LAB-AIDS®
INCORPORATED

Chemistry of Carbohydrates Model Kit

CAT. NO. 510 AND 510-8

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Chemistry of Carbohydrates Model Kit

CONTENTS FOR KIT 510

12 packages containing:

- 12 Carbon tetrahedral centers - black
- 13 Oxygen double electron atoms - blue
- 26 Hydrogen single electron atoms - white
- 26 Covalent Bonds

36 Student Worksheets and Guides

1 Instruction Manual

CONTENTS FOR KIT 510-8

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Chemistry of Carbohydrates Model Kit

Living organisms are composed of considerable numbers of different atoms constantly being exchanged, one for another. These atoms are united to form many types of molecules, all playing important roles in the functioning of the organism. It is difficult to select any one group of these molecules and say that it is the "most important." However, they are essential to the living organism and it is for that reason they should be studied.

Of the organic constituents of protoplasm (the living material) – carbohydrates, fats and proteins – the carbohydrates are the least abundant, the proteins the most abundant.

This kit will be devoted to the study of the Chemistry of Carbohydrates while the #511 kit is devoted to the Chemistry of Fats and the #512 kit is devoted to the Chemistry of Proteins.

In many respects carbohydrates are the simplest organic compounds, and compounds of other kinds are in fact built up from them. They contain the elements carbon, hydrogen, and oxygen, the ratio of hydrogen to oxygen being 2 to 1. This, of course, is the same ratio found in water. The *carbohydr–* portion of the word carbohydrate indicates the presence of carbon and hydrogen. The *-ate* ending denotes the presence of oxygen. The entire word, carbohydrate, implies a water-containing or hydrated carbon. Chemically speaking, this is incorrect, – it does emphasize however, the numerical ratio of these three atoms.

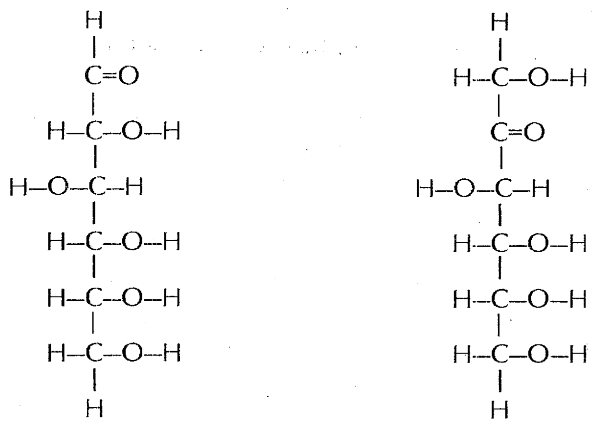
Since the ratio of carbon, hydrogen and oxygen atoms is so constant, a general or *empirical* formula can be devised that applies to almost all carbohydrates. This relationship is expressed by $(CH_2O)n$.

Examples of the simplest carbohydrates are the single sugars or monosaccharides. Glucose is the commonest and the most important as far as organisms are concerned. There are monosaccharides other than glucose, e.g., galactose and fructose. Each has the molecular formula $C_6H_{12}O_6$, but each has a different structural formula which has been determined by precise chemical methods.

The shape or configuration of the molecule may greatly affect its physical and chemical properties. Therefore the arrangement of the atoms and groups of atoms must be studied as well as their proportions. Structural formulas are used to illustrate the spatial arrangements of the parts. See Fig. 1.

The differences between the molecules may seem to be slight, but they are very important and affect their chemical and physical characteristics. In taste, e.g., glucose is not nearly so sweet as fructose.

In cases where two or more compounds have the same molecular formula, but differ structurally, the term *isomer* is applied. For a more complete study of isomers, see LAB-AIDS Kit #133, Organic Chemistry of Molecular Models Kit



GLUCOSE **FRUCTOSE**

FIG. 1. Structural Formulas.

(Isomers). Students will construct with this kit, #510, the three isomers, glucose, galactose and fructose, all with the formula $C_6H_{12}O_6$.

It should be noted that the structural formulas for glucose, galactose and fructose on the student worksheets differs from those in Fig. 1. These substances can exist in two molecular forms, a ring structure and a straight-chain form.

The ring structure of monosaccharides is formed when it reacts with water.

Two monosaccharide molecules can be joined together to form a discaccharide sugar. This is accomplished with the loss of a molecule of water as follows:

$$C_6H_{11}O_5OH + HOO_5H_{11}C_6 \rightarrow C_{12}H_{22}O_{11} + H_2O$$

The disaccharide has the formula $C_{12}H_{22}O_{11}$. The joining of two glucose molecules yields maltose. The joining of galactose and glucose yields lactose and when glucose and fructose unite, ordinary table sugar, sucrose, is formed.

Because synthesis is accomplished with he loss of a molecule of water, it is called *dehydration synthesis*.

Simple sugars may be joined to one another with the loss of water to form more complex carbohydrate molecules. The reverse may also occur. For example, the disaccharide sucrose can be broken down into monosaccharides – glucose and fructose – with the addition of a molecule of water. Similarly, more complex polysaccharides can be broken down into their simpler

constituents with the addition of molecules of water. Such breakdowns with the addition of molecules of water is called *hydrolysis*.

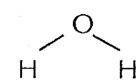
Diaccharides are only the beginning in the construction of complex carbohydrates. Three monosaccharides joined together yield a trisaccharide, such as raffinose. The number of monosaccharides that can be joined is almost limitless.

Beyond three units, the compounds formed are generally called *polysaccharides*. The most important polysaccharides to living organisms are starch, glycogen, cellulose and chitin.

As a general rule, the simplest sugars are highly soluble in water while the most complex carbohydrates are less soluble or insoluble. The insoluble forms are typical storage substances. These storage substances, which are regularly found in protoplasm, remain unchanged in cells until required by the organism. At this time they are hydrolyzed, and the soluble products are used either by the individual cell or by other cells to which they may be transported.

ANSWERS FOR STUDENT WORKSHEET

I. WATER

1. H represents hydrogen
   O represents oxygen
2. The subscript 2 represents the number of atoms of hydrogen
3. Oxygen only has one atom
4. The formula H_2O represents one molecule
5. A molecular formula shows the total number of atoms for each element
7. 
8. A structural formula is an attempt to show the 3-dimensional organization of the molecule.
9. The lines between the O and H represent the chemical bonds or points of attachment between the atoms.

II. A. MONOSACCHARIDES

3. There are six (6) carbon atoms in glucose, fructose and galactose
4. The molecular formulas for glucose, fructose and galactose is $C_6H_{12}O_6$
5. The number of hydrogen atoms to oxygen atoms in the sugars are all the same, that is 2 to 1. They compare the same to water, 2 to 1.
6. Molecules having identical numbers and kinds of elements but with different spatial arrangements of these elements are called isomers.

B. DISACCHARIDES

2. No
3. Yes
4. Water
6. $C_{12}H_{22}O_{11}$
7. $C_{12}H_{22}O_{11}$
8. The ratio is the same (2 to 1)
   The ratio is the same (2 to 1)
   Same (2 to 1)
   Same (2 to 1)
9. Yes
10. Two

C. POLYSACCHARIDES

2. An H and OH end
3. $C_6H_{10}O_5$
4. The same (2 to 1)
   The same (2 to 1)
   The same (2 to 1)

INTERPRETATIONS

1. Monosaccharide molecules must lose an H and OH (water) end before they can join together to form a disaccharide.

2. Glucose molecules must lose H and OH ends so that glucose molecules can join together.

3. All cabohydrates contain the element carbon plus hydrogen and oxygen in a two-to-one ratio just as in water.

LAB-AIDS® #510 and 510-8 Chemistry of Carbohydrates Kit
Student Worksheet and Guide

Biologists nowadays depend upon chemists for much of their understanding of life and the life processes. Therefore an understanding of some chemical concepts important to living things is necessary.

Carbohydrates, fats, proteins and nucleic acids are the four major groups of organic molecules found in living organisms. Carbohydrates make up a large group of organic compounds found in cells. They are generally used for energy or cell structures.

With this lab exercise you will be expected to: **1)** build on information about water in order to develop ideas about carbohydrates; **2)** construct carbohydrate molecular models; **3)** be able to distinguish between models and actual chemical formulas or molecules; and, **4)** be able to determine the molecular characteristics of carbohydrates.

Procedure:

Students should work independently or in teams as directed by their instructor. It will be necessary for each student to complete his own worksheet while *possibly* sharing a packet of molecular parts with other students. The packet of molecular parts consists of:

12	Carbon (C) - tetrahedral electrons - black	26	Hydrogen (H) - single electron - white
13	Oxygen (O) - double electrons - blue	26	Electron bond - plastic tube - white

I. WATER: The chemical formula of water is H_2O. By examining this formula, some information can be gained.

1. What elements make up water? ______
2. What does the subscript number 2 following the H represent? ______
3. Why doesn't the **O** have a subscript? ______
4. How many molecules of water are represented by the formula H_2O? ______
5. What is a molecular formula? ______
   What is the molecular formula of water? ______
6. Build a structural model of water with the parts provided.
7. Draw the structural formula for water.
8. What is a structural formula? ______
9. What do the lines between **O** and **H** represent? ______

II. CARBOHYDRATES: An important group of biological compounds are the saccharides (the sugars of carbohydrates). Carbohydrates contain carbon, hydrogen, and oxygen. The many different types of sugars have been grouped into three main categories:

monosaccharides **disaccharides** **polysaccharides**

A. Single sugars or monosaccharides:

1. Study the structural formulas of the three monosaccharides in Fig. 1.

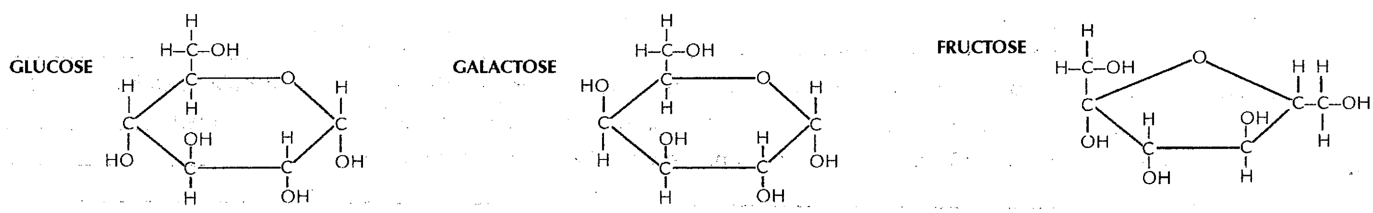


FIG. 1. Structural formulas of three monosaccharides.

2. Construct two different models of the monosaccharides. Join with another team so that all three monosaccharides are built and available for two teams.

The models constructed represent the three-dimensional shapes of the molecules. They illustrate that individual molecules of carbohydrates do differ from one another in general structural shape even though their molecular formulas are the same. They also will illustrate how it is possible for molecules to join together to form different carbohydrates.

3. How many atoms of carbon are there in each molecule of glucose? ______
   fructose? ______ and galactose? ______
4. Write the molecular formulas for glucose______ fructose______ and galactose ______
5. Compare the number of hydrogen atoms to the number of oxygen atoms in each sugar. What is the ratio of hydrogen to oxygen? (i.e., how many hydrogen atoms are there for each oxygen atom?) ______
   How do they compare to the ratio in water? ______
6. The structural arrangement of **C, H,** and **O** in glucose, fructose, and galactose differs. This helps explain why different model shapes are used for each monosaccharide.

Molecules of monosaccharides may have the same molecular formula but differ in three-dimensional structures. This is called isomerism. Using the three models and structural formulas, describe isomerism in you own words. ______

______

B. Double sugars or disaccharides:

Two monosaccharide molecules can chemically join together to form a large carbohydrate molecule called a double sugar, or disaccharide. When a glucose molecule chemically joins with another glucose molecule, a double sugar know as maltose is formed. When a glucose molecule joins with a fructose molecule, a different double sugar called sucrose is produced.

1. In your team, construct a glucose and a fructose model using the illustration in Fig. 1 as a guide.
2. Attempt to join the two molecules and build a sucrose molecule. Will the sucrose molecule stay together? ________
3. It will be necessary to remove an **—OH** end from one molecule and an **—H** end from another in order to join the molecules. Does this enable the two molecules to be joined together? ________________ If so, do so.
4. The **—OH** and **—H** ends removed from the glucose and fructose can now be joined to form what familiar compound? ________________________________ Do so.
5. In your team, construct a maltose by joining together two glucose molecules. Remember to remove **—OH** and **—H** ends to ensure proper joining.
6. Write the molecular formula for maltose. ________________
   (Use structural formulas as a guide and remember that H_2O was lost.)
7. Write the molecular formula for sucrose ________________
8. What are the ratios of hydrogen atoms to oxygen atoms for both molecules? ________________
   How does the ratio of **H** to **O** atoms compare in sucrose and maltose? ________________
   In glucose and fructose? ________________ In water? ________________
9. Compare the model of sucrose to the model of maltose. Does isomerism exist in double sugars? ________
10. How many monosaccharide molecules are needed to form a disaccharide molecule? ________

C. Complex sugars or polysaccharides:

Just as double sugars were formed from two monosaccharide molecules, complex sugars are formed when many single sugars are joined together chemically. The exact number of glucose molecules attached to form these polysaccharides is not known. The two most common polysaccharides in biology are starch and cellulose. They consist of long chains of glucose molecules joined together.

1. With another team, construct a starch molecule by joining four glucose molecules. This represents only a small part of a starch molecule because starch consists of hundreds of glucose molecules. It will be necessary to dismantle the previously made molecules.
2. What must be removed from some of the glucose molecules in order to join them? ________________
3. Using only one of the middle "glucose" molecules of the model, determine the molecular formula of starch. (Remember that a molecule of water has been lost from each glucose molecule when it joined with the others.) ________
4. How does the ratio of **H** to **O** atoms in starch compare with the ratio in double sugars? ________________
   In single sugars? ________________ In water? ________________

Interpretations:

1. **Synthesis** means the "process by which simple compounds are united to form more complex materials." **Dehydration** means "loss of water." Explain why chemists refer to the joining of monosaccharide molecules to form disaccharides as a dehydration synthesis reaction. ________________________________
   ____
2. Why is the joining of four glucose molecules in forming a polysaccharide an example of dehydration synthesis? ____
   ____
   ____
3. The word carbohydrate is derived from carbon and water (hydrate). Explain why this combination correctly describes this chemical group. ________________________________
   ____
   ____

Student's Name ________________________________ Date ________________