obtained as products of the reaction. However, a repetition of their work by Reichstein and Neracher[5] produced mainly 5-keto-D-gluconic acid and only questionable traces of 2-keto-D-gluconic acid. Under acidic conditions Ohle and Berend[6] were able to oxidize barium 2-keto-D-gluconate with barium permanganate to barium D-arabonate in small yield.

We have electrolyzed calcium 2-keto-D-gluconate in aqueous solution at 30° and have obtained calcium D-arabonate in a yield of 65%. Oxidation at 5 to 10° produced 84% of calcium D-arabonate. The absence of objectionable by-products allowed 90% of the product formed to be crystallized directly from the reaction mixture as practically pure calcium D-arabonate pentahydrate. These facts furnish evidence that the mechanism suggested by Honig and Tempus[4] is correct and that both 2-keto-D-gluconic and 5-keto-D-gluconic acids are produced by the hypobromite oxidation of glucose or gluconic acid, the 2-keto acid being converted to D-arabonic acid almost immediately.

Experimental

Oxidation of Calcium D-Gluconate.—A liter of solution was prepared for electrolysis by dissolving 56.1 g. (0.125 mole) of calcium D-gluconate monohydrate and 8 g. of calcium bromide in water. Oxidation took place in a 1500-ml. beaker containing two graphite electrodes ($3 \times 7^{1}/_{2} \times {}^{5}/_{16}$ inches) placed 2 inches apart and immersed about 4 inches. The solution was stirred mechanically and 1 ampere of current passed through for 13.4 hours (0.5 faraday) at 6 to 7 volts. A short time after the electrolysis was begun, the cell temperature rose to 30° and remained at approximately that temperature for the duration of the reaction. The oxidized solution was filtered from 0.5 g. of calcium oxalate and had a reducing value equivalent to 12% of calcium 5-keto-D-gluconate. The latter was isolated in 7.4% yield from half of the solution by the method of Cook and Major.[2] The other half of the reaction mixture was concentrated *in vacuo* to 100 ml. and the calcium salts precipitated by the addition of 1 liter of ethanol. Reaction of the calcium salts with *o*-phenylenediamine[3] gave 9% of crude D-arabobenzimidazole. The more soluble D-glucobenzimidazole remained in solution and was not recovered. Recrystallization of the crude material from 50% ethanol yielded D-arabobenzimidazole of m. p. 234–235° (dec.); $[\alpha]^{25}$D $-49.6°$ (c, 2; 5% citric acid solution). The picrate melted at 161–162°. For L-arabobenzimidazole, Moore and Link[3] reported a melting point of 235° (dec.); $[\alpha]^{26}$D $+49.2°$ and a picrate which melted at 158°.

Oxidation of Calcium 2-Keto-D-gluconate.—A solution of 60.1 g. (0.125 mole) of calcium 2-keto-D-gluconate trihydrate and 8 g. of calcium bromide in 1 liter of water was electrolyzed by the procedure used for calcium D-gluconate. The oxidation was rapid as at no time could bromine be detected. During the reaction, it was necessary to reverse the polarity of the electrodes periodically to remove a deposit of calcium carbonate from the cathode. After the passage of 16.5 ampere-hours (0.62 faraday) of current at a reaction temperature of 5 to 10° the solution had practically no reducing value. Substantially complete oxidation of the calcium 2-keto-D-gluconate had occurred. The oxidized solution was heated on the steam-bath for two hours with 10 g. of calcium carbonate to convert D-arabonolactone present to calcium D-arabonate. The hot mixture was filtered from excess calcium carbonate and the clear filtrate concentrated *in vacuo*. Practically pure calcium D-arabonate pentahydrate crystallized out. The product was collected on a filter and washed with 95% ethanol. The air-dried salt weighed 43.1 g. which is a yield of 75% of theory. It had a specific rotation at 25° of $-3.5°$ (c, 1.00; water) and contained 8.73% calcium. D-Arabobenzimidazole of m. p. 234–235° was obtained from the product in 72% yield. The melting point of a mixture with authentic D-arabobenzimidazole was unchanged. Pure calcium D-arabonate pentahydrate has a calcium content of 8.71% and $[\alpha]^{25}$D $-3.0°$ (c, 1.00; water).

The mother liquor contained 5.8 g. of dissolved calcium D-arabonate which was isolated as D-arabobenzimidazole. The total yield of calcium D-arabonate was therefore 84% of the theoretical.

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[5] Reichstein and Neracher, *Helv. Chim. Acta*, **18**, 892 (1935).

[6] Ohle and Berend, *Ber.*, **60**, 1159 (1927).

[7] One of the laboratories of the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture. Not copyrighted.

The Equilibrium between Ammonia and Hydrogen Telluride[1]

BY F. F. MIKUS[2] AND S. J. CARLYON[2]

In a previous paper,[3] the equilibrium between ammonia and hydrogen selenide has been reported. The investigation has been extended to include the next member of the sulfur family. In this work the equilibrium constants for the dissociation of ammonium hydrotelluride according to the reaction $NH_4HTe(s) \rightleftarrows H_2Te\ (g) + NH_3\ (g)$ were determined in the temperature range of 2.5–25°.

Hydrogen telluride was prepared in a manner similar to that described for the preparation of hydrogen selenide in the previous paper. Extreme precautions to eliminate all air from the system had to be taken as the hydrogen telluride decomposed immediately upon contact with the slightest trace of air. The preparation of anhydrous ammonia and the method of determining the equilibrium have also been described in the previous paper.

Equilibrium pressures over the temperature range 2.5–25° are given in Table I. Three different samples were used at the various temperatures. The equilibrium pressure was obtained by subtracting the difference between the levels of the mercury in the buret and the leveling bulb from the barometric pressure.

Since the total pressure, P, is equal to the sum of the partial pressures of NH_3 and H_2Te, which are found in equivalent amounts as the products of the decomposition of NH_4HTe, the equilibrium constant, $K_p = (P/2)^2$. Determinations made with excesses of H_2Te and NH_3 did not yield con-

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[3] F. F. Mikus and F. J. Poss, THIS JOURNAL, **71**, 429 (1949).

TABLE I

DISSOCIATION OF AMMONIUM HYDROTELLURIDE

Pressure, mm.			Temp., °C.	$K_p \times 10^5$ (p in atm.), av.
9.9	9.9	10.0	2.5	4.2
10.7	10.6	10.7	5.0	5.0
13.3	13.0	13.2	10.0	7.5
16.3	16.0	16.2	15.0	11.3
19.9	20.0	19.7	20.0	17.1
22.7	23.0	22.9	25.0	22.7

sistent results due to the rapid rate at which H_2Te decomposes. The extent to which the decomposition proceeded could not be determined quantitatively.

It was difficult to obtain an accurate analysis on the small amount of solid formed from the reaction between ammonia and hydrogen telluride. The indirect method used in the previous paper could not be used because of the difficulty of handling H_2Te without complete decomposition. The assumption that the product was NH_4HTe is supported by the fact that both NH_4HS and NH_4HSe are formed by the reaction between ammonia and the corresponding hydride at the temperatures used in this work. Bineau[4] stated that he obtained ammonium hydrotelluride under similar conditions.

A plot of log K_p vs. $1/T$, gives a straight line, indicating that the data herein presented satisfy the requirements of van't Hoff's equation. The slope of the line is $-2{,}792$, hence ΔH for the dissociation is 12,280 calories within the indicated temperature range. ΔF at 25° is 4,972 cal./mole and ΔS 24.5 cal./mole/degree K. Using thermodynamic constants from Latimer[5] and the data above, constants were obtained, for 25°, for NH_4HTe: $\Delta H^0_f = 10{,}900$ cal., $\Delta F^0_f = 22{,}090$ cal., and $\Delta S^0_f = -37.6$ e. u.

(4) Bineau, *Ann. chim. phys.*, **67**, 230 (1838).

(5) W. L. Latimer, "Oxidation Potentials," Prentice-Hall, Inc. (1938).

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The Synthesis of 5-Fluoro-DL-tryptophan

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The results obtained in metabolic and toxicity studies based upon the use of the various nuclear substituted monofluoro-phenylalanines and tyrosines[3] have been sufficiently enlightening to justify the extension of this program to include the fluorine derivatives of other naturally occurring α-amino acids. As a step toward this end we wish to report the synthesis of 5-fluoro-DL-tryptophan, a compound of particular interest as a metabolic antagonist in view of the manifold functions of the parent amino acid. The synthesis was patterned after the DL-tryptophan synthesis described by Warner and Moe.[4]

Experimental[5]

***p*-Fluorophenylhydrazine.**[6,7]—*p*-Nitrophenyldiazonium fluoroborate (35.0 g.) prepared as described previously[6,7] was suspended in 50 ml. of mineral oil, the decomposition initiated by heating with a free flame, the reaction mixture steam distilled and the distillate fractionally distilled to give 10.75 g. (52%) of *p*-nitrofluorobenzene, b. p. 97.5° at 15 mm. To a suspension of 3 g. of 7% palladized acid washed Norite in 100 ml. of methanol and 5 ml. of concd. hydrochloric acid was added 12.23 g. of *p*-nitrofluorobenzene, the mixture reduced with hydrogen at 25° and atmospheric pressure, the catalyst removed, 10 ml. of concd. hydrochloric acid added to the filtrate, the solvents and excess hydrogen chloride removed by repeated distillations the residue suspended in 100 ml. of hot acetone, sufficient methanol added to form a single phase, and the solution cooled to give 11.60 g. (91%) of *p*-fluoroaniline hydrochloride, m. p. 253° with dec.

Anal. Calcd. for C_6H_7NFCl (147.6): Cl, 2.4. Found: Cl, 2.4.

The amine was converted into the hydrazine as directed by Schiemann and Winkelmueller.[7] The yield of *p*-fluorophenylhydrazine hydrochloride was 80% and the free base, b. p. 133–134° at 25 mm., was obtained from the hydrochloride in 84% yield. The b. p. of the free base is reported[7] to be 133° at 25 mm. and 129.2° at 21 mm.

***p*-Fluorophenylhydrazone of γ-Acetamido-γ,γ-dicarbethoxybutyraldehyde** (I).—To the reaction product obtained from 13.2 g. of acetamidomalonic ester, 0.075 g. of sodium methoxide, and 4.15 ml. of redistilled acrolein in 19 ml. of benzene[8] was added 2.1 ml. of glacial acetic acid and 7.6 g. of *p*-fluorophenylhydrazine and the reaction conducted essentially as described previously[8] to give 13.9 g. (61%) of crude I. Crude I was recrystallized successively from aqueous ethanol and ethanol to give I, m. p. 105–106°.

Anal. Calcd. for $C_{18}H_{24}O_5N_3F$ (381.4): C, 56.8; H, 6.3; N, 11.0. Found: C, 56.7; H, 6.3; N, 11.0.

Ethyl α-Acetamido-α-carbethoxy-β-(5-fluoro-3-indole)-propionate (II).—Crude I (11.9 g.) was cyclized with aqueous sulfuric acid[4] (heated for two hours) to give 10.1 g. (89%) of crude II, m. p. 130–132°. Repeated recrystallization of a portion of crude II from ethanol gave II, m. p. 137–138°.

Anal. Calcd. for $C_{18}H_{21}O_5N_2F$ (364.4): C, 59.3; H, 5.8; N, 7.7. Found: C, 59.3; H, 5.8; N, 7.7.

α-Acetamido-α-carboxy-β-(5-fluoro-3-indole)-propionic Acid (III).—Saponification[9] of II (3.0 g.) gave 2.3 g. (91%) of III, m. p. 163° with decomp. after recrystallization from aqueous ethanol.

Anal. Calcd. for $C_{14}H_{13}O_5N_2F$ (308.2): N, 9.1. Found: N, 9.1.

Acetyl-5-fluoro-DL-tryptophan (IV).—A 10% aqueous solution of III was heated for two hours at the refluxing temperature and the solution cooled to give IV, m. p. 189–192° after two recrystallizations from ethanol.

Anal. Calcd. for $C_{13}H_{13}O_3N_2F$ (264.2): C, 59.0; H, 5.0; N, 10.6. Found: C, 59.1; H, 4.9; N, 10.6.

5-Fluoro-DL-tryptophan (V).—The saponification of IV with aqueous sodium hydroxide[9] gave preparations of V which were grossly contaminated with inorganic constitu-

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[3] These studies are being conducted in collaboration with Dr. H. K. Mitchell of this Institute. For a preliminary account see THIS JOURNAL, **68**, 1671 (1946); **69**, 1232 (1947)

[4] D. T. Warner and O. A. Moe, *ibid.*, **70**, 2765 (1948).

[5] All melting points are corrected.

[6] G. Schiemann and R. Pillarsky, *Ber.*, **62**, 3035 (1929).

[7] G. Schiemann and W. Winkelmueller, *ibid.*, **66**, 727 (1933).

[8] O. A. Moe and D. T. Warner, THIS JOURNAL, **70**, 2763 (1948).

[9] H. R. Snyder and C. W. Smith, *ibid.*, **66**, 350 (1944).