color persisted for an hour. The excess permanganate was destroyed with a few drops of 4% sodium bisulfite and the manganese dioxide removed by gravity filtration. The filtrate was divided into two equal portions and to one portion was added a filtered solution of 0.40 g. of 2,4-dinitrophenylhydrazine in 100 ml. of 2 *N* hydrochloric acid. The resulting acetone 2,4-dinitrophenylhydrazone (0.37 g.) was collected, dried and purified by several crystallizations from methanol-water, m. p. 123–124°.

Potassium hydroxide (3 g.) was dissolved in the remaining portion of the filtrate and to the resulting solution was added an excess of iodine–potassium iodide solution. The iodoform precipitate amounted to 0.60 g., m. p. 118–121° (dec.).

Iodoform from C-4 of the glycol was obtained by the following procedure. A mixture of 0.31 g. of 2-methyl-2,3-butanediol, 20 ml. of water and 1.5 ml. of concentrated sulfuric acid was distilled through a short Vigreux column until about 15 ml. of distillate were obtained. The distillate was diluted to 50 ml. and then made alkaline with a solution of 2 g. of potassium hydroxide in 5 ml. of water. Excess iodine–potassium iodide solution was added dropwise and the resulting iodoform removed by filtration. The yield was 0.42 g.; m. p. 119–121° (dec.).

Degradation of Isotopic 2-Methyl-1,2-propanediol.—The procedure for the degradation of 2-methyl-1,2-propanediol paralleled that used for degradation of 2-methyl-1,2-butanediol. The portion of the distillate from the sodium metaperiodate which was treated with methone in water afforded formaldehyde dimethone, m. p. 190.5–191°. The remaining distillate was treated with permanganate and divided into two portions for the preparation of acetone 2,4-dinitrophenylhydrazone and iodoform as described for 2-methyl-1,2-butanediol.

Summary

Several carbonium ion reactions of C^{14}-labeled *t*-butyl and *t*-amyl derivatives have been investigated to determine the ease of rearrangement in such processes to substances with identical carbon skeletons but different locations of the isotopic atoms. This type of rearrangement does not appear to be important in the usual essentially nonreversible metathetical and elimination reactions of *t*-butyl and *t*-amyl alcohols and chlorides.

Isotope-position rearrangements occur in *t*-amyl chloride and less readily in *t*-butyl chloride under the influence of aluminum chloride. The relative rates of formation of the various products are in accord with the accepted order of carbonium ion stabilities.

CAMBRIDGE 39, MASSACHUSETTS
RECEIVED FEBRUARY 7, 1950

[CONTRIBUTION FROM THE EXPERIMENT STATION OF THE HERCULES POWDER COMPANY]

The Synthesis of Acid-soluble Derivatives of Cellulose

BY DAVID S. BRESLOW

Since carboxymethylcellulose, a commercially available cellulose derivative, is soluble in dilute alkali but not in dilute acid, it was considered of interest to prepare a cellulose derivative which would be soluble in dilute acid but not in dilute alkali.

Although there are numerous references in the literature to the preparation of derivatives of cellulose containing basic nitrogen, the great majority of the derivatives prepared were insoluble in dilute acids. The two reactions used most frequently were the reaction of an arylsulfonate ester of cellulose or a cellulose derivative with ammonia or an amine,[1] and the reaction of cellulose or its derivatives with an aminoalkyl halide[1d,2] or sulfate.[3] Hardy[1d] prepared derivatives soluble in dilute acetic acid by treating the *p*-toluenesulfonate ester of a hydroxyalkylcellulose with a secondary alkylamine. Haskins[1e] showed that an acid-soluble derivative was obtained when a *p*-toluenesulfonate ester of cellulose or one of its derivatives which was soluble in organic solvents reacted with a primary or secondary alkylamine. The only successful synthesis of an acid-soluble derivative involving an aminoalkyl halide was that of Hardy,[1d] who prepared sodium cellulosate using sodium in liquid ammonia and treated it with a monohalogen amine salt, such as bromoethylamine hydrobromide.

In recent years it has been shown[4] that cellulose derivatives react readily with aromatic isocyanates to give cellulose aryl carbamates which are soluble in organic solvents. Since little degradation of the cellulose derivatives takes place during this reaction[4b] and since the carbamates are highly resistant to acid hydrolysis,[5] this appeared to be an excellent reaction for preparing cellulose derivatives soluble in dilute acid.

It has been found that the reaction of nicotinyl azide with ethylcellulose and cellulose acetate and the reaction of *p*-dimethylaminophenyl isocyanate with hydroxyethylcellulose give cellulose derivatives soluble in dilute acid. The general procedure for the preparation of the cellulose carbamates involved drying the cellulose derivative by azeotropic distillation of the water with benzene, then the azide or isocyanate plus dry pyridine were added and the reaction mixture was heated at 60–100° until the reaction was com-

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(1) (a) Karrer and Wehrli, *Helv. Chim. Acta*, **9**, 591 (1926); (b) British Patent 279,801 (1926); (c) Hagedorn and Ossenbrunner, U. S. Patent 1,833,286 (1931); (d) Hardy, U. S. Patent 2,136,296 (1938); (e) Haskins, U. S. Patent 2,136,299 (1938); (f) Dreyfus, U. S. Patent 2,241,542 (1941); (g) Kenyon and Reynolds, U. S. Patent 2,360,238 (1944).

(2) (a) Hartmann, U. S. Patent 1,777,970 (1930), (b) German Patent 719,241 (1942).

(3) Guthrie, *Textile Research Journal*, **17**, 625 (1947); U. S. Patent 2,459,222 (1949).

(4) (a) Hearon, Hiatt and Fordyce, THIS JOURNAL, **65**, 829 (1943); (b) Dyer and McCormick, *ibid.*, **68**, 986 (1946); (c) Hearon and Lobsitz, *ibid.*, **70**, 296 (1948).

(5) Hearon, Hiatt and Fordyce, *ibid.*, **65**, 833 (1943).

pleted. The derivatives were precipitated and purified. Their properties are listed in Table I.

TABLE I

PROPERTIES OF ACID-SOLUBLE CELLULOSE DERIVATIVES

	Ethylcellulose β-pyridyl carbamate	Cellulose acetate β-pyridylcarbamate	Hydroxyethylcellulose *p*-dimethylaminophenyl carbamate
Color	Light tan	Tan	Light tan
Nitrogen, %	5.82	11.36	10.20
Degree of substitution	0.62	1.71	1.83
Intrinsic viscosity:			
Derivative	1.3[a]	0.6,[b] 1.8[c]	3.2[e]
Starting material	1.7[a]	...[d]	2.3[e]
Solubility[f]:			
0.1 *N* Hydrochloric acid	S	S	S
5% Acetic acid	I	I	S
10% Acetic acid	I	S	S
Water	I	I	I
Pyridine	S	S	S
Benzene–ethanol (70:30)	S	I	I
Methylene chloride	I	I	I
Methylene chloride–methanol (80:20)			S
Methanol	I	I	I
Acetone	I	I	I
Ethyl acetate	I	I	I

[a] In benzene–ethanol (70:30). [b] In pyridine. [c] In 10% acetic acid. [d] Insoluble in common organic solvents. [e] In 80% acetic acid. [f] In 2.5% solutions; S = soluble, I = insoluble. If the material was swollen but not dissolved, it was considered insoluble.

All three derivatives were soluble in 0.1 *N* hydrochloric acid, but ethylcellulose β-pyridylcarbamate was insoluble in dilute acetic acid, probably because of its comparatively low degree of substitution. The fact that hydroxyethylcellulose *p*-dimethylaminophenylcarbamate was soluble in 5% acetic acid, whereas cellulose acetate β-pyridylcarbamate was soluble only in 10% acetic acid, is rather difficult to explain. Since the degrees of substitution are similar and since pyridine and dimethylaniline are bases of comparable strength, the difference in solubility should probably be attributed to the free hydroxyl groups in the hydroxyethyl derivative.

The intrinsic viscosities were determined by plotting the logarithm of the specific viscosity divided by the concentration against the concentration, reasonably straight lines being obtained in all cases. The fact that the intrinsic viscosity of hydroxyethylcellulose *p*-dimethylaminophenylcarbamate in 80% acetic acid was higher than that of the starting material is apparently due to a solvent effect, since cellulose acetate β-pyridylcarbamate showed a considerably higher intrinsic viscosity in 10% acetic acid than it did in pyridine.

Since cellulose derivatives are known to degrade in the presence of acids, it was of interest to determine the stability of these derivatives in acid solutions. Figure 1 shows the change in viscosity at 25° of 1% solutions of cellulose acetate β-pyridylcarbamate and ethylcellulose β-pyridylcarbamate in 10% acetic acid and in dilute hydrochloric acid (*p*H 2.6), respectively. In acetic acid there was a decrease of about 3% in two weeks and no essential change in viscosity for the next two weeks. In hydrochloric acid there was about a 5% decrease in viscosity in one week. Unfortunately a mold grew in the solution and measurements had to be discontinued after ten days. Although the curve was leveling off at this point, this was probably too short a period to be able to say that the viscosity had reached a constant value.

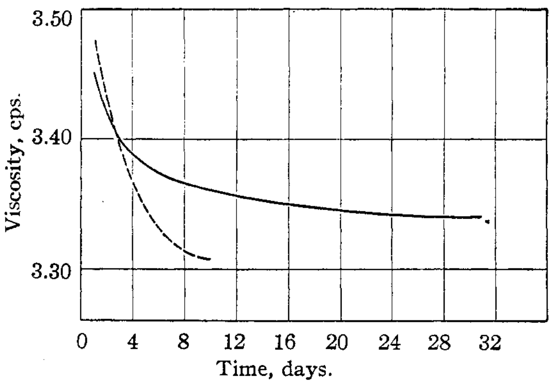

Fig. 1.—Stability of acid-soluble cellulose derivatives: —, cellulose acetate β-pyridylcarbamate in 10% acetic acid; - - - -, ethylcellulose β-pyridylcarbamate in hydrochloric acid.

Experimental

Nicotinyl Azide.—Nicotinyl azide was prepared from ethyl nicotinate by a modification of the method of Curtius and Mohr.[6] To 181 ml. (2.18 moles) of concentrated hydrochloric acid chilled in an ice–salt-bath was added 149 g. (1.09 moles) of nicotinyl hydrazide[6] in small portions below 10°. Keeping the reaction mixture below this temperature, a solution of 154.7 g. (2.18 moles) of 97% sodium nitrite in 250 ml. of water was added drop by drop with stirring. Stirring was continued for fifteen minutes at 0°, and the resulting green oil was separated. The aqueous phase was extracted with ether, the ether layer was combined with the oil, and extracted with saturated sodium bicarbonate solution until neutral. The ether layer was dried over anhydrous calcium chloride for five minutes, over Drierite for thirty minutes, and the ether was then distilled *in vacuo* at room temperature; 131 g. of nicotinyl azide was obtained as a pink solid, melting point 45–49°. Neutralization of the aqueous phase with sodium bicarbonate yielded an additional 10.6 g. of azide, melting point 46–48° (the reported melting point is 47–48°[6]). The total yield was 141.6 g. (88% based on the hydrazide).

Nicotinyl azide has a choking smell and appears to be a skin irritant; it should be prepared and handled in a hood.

***p*-Dimethylaminophenyl Isocyanate.**—*p*-Dimethylaminobenzoic acid was prepared by a modification of the method of Rivier and Richard.[7] Two moles (242 g.) of

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[6] Curtius and Mohr, *Ber.*, **31**, 2493 (1898).

[7] Rivier and Richard, *Helv. Chim. Acta*, **8**, 490 (1925).

dimethylaniline (dried over sodium) was placed in a one-liter, three-necked flask equipped with a stirrer, thermometer, and gas-inlet tube and 99 g. (1 mole) of phosgene (Matheson) was passed in, the temperature being maintained at 0–10°. The mixture was stirred at 0° for one hour, allowed to warm up to room temperature slowly, and left there for three days. The solid, purple mass was treated with excess dilute sodium hydroxide, extracted with ether to remove dimethylaniline, filtered and acidified with acetic acid. The chilled mixture was filtered, the precipitate was washed with water and dried; 82.3 g. (50% yield based on phosgene) of *p*-dimethylaminobenzoic acid was obtained as a blue powder, probably contaminated with Michler ketone, melting point 231–234°. The recorded melting points vary from 234°[8] to 242.5–243.5°.[9]

The methyl ester was prepared by Fischer esterification in the usual manner, melting point 95–97° (the reported melting point is 102°[10]). The yield was 70%, the unreacted acid being readily recovered.

p-Dimethylaminobenzhydrazide was prepared according to Staudinger and Endle.[10] A mixture of 105 g. (0.59 mole) of methyl *p*-dimethylaminobenzoate and 35.2 g. (0.60 mole) of 85% hydrazine hydrate (Edwal Laboratories) was sealed in a Carius tube and heated for five hours at 155°. The semisolid mass was recrystallized from 500 ml. of alcohol, 62.1 g. (59%) of hydrazide being obtained as brown crystals, melting point 164–166° (the reported melting point is 170–171°).[10]

For the preparation of *p*-dimethylaminophenyl isocyanate, 62.1 g. (0.35 mole) of *p*-dimethylaminobenzhydrazide was dissolved in 200 ml. of dilute hydrochloric acid containing 0.38 mole of acid. The solution was cooled to 0°, 200 ml. of ether was added, and then a solution of 27.0 g. (0.38 mole) of 97% sodium nitrite in 50 ml. of water was added drop by drop with stirring at 0–10°. A heavy precipitate formed during the addition. Stirring was continued for fifteen minutes and the reaction mixture was filtered. The filtrate was separated, the aqueous phase was extracted with ether, and the combined ether layers were washed with sodium bicarbonate solution. The solid was dissolved in ether, a small black precipitate was filtered off, and the combined ether solutions were dried over sodium sulfate followed by Drierite. The solution was concentrated to 500 ml. on a steam-bath, and on cooling, yellow crystals were obtained, melting point 93–95° (dec.). The recorded decomposition point of *p*-dimethylaminobenzoyl azide is 97°.[10] The supernatant liquid was added drop by drop to 200 ml. of toluene kept at 100°, and after all the ether had distilled, the solid was added in small portions. The solvent was removed from an oil-bath at 140° and the residue was distilled; 31.5 g. (56% yield) of *p*-dimethylaminophenyl isocyanate was obtained as yellow crystals, boiling point 100–108° at 2 mm., melting point about 35°. The reported melting point of *p*-dimethylaminophenyl isocyanate is 39°.[10]

Ethylcellulose β-Pyridyl Carbamate.—Twenty grams of ethylcellulose[11] (43.9% ethoxyl, degree of substitution 2.2) was dried by adding 150 ml. of benzene and distilling about 100 ml. under slightly reduced pressure. To this was added 200 ml. of pyridine (dried over barium oxide) and 17.2 g. of nicotinyl azide. The reaction mixture was stirred and heated on a steam-bath in an atmosphere of nitrogen for four hours, a clear, brown, viscous solution being formed. Unreacted isocyanate was destroyed by the addition of 50 ml. of methanol, and the cellulose derivative was precipitated by adding the solution to 2 liters of hexane. The hexane was decanted and the precipitate was washed with ether. The tan mass was tumbled with 350 ml. of 1 *N* hydrochloric acid overnight, 500 ml. of water was added, and the resulting faintly cloudy solution was clarified by adding 5 g. of Celite Filter-Aid and filtering. The cellulose derivative was precipitated by adding the filtrate to 2 liters of 1% sodium hydroxide, the precipitate was washed thoroughly with water and dried; 23.0 g. of ethylcellulose β-pyridyl carbamate was obtained as a light tan, granular solid. *Anal.*[12] N (Dumas): 5.94, 5.69; av., 5.82.

Cellulose Acetate β-Pyridylcarbamate.—Cellulose acetate (21.7 g.) containing 35.7% combined acetic acid (degree of substitution 1.3)[13] was dried by adding 100 ml. of benzene and distilling off 90 ml. Dry pyridine (100 ml.) was added, the mixture was stirred and heated on a steam-bath, and a solution of 59.2 g. of nicotinyl azide in 200 ml. of dry pyridine was added drop by drop. The thick gel which formed gradually dissolved, and at the end of five hours a clear, dark-red solution was obtained. The cellulose derivative was precipitated by adding this solution to 2 liters of methanol. The solid was filtered, washed with methanol until the solution remained colorless, then with ether, and finally dried; 25.5 g. of cellulose acetate β-pyridylcarbamate was obtained as a tan solid. *Anal.*[12] N (Dumas): 11.42, 11.30; av., 11.36.

Hydroxyethylcellulose *p*-Dimethylaminophenylcarbamate.—Twenty grams of hydroxyethylcellulose (29.8% hydroxyethoxyl, degree of substitution 1.0)[14] was added to 200 ml. of benzene and 150 ml. of benzene was distilled. To the reaction mixture were added 200 ml. of dry pyridine and 31.5 g. of *p*-dimethylaminophenyl isocyanate. After stirring for 60 hours at 50°, the reaction consisted of a thick, pasty mass; 200 ml. of pyridine and 25 ml. of methanol were added, and the resulting clear solution was poured into 2 liters of isopropyl alcohol. The precipitated cellulose derivative was washed with isopropyl alcohol, dissolved in 900 ml. of 80:20 methylene chloride–methanol, and reprecipitated by adding the resulting solution to 2 liters of isopropyl alcohol. The almost white, fibrous material was washed with isopropyl alcohol and dried, 44.7 g. of hydroxyethylcellulose *p*-dimethylaminophenylcarbamate being obtained. *Anal.*[12] N (Dumas): 10.12, 10.27; av., 10.20.

Summary

Derivatives of cellulose which are soluble in dilute acids have been prepared by the reaction of nicotinyl azide or *p*-dimethylaminophenyl isocyanate with cellulose derivatives. The compounds prepared were ethylcellulose β-pyridylcarbamate, cellulose acetate β-pyridylcarbamate, and hydroxyethylcellulose *p*-dimethylaminophenylcarbamate.

WILMINGTON 99, DELAWARE RECEIVED MARCH 10, 1950

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(8) Bischoff, *Ber.*, **22**, 341 (1889).

(9) Baudisch, *ibid.*, **51**, 1051 (1918).

(10) Staudinger and Endle, *ibid.*, **50**, 1045 (1917).

(11) Hercules Powder Company, Ethyl Cellulose D.

(12) Analysis by Mr. Veto A. Aluise of this Laboratory.

(13) I am indebted to Dr. W. B. Hewson of this Laboratory for a sample of cellulose acetate.

(14) Carbide and Carbon Chemicals Corporation, Cellosize WS500.