CCCXLVI.—*Degradations in the Sugar Group.*

By VENANCIO DEULOFEU.

THE methods commonly used for the degradation of carbohydrates are those of Ruff, Wohl, Weermann, and Zemplén, the last being a modification of Wohl's method. The first three appear to be applicable in all cases. Zemplén's method is to be recommended only for sugars higher than the pentoses and methylpentoses, because the high concentration of alkali that is necessary for the reaction decomposes the lower members of the monose series and low yields of sugars are obtained.

Experiments have been made on some sugars by the four methods.

d-*Arabinose.*—The sugar, hitherto degraded only by Ruff (*Ber.*, 1899, **32**, 3674), has now been converted by Wohl's method into *d*-erythrose diacetamide : hydrolysis of this gave *d*-erythrose as a non-crystallising syrup. The production of triacetyl *d*-erythrose by the action of silver oxide on tetra-acetyl *d*-arabononitrile, and also of ammonia-erythrose (erythroseimine) (compare Wohl, *Ber.*, 1899, **32**, 3671, for the *l*-series) has been confirmed. These two compounds could not be obtained by the degradation of *d*-xylose (Deulofeu and Mendive, unpublished work).

Treated by Zemplén's methods, *d*-arabinose gave results similar to those recorded for *l*-arabinose (Deulofeu and Selva, J., 1929, 225).

d-*Xylose.*—The sugar, which has been degraded by Maquenne (*Compt. rend.*, 1900, **130**, 140) by a modification of Wohl's method, and also by Ruff (*Ber.*, 1901, **34**, 1370), was transformed into tetra-acetyl xylononitrile, and this was treated (a) with sodium methoxide and (b) after deacetylation with sulphuric acid, with silver carbonate. In both cases, only traces of erythrosazone were obtained. The syrup obtained in (a) yielded tartaric acid on oxidation with nitric acid.

l-*Rhamnose.*—This methylpentose has been degraded by Fischer (*Ber.*, 1896, **29**, 1380), who used Wohl's method, and also by Ruff (*Ber.*, 1902, **35**, 2360). By the action of alkaline sodium hypochlorite (compare Weermann, *Rec. trav. chim.*, 1917, **16**, 37) the corresponding methyltetrose has now been obtained; it was isolated as the osazone. Zemplén's methods gave results comparable with those recorded above [(a) and (b)], only small quantities of the osazone being isolated.

d-*Galactose.*—The sugar has been degraded by Wohl and List (*Ber.*, 1897, **30**, 3105), Ruff and Ollendorf (*Ber.*, 1900, **33**, 1798), and Weermann (*loc. cit.*), and Neuberg, Scott, and Lashmann

(*Biochem. Z.*, 1909, **24**, 156) have obtained lyxose by the electrolysis of galactonic acid and of its calcium salt.

Treated by Zemplén's methods, penta-acetyl galactononitrile gave 30% of lyxose in method (a) (above) and 22% in method (b). From the *p*-bromophenylhydrazone, crystalline lyxose was obtained identical with the β-form described by Haworth and Hirst (J., 1928, 1221).

d-*Mannose.*—The sugar, hitherto degraded to *d*-arabinose only by Weermann (*loc. cit.*), has now been examined by the other methods. In Wohl's method a 32% yield of *d*-arabinose diacetamide was obtained from the nitrile. Zemplén's methods (a) and (b) gave 61% and 56%, respectively, of arabinose (calculated from the osazone obtained). Method (a) is the best method of degradation, starting with the nitrile. Ruff's method gave only 23% of arabinose, calculated on the calcium mannonate employed.

EXPERIMENTAL.

(1) d-*Arabinose.*—The sugar was obtained from the *p*-bromophenylhydrazone and converted without isolation into the oxime, m. p. 136° : from this, tetra-acetyl arabononitrile was obtained, by treatment with fused sodium acetate and acetic anhydride, in colourless crystals, m. p. 118°, insoluble in water and soluble in chloroform, alcohol, and ether (Found : CN, 8·0. Calc. for $C_{13}H_{17}O_8N$: CN, 8·2%). The nitrile was also prepared from the mother-liquor of the oxime (compare Deulofeu and Selva, *loc. cit.*).

d-*Erythrose diacetamide.* Tetra-acetyl arabononitrile (5 g.) in alcohol (15 c.c.) was treated with a solution of the silver oxide from 3·5 g. of silver nitrate in 40 c.c. of aqueous ammonia (30%). After being kept for 36 hours at room temperature, the liquid was freed from ammonia by a strong current of air, filtered, evaporated, diluted with 50% alcohol, treated with hydrogen sulphide, again filtered, and evaporated in a vacuum. The residual syrup, treated with alcohol–ether (2 : 1), slowly crystallised. Recrystallised from alcohol, the product (1·27 g.; yield, 40%) was obtained colourless, m. p. 210° (Found : N, 12·8. Calc. for $C_8H_{16}O_5N_2$: N, 12·7%).

d-*Erythrose.* A solution of *d*-erythrose diacetamide (3 g.) in 180 c.c. of water was boiled with 9 c.c. of 60% sulphuric acid for an hour, and then concentrated to 18 c.c. in a vacuum. After ten extractions with 18 c.c. of ether to remove most of the acetic acid produced, the liquid was diluted and made alkaline with barium hydroxide, the barium sulphate removed, and the filtrate evaporated. The syrup obtained was repeatedly dissolved in alcohol and recovered by evaporation until it was free from ammonium sulphate. It reduced Fehling's solution in the cold, was very soluble in water, and gave erythrosazone, m. p. 163—165°, on treatment with phenylhydrazine.

Triacetyl erythrose. A solution of tetra-acetyl arabononitrile (5 g.) in 200 c.c. of methyl alcohol was treated with silver oxide (obtained from 10 g. of silver nitrate by means of barium hydroxide) and two drops of concentrated aqueous ammonia. After 42 hours, the solution, which no longer responded to the test for nitrile, was filtered, treated with hydrochloric acid, neutralised, and evaporated at a low temperature in a vacuum; crystals and a syrup were then obtained. The former were separated and recrystallised from alcohol, giving triacetyl erythrose, m. p. 133° (Found: C, 49·2; H, 5·3. Calc. for $C_{10}H_{14}O_7$: C, 48·7; H, 5·6%).

Ammonia-d-*erythrose* (d-*erythroseimine*). A solution of 3 g. of erythrose diacetamide in 180 c.c. of water was treated as described above for the preparation of *d*-erythrose, but after the extraction with ether the sulphuric acid was quantitatively removed with barium hydroxide and the filtrate was freed from barium by means of carbon dioxide, filtered again, and evaporated at 35° under diminished pressure. The crystalline substance obtained was washed with alcohol–ether and recrystallised from water, giving colourless crystals, m. p. 156° (Found: N, 7·3. Calc. for $C_8H_{15}O_6N$: N, 7·1%).

Degradation of tetra-acetyl arabononitrile by Zemplén's methods. (a) After the substance (5 g.) had been treated in the usual manner with sodium methoxide, the solution obtained had reducing properties in the cold, but yielded only 0·04 g. of erythrosazone, m. p. 165—166° (Deulofeu and Selva, *loc. cit.*).

(b) The nitrile (5 g.) was deacetylated with sulphuric acid and then treated with 6 g. of barium hydroxide and 1·5 g. of silver carbonate. From the solution finally obtained, a small quantity of erythrosazone, m. p. 164—165°, was isolated.

(2) d-*Xylose.*—The necessary tetra-acetyl xylononitrile was prepared by a method similar to that employed in the case of *l*-xylose (Deulofeu, J., 1929, 2458).

Degradation of the acetylated nitrile. When 5 g. of the substance were treated as in methods (a) and (b) for the degradation of *d*- and *l*-arabinose, only 0·045 g. and 0·015 g., respectively, of erythrosazone were finally isolated.

Oxidation of d-*threose.* The syrup resulting from the degradation of 20 g. of tetra-acetyl xylononitrile with sodium methoxide was purified by extraction with absolute alcohol. The residue left on evaporation of the extract had the reducing power of 2·9 g. of glucose. 30% Nitric acid (15 c.c.) was added to it, and the solution was kept at 55—60° during 24 hours and then evaporated at low pressure to a syrup; this was diluted with water, re-concentrated, again diluted with water (to 400 c.c.), neutralised while boiling with calcium carbonate, and filtered hot. From the filtrate, after the usual treatment with lead acetate, hydrogen sulphide, acetic acid, potassium acetate, and two volumes of alcohol, crystals of potassium hydrogen tartrate were obtained (Found : K, 20·4. Calc. : K, 20·7%).

(3) l-*Rhamnose.*—*l*-Rhamnonoamide slowly separated from a solution of 10 g. of rhamnonolactone in 70 c.c. of saturated alcoholic ammonia; after recrystallisation from alcohol, it melted at 135° (yield, 6 g. or 60%) (Found : N, 8·1. Calc. : N, 7·8%) (compare Jackson and Hudson, *J. Amer. Chem. Soc.*, 1930, **52**, 1270).

Degradation with hypochlorite. A solution of 20 g. of the amide (1 mol.) in 250 g. of ice-water was treated with a solution of sodium hypochlorite (1 mol.) and sodium hydroxide (1 mol.). After 5 minutes, the liquid was acidified with hydrochloric acid, heated in a water-bath until carbon dioxide ceased to be evolved, neutralised with calcium carbonate, filtered, and concentrated under low pressure. Addition of absolute alcohol then produced a precipitate; this was removed, and the filtrate evaporated in a vacuum : these operations were repeated and the syrup obtained was dissolved in a little water. The solution reduced Fehling's solution in the cold and, when treated with acetic acid and phenylhydrazine, gave an osazone, m. p. 170° (methylerythrosazone melts at 171—176°).

Degradation by Zemplén's methods. (a) Tetra-acetyl rhamnononitrile (5 g.), dissolved in 10 c.c. of chloroform, was treated with a solution of 1·2 g. of sodium in 10 c.c. of methyl alcohol. A reducing solution was finally obtained from which a small quantity of methylerythrosazone, m. p. 170—172°, was isolated.

(b) The acetylated nitrile (5 g.) was boiled with dilute sulphuric acid, and the solution obtained was treated with 1·5 g. of silver carbonate and 6 g. of barium hydroxide. After the usual treatment the solution gave methylerythrosazone, m. p. 171—173°, by interaction with phenylhydrazine in acetic acid. The solutions of the methyltetrose gave positive reactions with α-naphthol and reduced Fehling's solution in the cold.

(4) d-*Galactose.*—*Degradation by Zemplén's methods.* (a) When solutions of 6 g. of penta-acetyl galactononitrile in 15 c.c. of chloroform (cooled in ice and salt) and of 1·2 g. of sodium in 10 c.c. of methyl alcohol were shaken together, a solid mass was produced. After 5 minutes, this was dissolved by the addition of 20 c.c. of water, 2 c.c. of acetic acid were added, the chloroform layer was removed and the aqueous solution evaporated in a vacuum. The residue, after being evaporated twice with 20 c.c. of absolute alcohol, was dissolved in 50 c.c. of water. Titration by the furfural method indicated the presence of 0·69 g. of pentose in the solution (0·121 g.

of phloroglucide compound from 10 c.c.). Another 10 c.c., treated with the calculated quantity of *p*-bromophenylhydrazine, gave 0·3 g. of lyxose-*p*-bromophenylhydrazone, m. p. 155—156° after recrystallisation from water. The yield of pentose from the nitrile was 30%.

The lyxose-*p*-bromophenylhydrazone was boiled with benzaldehyde and water, and the solution obtained was extracted several times with ether and evaporated at 40°. The residual syrup partly crystallised after being kept in a desiccator for 21 days. The solid, recrystallised from absolute alcohol, melted at 115—116° (Haworth and Hirst give m. p. 117—118°), and a solution had $[\alpha]_D$ — 35·1° after 6½ minutes and $[\alpha]_D$ — 15° after ½ hour. The sugar was therefore the β-variety.

(b) The acetylated nitrile (5 g.) was deacetylated with sulphuric acid, and the product treated with silver carbonate and barium hydroxide, in the usual way. Ultimately, 1·1 g. of lyxose-*p*-bromophenylhydrazone were obtained, corresponding to 0·51 g. of lyxose (yield, 22% calculated on nitrile employed).

(5) d-*Mannose.—Penta-acetyl mannononitrile.* A mixture of 5 g. of mannoseoxime (Fischer and Hirschberger, *Ber.*, 1889, **22**, 1155), 5 g. of fused sodium acetate, and 25 g. of acetic anhydride was heated to boiling for a minute and then poured into 50 c.c. of cold water; the resulting black syrup crystallised after some days. The solid was dried and extracted with ether. The extract on evaporation gave penta-acetyl mannononitrile, which separated from alcohol in colourless crystals, m. p. 94°, soluble in ether, alcohol, and chloroform and insoluble in water (yield, 4·2 g., that is, 45%) (Found : CN, 6·7. Calc. for $C_{16}H_{21}O_{10}N$: CN, 6·7%).

Degradation of the nitrile. (i) *By Wohl's method.* Penta-acetyl mannononitrile (5 g.) in 15 c.c. of alcohol was treated with the silver oxide from 2·5 g. of the nitrate dissolved in 25 c.c. of 30% aqueous ammonia. After the usual operations, *d*-arabinose diacetamide (1·03 g.) was obtained, m. p. 187°. The yield corresponds to 0·618 g. of arabinose, that is, 32% calculated on the nitrile used.

(ii) *By Zemplén's methods.* (a) The acetylated nitrile (6 g.) in 10 c.c. of chloroform was treated in the way already described with a solution of 1·2 g. of sodium in 10 c.c. of methyl alcohol. Decomposition of the addition product with water and acidification with acetic acid gave, after evaporation and treatment with ethyl alcohol, a residue, which was dissolved in water. From an aliquot part of the solution, a quantity of arabinosazone (m. p. 203—206°) corresponding to a total yield of 1·42 g. of arabinose (61%, calculated on the nitrile employed) was obtained. (b) When the nitrile was first deacetylated and then treated with silver carbonate and barium hydroxide, the yield of arabinose calculated from the osazone obtained was 1·1 g. or 56% (calculated on the nitrile used).

Degradation of calcium mannonate. A solution of 12 g. of the calcium salt in 50 c.c. of water was warmed at 35° and hydrogen peroxide (1½ mols.) and 3 g. of ferric acetate sol were added. Carbon dioxide was evolved and calcium salts were precipitated. After 10 hours, these were removed and the filtrate was concentrated to a syrup in a vacuum. Addition of 50 c.c. of absolute alcohol then precipitated a further quantity of calcium salts. The solution was decanted and the salts were repeatedly dissolved in a little water and precipitated with alcohol until they were free from reducing substances. The mixed alcoholic extracts were concentrated at a low pressure and the syrup obtained was dissolved in a little water and treated with an alcoholic solution of phenylhydrazine; 3·8 g. of *d*-arabinosazone were precipitated after some time, corresponding to 1·8 g. of arabinose or a yield of 23%, calculated on the calcium mannonate used.

FACULTAD DE CIENCIAS EXACTAS FÍSICAS Y NATURALES,
BUENOS AIRES.

[*Received, August* 19*th*, 1930.]