

Chem 221b

Problem Set 9, Chapter 23

Carbohydrates

Due: Monday, April 18, 2005

Last year's PS9 was so good, here it is again.



The graphic on the left was conceived by [M. A. Rosanoff](#) in 1906 as a means of classifying the carbohydrates. It is from this scheme that the modern pyramidal presentation of the carbohydrates is derived. Although the left side of the diagram is the L-series and the right side is the D-series, you will see D's and L's interspersed. The D's and L's within the circle were [Fischer's](#) assignments. Check out the links for Fischer-Rosanoff convention.

For more on Emil Fischer, go [here](#).

Reading Assignments: There are three interconnected websites. [Start here](#). They will be of some assistance for the problems and they will give you the procedure that Fischer actually used in his proof. For a translation of Fischer's original paper, [click here](#). The Powerpoint of the lectures is [here](#).

1. [Manna](#), the sweet exude of the Flowering Ash, has been known for millennia. ["And the house of Israel called its name Manna. And it was like white coriander

seed, and the taste of it was like wafers made with honey." Exodus 16:31] Manna consists of 90% mannite (mannitol). Mannitol forms a bis-acetonide (two equivalents of acetone) to form compound **A**. Compound **A** reacts with HIO_4 to give a single product **B**, D-glyceraldehyde acetonide. Illustrate the reactions involved. What other alditols can, in principle, provide **B** by the same series of reactions?

2. The α -anomer of D-mannose has a rotation 46.3 degrees higher than the β -anomer. [Hudson's Rule: In the D-series the anomer with the higher positive rotation is the α -anomer]. Mutarotated D-mannose has a rotation of $[\alpha]_D = +14.2^\circ$. The ratio α -anomer / β -anomer = 2.1. Calculate the optical rotations of the two anomers and draw their conformational structures.

3. You have learned that the Clemmensen and Wolff-Kishner reductions convert the carbonyl group of aldehydes and ketones to methylene groups. These methods are not applicable in carbohydrate chemistry. An alternative procedure is shown below. [The first step is the same as dithiane formation.]



L-Carbohydrate **A** ($\text{C}_6\text{H}_{12}\text{O}_5$; Yes, the formula is correct) forms an osazone, gives a positive Tollens' test, and reacts with bromine water. When **A** is subjected to the steps shown in the illustration, optically inactive compound **B** is formed. Compound **B** reacts with three equivalents of HIO_4 to give equal amounts of formic acid and acetaldehyde. Ruff degradation of **A** forms **C**, which forms an osazone, gives a positive silver mirror test to give an aldonic acid **D**. However, subjection of **C** to the sequence of two steps in the illustration leads to compound **E**, which is optically active. What are the structures **A-E**? Explain and illustrate.

4. D-Carbohydrate **A** gives an osazone and forms a mixture of methyl pyranosides α -**B** and β -**B** upon exposure to methanolic HCl . Treatment of the mixture of α -**B** and β -**B** with excess aq. $\text{NaOH}/\text{Me}_2\text{SO}_4$ followed by aqueous acid hydrolysis affords pyranoses α -**C** and β -**C**. Treatment of either compound **C** with HNO_3 provides an optically inactive trimethoxyglutaric acid **D**. Fischer-Kiliani synthesis of **A** gives two optically active aldoses **E** and **F**, both of which form optically active alditols **G** and **H**, respectively. **G** cannot be formed from any other aldose than **E**. What are the structures **A-H**? Explain and illustrate.

5. Aldose **A** undergoes Fischer-Kiliani synthesis to form two new aldoses, **B** and **C**. Both **B** and **C**



Fraxinus ornus L.

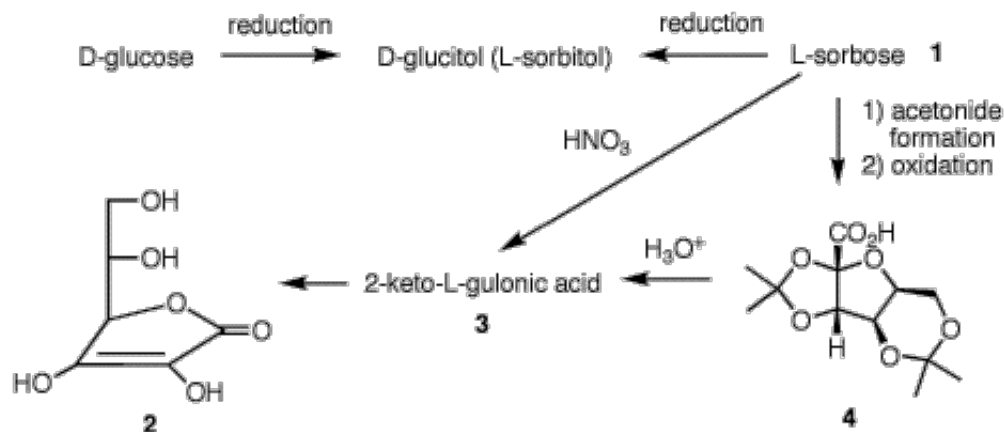
Flowering Ash

give optically active aldaric acids. Ruff degradation of **A** affords **D**, which gives an aldaric acid **E** identical with (+)-tartaric acid (see Chapter 5). What are the structures **A-E**? Explain and illustrate.

6. A newly discovered disaccharide **A** ($C_{12}H_{22}O_{11}$) gives a positive silver mirror test. It is found to mutarotate to a mixture of anomers whose optical rotation is less than that of **A**. Aqueous acid hydrolysis of **A** followed by treatment of the hydrolysate with phenylhydrazine gave **B** and **C**, which were found to be identical with the osazones of D-talose and D-mannose, respectively. When **A** was treated with phenylhydrazine followed by aqueous acid hydrolysis, the only osazone isolated was that of D-talose. Permethylation (total methylation) of **A** with CH_3I/Ag_2O gave **D** (negative Tollens test).

The two lowest field signals in the 1H NMR spectrum of **D** appeared as 12 Hz doublets. Aqueous acid hydrolysis of **D** gave **E** and **F**, both of which form O-methylated aldonic acids. Reduction of compound **E** ($C_{10}H_{20}O_6$) with $NaBH_4$ gave **G**, which upon treatment with acetic anhydride gave (2S,3R,4R,5R)-1,5-diacetoxy-2,3,4,6-tetramethoxyhexane (**H**). Compound **F** ($C_9H_{18}O_6$), upon successive exposure to HIO_4 and nitric acid oxidation, gave **I**, (2R,4R)-2,3,4-trimethoxyglutaric acid. What are the structures **A-I**? Name **A**. Explain and illustrate.

7. The research of Reichstein in the early 1930's employed a combination of biochemical and chemical reactions to produce ascorbic acid **2** (vitamin C). L-Sorbose (**1**) is formed from L-sorbitol by the action of *Acetobacter xylinum*, while L-sorbitol is formed by reduction of D-glucose. L-Sorbose forms the same osazone as L-idose. L-Sorbose forms a bis-acetonide **5** which can be oxidized to carboxylic acid **4**. Hydrolysis of **4** gives **3** which lactonizes to ascorbic acid. Later research showed that **1** could be converted to **3** directly.



a) What is the structure of L-sorbose? Show that D-glucitol and L-sorbitol are identical. Explain and illustrate with Fischer projections.

b) i) What is the structure of **5**? Draw it with absolute stereochemistry numbering the atoms as they are numbered in L-sorbose. ii) Confirm with R,S-configurations that your structures for **1** and **5** have the same absolute stereochemistry at each stereogenic carbon. iii) Why is the stereochemistry at the fusion of the two 5-membered rings in **4** (and/or **5**) cis?

c) Draw a mechanism for the formation of **2** from **3** (lactonization and enediol formation). Does it matter whether the secondary hydroxyl group is drawn on the right or left of the vertical carbon chain in **2**? Why?

d) There are two possible NaBH_4 reduction products of L-sorbose. One is L-sorbitol (D-glucitol), the other one has only one name. Explain and illustrate.

8. The advertisement on the right appeared in the New York Times Magazine on Sunday, April 4, 2004. You can see the Xerox story [here](#).

The structure shown may indeed be one of many that Dow Chemical Company has in its data base. An on-line search of Chemical Abstracts did not find it. If it appears in an ad it is undoubtedly patented and should have been found.

a) Draw this 3-D structure as a flat structure viewing it from the top with bold and dashed lines to indicate stereochemistry. [There is a hidden hydrogen behind the blue oxygen indicated by the blue arrow.]

Clearly this compound has a boat conformation and it has the formula of a hexose, $\text{C}_6\text{H}_{12}\text{O}_6$.

b) It is a hydrate of what structure?

Calls to Xerox and Dow have not been fruitful in determining if this is a known compound or a graphic artist's misrepresentation of a glycopyranose. If the atoms indicated by the

The Dow Chemical Company's archives held 5.5 million pages of R&D. To help researchers access them in minutes instead of days, they turned to Xerox for the correct formula. There's a new way to look at it.

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green arrows had been switched, a true pyranose form of a hexose is formed.

c) Draw a 3-D structure of the "corrected" compound using the template below. Name it.

