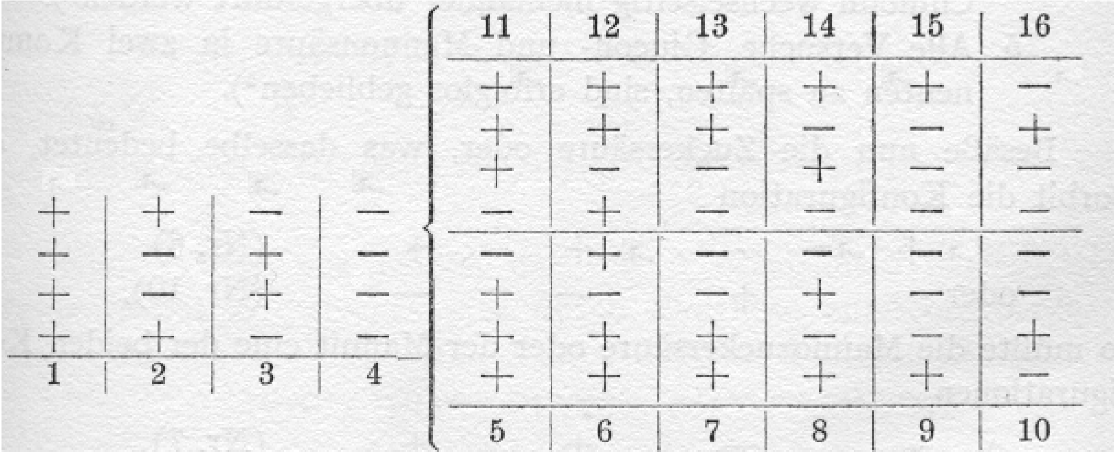
*Berichte der deutschen chemischen Gesellschaft* **24**, 1836 (1891)

# 47. Emil Fischer: On the Configuration of Grape Sugar and its Isomers. I.

*(Received June 6)*
*(Presented by Mr. Tiemann)*

All previous observation on the sugar group agree with the theory of the asymmetric carbon atom is such a complete way that one may now try to use it as a foundation for the classification of these substances. The theory predicts 16 isomers of the structure of grape sugar. This number is reduced to 10 for their symmetrical derivatives.

The following table, taken from page 11 of the van't Hoff-Herrmann pamphlet "The Arrangement of Atoms in Space", presents the 16 different forms of the sugar, wherein Numbers 11-16 become identical with 5-10 for the hexa-alcohol and the dibasic acid:



| | | | |
|---|---|---|---|
| + | + | − | − |
| + | − | + | − |
| + | − | + | − |
| + | + | − | − |
| 1 | 2 | 3 | 4 |

| 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|
| + | + | + | + | + | − |
| + | + | + | − | − | + |
| + | − | − | + | − | − |
| − | + | − | − | − | − |
| − | + | − | − | − | − |
| + | − | − | + | − | − |
| + | + | + | − | − | + |
| + | + | + | + | + | − |
| 5 | 6 | 7 | 8 | 9 | 10 |

For the purpose of choosing the form belonging to grape sugar on the basis of facts, it is first necessary to treat glucaric acid. The two optical antipodes of this are known; furthermore d-glucaric acid can be prepared on one hand from grape sugar (d–glucose) and on the other from the stereoisomeric d-gulose[1].

This implies that both glucaric acids must be among Numbers 5-10, since only these may be formed from two stereoisomeric sugars.

Among these six numbers two, however, are optically inactive (7 and 8) and must therefore be excluded.

Finally Numbers 6 and 10 can now be excluded by the following argument. Glucose and Mannose differ from one another only because of different orientation of the asymmetric carbon atom indicated by * in the following formula:

$$CH_2.OH - CH.OH - CH.OH - CH.OH - \overset{*}{C}H.OH - COH.$$

The same also holds for gluconic and mannonic acid or sorbitol and mannitol, or finally for glucaric and mannaric acid.

I collect here the facts that agree in leading to this conclusion:

---

[1] Berichte d. d. chem. Gesellsch. 24, 521 (1891).

1. Mannose and glucose yield the same osazone[2].
2. On addition of HCN arabinose gives both l-mannonic and l-gluconic acids[3].
3. Fructose is converted by sodium amalgam into a mixture of mannitol and sorbitol[4].
4. Mannonic acid and gluconic acid can be interconverted by heating with quinoline[5].
5. All attempts to separate gluconic and mannonic acid into two components have been futile[5].

If grape sugar or, to the same effect, sorbitol had the configuration

+ - + + (No. 6)

or - + - - (No. 10),

then manaric acid or mannitol would have one of the two configurations

- - + + (No. 7)

or - + - + (No. 8).

These however are optically inactive systems, and are thus excluded by the activity of mannitol and manaric acid.

Thus only two configurations remain for *d*- and *l*-glucaric acid

- + + + (No. 5)

and + - - - (No. 9)

Since it makes no difference what one means by + and -, I arbitrarily give *d*–glucaric acid the formula

$$COOH - \underset{-}{C}H.OH - \underset{+}{C}H.OH - \underset{+}{C}H.OH - \underset{+}{C}H.OH - COOH$$

and the *l*-compound the opposite designation.

*d*-Glucaric acid corresponds to two aldoses

$$COH.\underset{-}{CH(OH)}.\underset{+}{CH(OH)}.\underset{+}{CH(OH)}.\underset{+}{CH(OH)}.CH_2OH$$

or $$COH.\underset{+}{CH(OH)}.\underset{+}{CH(OH)}.\underset{+}{CH(OH)}.\underset{-}{CH(OH)}.CH_2OH.$$

To distinguish which of these formulae belongs to glucose and which to *d*-gulose, it is necessary to consider arabinose and xylose. They belong to the *l*-series; but this is not relevant to the conclusions.

Arabinose can be transformed into *l*–gluose, while under the same conditions *l*–gulose forms from xylose.[6]

---

[2] Berichte d. d. chem. Gesellsch. 22, 374 (1889).
[3] Berichte d. d. chem. Gesellsch. 23, 2611 (1890).
[4] Berichte d. d. chem. Gesellsch. 23, 3684 (1890).
[5] Berichte d. d. chem. Gesellsch. 23, 800 (1890).
[6] Berichte d. d. chem. Gesellsch. 24, 529 (1891).

For *l*-glucose and *l*–gulose there is still the choice between the formulae

$$COH.\overset{*}{\underset{+}{CH}}(OH).\underset{-}{CH}(OH).\underset{-}{CH}(OH).\underset{-}{CH}(OH).CH_2OH$$

$$\text{or}\quad COH.\overset{*}{\underset{-}{CH}}(OH).\underset{-}{CH}(OH).\underset{-}{CH}(OH).\underset{+}{CH}(OH).CH_2OH.$$

If one removes the two asymmetric carbons labeled with *, which were created during the synthesis, the following two formula would remain for arabinose and xylose:

$$COH.\underset{-}{CH}(OH).\underset{-}{CH}(OH).\underset{-}{CH}(OH).CH_2OH$$

$$\text{and}\quad COH.\underset{-}{CH}(OH).\underset{-}{CH}(OH).\underset{+}{CH}(OH).CH_2OH.$$

For the pentoses (of the structure of arabinose and xylose) theory predicts eight isomers; but the number is reduced to four if the molecule becomes symmetric. There are thus only four penta alcohols $CH_2OH.(CHOH)_3.CH_2OH$ or four different trioxyglutaric acids.[7]

Two of these are optically active and opposite one another. These are the two acids of the form:

$$COOH.\underset{+}{CH}(OH).CH(OH).\underset{+}{CH}(OH).COOH$$

$$\text{and}\quad COOH.\underset{-}{CH}(OH).CH(OH).\underset{-}{CH}(OH).COOH;$$

here the middle carbon atom has lost its asymmetry.

The other two forms

$$COOH.\underset{+}{CH}(OH).\underset{+}{CH}(OH).\underset{-}{CH}(OH).COOH$$

$$\text{and}\quad COOH.\underset{+}{CH}(OH).\underset{-}{CH}(OH).\underset{-}{CH}(OH).COOH$$

are on the other hand identical with their mirror images and must thus be optically inactive. It is possible that such isomers are so similar that one cannot differentiate them, since the optical test is naturally excluded.

This makes it possible to distinguish between the two formulae given above for arabinose and xylose, since it is sufficient to test optically the penta alcohols and diacids corresponding to these two sugars.

Experiment yields an unambiguous result.

The arabitol prepared by Kiliani from arabinose is levorotatory for polarized light, as shown previously, upon addition of borax. The same is true for the trihydroxyglutaric acid already prepared by Kiliani from arabinose, as shown below.

On the other hand xylitol prepared from xylose remains inactive even in the presence of borax, and the same applies to the dibasic acid derived from the sugar and described below.

---

[7] In the publication of van't Hoff-Herrmann, on page 10, this case is very briefly reported and the number of isomers is said to be three. However Mr. van't Hoff has been good enough to inform me in response to a private question, that an oversight was involved and that in fact his theory rather predicts 4 isomers, two active and two inactive.

Since the carboxylic acids generally give very strong optical rotation, one may conclude from these results with hight certainty that these derivatives of xylose are in fact optically inactive substances.  Thus it would follow that arabinose has the first of the two formulae given above
and xylose the second.

Thus it is easy to see that the compounds of the hexose family have the following configurations:

Aldoses:

Glucose
Gulose
Mannose

Ketose:
Fructose

etc.