic ammonia. In spite of the low yield (8%) this reaction is of considerable interest, not only in respect to the formation of N-acylglycosylamines of the above type, but also because alcoholic am-

(1) Taken in part from the Ph.D. Thesis of J. T. Hays, California Institute of Technology, June, 1942.

(2) Present address, Hercules Experiment Station, Wilmington, Delaware.

(3) (a) R. C. Hockett and L. B. Chandler, Division of Organic Chemistry, Cincinnati Meeting, American Chemical Society, April 1940; (b) THIS JOURNAL, **66**, 957 (1944).

(4) (a) P. Brigl and H. Keppler, *Z. physiol. chem.*, **180**, 38 (1929); (b) C. Niemann and J. T. Hays, THIS JOURNAL, **62**, 2960 (1940).

(5) We have observed that the substitution of methanolic ammonia for aqueous ammonia does not significantly alter the yield of the first reaction.

monia has been used repeatedly for the saponification of sugar acetates[6] with no recognition being given to the possibility of secondary reactions.

The known physical properties of the N-acetyl-*d*-glucosylamine $(\alpha)_D$ 87° and its fully acetylated derivative are given in Table I. It will be noted that while the values reported by Hockett and Chandler[3b] and by the authors for the N-acetyl compound are in excellent agreement such is not the case for the pentaacetate.

TABLE I

PROPERTIES OF SECOND N-ACETYL-*d*-GLYCOSYLAMINE AND ITS PENTAACETATE

	N-Acetyl-*d*-glucosylamine		Pentaacetyl-*d*-glucosylamine	
Investigator	M. p., °C.	$(\alpha)_D$ (H_2O)	M. p., °C.	$(\alpha)_D$ ($CHCl_3$)
Hockett and Chandler	192–194	86.9°	82.5–84.5	32.7°
Authors	193–194	86.9°	121.0–121.5	37.2°

The pentaacetyl-*d*-glucosylamine $(\alpha)_D$ 37°, prepared by the acetylation of N-acetyl-*d*-glucosylamine $(\alpha)_D$ 87° with pyridine and acetic anhydride, contains one N-acetyl and four O-acetyl groups and can be readily reconverted into the original N-acetyl-*d*-glucosylamine $(\alpha)_D$ 87° by reaction with methanolic ammonia. In this respect the N-acetyl-*d*-glucosylamine $(\alpha)_D$ 87° is similar in its behavior to the previously described N-acetyl-*d*-glucosylamine $(\alpha)_D$ −22° and one may conclude that both of these compounds possess cyclic carbon–oxygen ring systems with an acetamido group on the first carbon atom.

Hockett and Chandler[3b] have observed that N-acetyl-*d*-glucosylamine $(\alpha)_D$ 87° upon oxidation with lead tetraacetate yields formaldehyde and on the basis of this and a comparison of the rate of oxidation of this substance with that of other glycosides, by lead tetraacetate, concluded that the compound in question is a N-acetyl-*d*-glucofuranosylamine. As previous investigations of Hockett and of Criegee[7] have shown that the oxidation of glycosides by lead tetraacetate may be rather complicated it appeared desirable to compare the rate and extent of oxidation of the two isomeric N-acetyl-*d*-glucosylamines by this reagent. The results of our experiments are given in Table II.

The data presented in Table II suggest that in the case of the N-acetyl-*d*-glucosylamine $(\alpha)_D$ −22°, which contains a glucopyranoside ring system,[4b] the reaction proceeds with the rather slow consumption of slightly more than two moles of oxidant per mole of substance, which is what one might expect on the basis of previous studies.[7] With the N-acetyl-*d*-glucosylamine $(\alpha)_D$ 87° which is considered to contain a glucofuranoside ring system,[3b] one apparently encounters a situation analogous to that observed in the oxidation

(6) Tollens–Elsner, "Kurzes Handbuch der Kohlenhydrate," 4th ed., J. A. Barth, Leipzig, 1935.

(7) See R. C. Hockett, M. H. Nickerson and W. H. Reeder, THIS JOURNAL, **66**, 472 (1944), for references to earlier investigations.

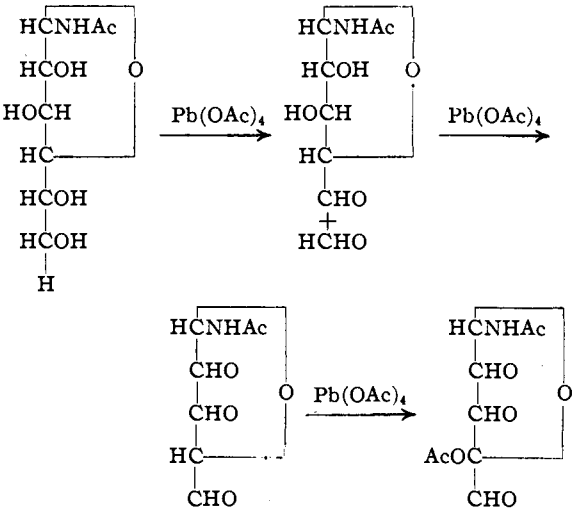
TABLE II

OXIDATION OF ISOMERIC N-ACETYL-*d*-GLUCOSYLAMINES BY LEAD TETRAACETATE

	Moles oxidant consumed per mole substance[a]	
Time, hrs.	Glycoside $(\alpha)_D$ −22°	Glycoside $(\alpha)_D$ 87°
10	0.55	2.35
20	1.00	2.72
30	1.36	2.92
40	1.64	3.06
50	1.84	3.15
60	1.98	3.23
70	2.10	3.28
80	2.18	3.32
90	2.23	3.34
100	2.28	3.36
110	2.30	3.37
120	2.32	3.38

[a] Values interpolated from smooth curves drawn through 8–12 experimentally determined points. Initial molar ratio of oxidant to substance was 7.3:1.

of ethyl-β-*d*-galactofuranoside, studied by Hockett, Nickerson and Reeder,[7] and one may explain, at least in part, our experimental results in terms of the reactions



In an attempt to compare the rate and extent of oxidation of the two isomeric N-acetyl-*d*-glucosylamines by periodate it was observed that while the N-acetyl-*d*-glucosylamine $(\alpha)_D$ −22° behaves in a manner analogous to the corresponding α- and β-methyl-*d*-glucopyranosides, as shown in Table III, the behavior of the N-acetyl-*d*-glucosylamine $(\alpha)_D$ 87° was anomalous in that eventually at least five moles of oxidant were consumed per mole of substance although the rate of reaction was somewhat slower, at least in the later stages, than is usually observed for aldoses[8] or glycosides.[9] Pacsu and Trister[10] noted the con-

(8) L. Malaprade, *Bull. soc. chim.*, [5] **1**, 833 (1934).

(9) E. L. Jackson and C. S. Hudson, THIS JOURNAL, **59**, 994 (1937).

(10) E. Pacsu and S. M. Trister, *ibid.*, **62**, 2301 (1940).

sumption of one mole of periodate by one mole of 5,6-monoacetone-β-ethyl-*d*-galactofuranoside but unfortunately there appears to be no information available on the extent of oxidation of unsubstituted alkyl-*d*-hexofuranosides by this reagent.[11] Therefore the only conclusion that can be drawn from the periodate oxidation studies is that the two N-acetyl-*d*-glucosylamines, $(\alpha)_D$ −22° and $(\alpha)_D$ 87°, are not α,β-isomers.

TABLE III

OXIDATION OF ACETAMIDO- AND METHYL-*d*-GLUCOPYRANOSIDES BY PERIODATE[a]

Time, hr.	*d*-Methyl-glucoside	β-Methyl-glucoside	Acetamido-glucoside
1	1.45		1.49
2	1.74		1.80
3	1.93		1.91
4	2.03	1.95	2.00
10		2.08	2.15

Initial molar ratio of oxidant to substance was 3:1.

While our experimental data support the view of Hockett and Chandler[3b] that the N-acetyl-*d*-glucosylamine $(\alpha)_D$ 87° is a monocyclic N-acetyl-*d*-glucofuranosylamine, it should be pointed out that bicyclic structures containing an ortho-acetamido ring system cannot be rigorously eliminated on the basis of present knowledge.

Experimental

N-Acetyl-*d*-glucosylamine $(\alpha)_D$ 87°. (A).—To 125 ml. of methanol containing 25 g. of ammonia was added 8.7 g. of *aldehydo*-*d*-glucose pentaacetate,[12] m. p. 115–116°, and the solution allowed to stand for five hours before being filtered. The filtrate was concentrated *in vacuo* at 60° to a sirup which was then extracted with several portions of warm ethyl acetate, with discard in each instance of the ethyl acetate phase. The addition of 25–30 ml. of 95% ethanol to the sirup induced crystallization and upon filtration 2.25 g. (45%) of a colorless solid was collected. Recrystallization of this product from 200 ml. of 95% ethanol gave N-acetyl-*d*-glucosylamine, m. p. 193–194°, $[\alpha]^{22}_D$ 86.3° (*c* = 1.1% in water).

Anal. Calcd. for $C_8H_{15}O_5N$ (221): C, 43.4; H, 6.8; N, 6.3. Found: C, 43.6; H, 6.7; N, 6.2.

(B).—Commercial β-*d*-glucose pentaacetate (109 g.) was added to one liter of methanol containing 250 g. of ammonia. After standing for twenty-four hours the solution was filtered, the filtrate concentrated to a sirup *in vacuo* at 60°, and the sirup extracted with several portions of warm ethyl acetate. The residue was dissolved in 500 ml. of boiling 95% ethanol, the solution decolorized with Norite and filtered hot. Five grams of crystalline material (8%) separated on cooling and long standing and was recrystallized first from 95% ethanol and then from aqueous acetone to give N-acetyl-*d*-glucosylamine, m. p. 191–194°, $[\alpha]^{22}_D$ 86.7° (*c* = 1.5% in water). The recrystallized product can be recovered unchanged after refluxing with pyridine, aqueous pyridine and distilled water.

Pentaacetyl-*d*-glucosylamine $(\alpha)_D$ 37°.—A mixture of 1 g. of N-acetyl-*d*-glucosylamine $(\alpha)_D$ 87°, 10 ml. of pyridine and 6 ml. of acetic anhydride was shaken until the solid phase disappeared and allowed to stand for twenty-four hours before the addition of 25 ml. of chloroform. Water was then added to the solution, the chloroform phase washed with aqueous sodium bicarbonate and water, dried, and concentrated to a sirup, and allowed to stand over concd. sulfuric acid. After about a week the sirup set to a solid mass of crystals which were collected, with the aid of ligroin, to give 1.25 g. of crude pentaacetate. This product was recrystallized first from a chloroform–ligroin mixture and then to constant rotation from isopropyl ether to give pentaacetyl-*d*-glucosylamine, m. p. 121–121.5°, $[\alpha]^{22}_D$ 37.2° (*c* = 0.75% in chloroform).

Anal. Calcd. for $C_{16}H_{22}O_{10}N$ (389): C, 49.3; H, 5.9; N, 3.6; O-acetyl, 44.3. Found: C, 49.3; H, 5.8; N, 3.7; O-acetyl, 44.2.[13] The recrystallized pentaacetate (0.4 g.) was added to 15 ml. of methanol saturated with ammonia at 0°. After standing for three hours at room temperature the solution was evaporated to dryness and the residue exhaustively extracted with warm ethyl acetate to give 0.2 g. of a product, m. p. 187–189°, which was recrystallized from 95% ethanol to give N-acetyl-*d*-glucosylamine, m. p. 190–192°, α^{22}_D 87.6° (*c* = 1.2% in water).

Oxidation of the Two N-Acetyl-*d*-glucosylamines with Lead Tetraacetate.—Each of the N-acetyl-*d*-glucosylamines $(\alpha)_D$ −22° and $(\alpha)_D$ 87° (0.0005 mole) was dissolved in 45 ml. of dry acetic acid, 50 ml. of 0.1507 *N* lead tetraacetate solution (0.00367 mole) added and the total volume made up to 100 ml. with dry acetic acid. The solutions were allowed to stand at 25° and at intervals 10 ml. aliquots were withdrawn, added to potassium iodide–sodium acetate solution[14] and titrated with standard thiosulfate solution. The results of these experiments are given in Table II.

Oxidation of the Two N-Acetyl-*d*-glucosylamines with Periodate.—Ten-ml. aliquots of 0.1 *M* solutions of α-methyl-*d*-glucopyranoside, β-methyl-*d*-glucopyranoside, N-acetyl-*d*-glucosylamine $(\alpha)_D$ −22.4° and N-acetyl-*d*-glucosylamine $(\alpha)_D$ 86.9° were allowed to react, at 25°, with 30-ml. portions of 0.1 *M* periodic acid. At suitable intervals the samples were neutralized with aqueous sodium carbonate to a phenolphthalein end-point, and the excess periodic acid determined as previously described.[4b] The results obtained for the first three compounds mentioned are given in Table III. In the case of the N-acetyl-*d*-glucosylamine $(\alpha)_D$ 87° no excess periodate was present at the end of one hour. Consequently an aqueous solution containing 0.001 mole of this compound was added to 50 ml. of 0.1 *M* periodic acid (0.005 mole) and 100 ml. of appropriate buffer solution and the whole made up to 250 ml. at 25°. Aliquots were withdrawn at intervals and the excess periodate determined.[4b] At *p*H 6.9, 2.5 mole of periodate, per mole of substance, was consumed in four hours and 4.7 moles in twenty-four hours. At *p*H 9.3, 0.6 mole of periodate was consumed in four and one-half hours, 2.3 mole in fifteen hours and 5.0 mole in forty hours. In the absence of buffer, 3.6 mole of periodate was consumed in fifteen hours.

Summary

N-Acetyl-*d*-glucosylamine $(\alpha)_D$ 86.9°, previously obtained by reaction of aqueous ammonia with *aldehydo*-*d*-glucose pentaacetate[3] or pentaacetyl-*d*-glucoheptonic nitrile,[3] has now been prepared by reaction of methanolic ammonia with β-*d*-glucose pentaacetate. The behavior of this compound, which is considered to be a N-acetyl-*d*-glucofuranosylamine,[3] toward lead tetraacetate and periodate is described.

PASADENA, CALIFORNIA RECEIVED APRIL 9, 1945

(11) Compare, *e. g.*, E. L. Jackson, "Organic Reactions," **2**, 341 (1944).

(12) M. L. Wolfrom, THIS JOURNAL, **51**, 2188 (1929).

(13) M. L. Wolfrom, M. Konigsberg and S. Soltzberg, *ibid.*, **58**, 490 (1936).

(14) R. C. Hockett and W. S. McClenahan, *ibid.* **61**, 1667 (1939).