Name   Date

Carbohydrates:. Chemistry And Identification

6

Today, scientists use a combination of biology and chemistry for their understanding of life and life processes. Thus, an understanding of some chemistry of living things is necessary. Carbohydrates make up a large group of chemical compounds found in cells. Carbohydrates are an energy source or are used in making cell structures.

In this investigation, you will

(a) learn how to write a molecular formula for several carbohydrates.
(b) learn how to read a structural formula for several carbohydrates.
(c) use models to construct the three main types of carbohydrates.
(d) identify the three main types of carbohydrates by using chemical tests.
(e) test different food samples to determine what type of carbohydrate they are.

REMEMBER: Models do not represent the actual three-dimensional shapes of the molecules. Models serve to help you learn how smaller molecules can be grouped into larger, more complex molecules.

Materials

paper models
scissors
test tubes
test tube holder
glass marking pencil or labels
Benedict's solution
iodine solution
droppers
hot plate
water
beaker (Pyrex)
monosaccharide solution
disaccharide solution
polysaccharide solution
apple juice
oat solution
table sugar solution
honey solution
powdered sugar solution

Procedure

Part A. Water Model

- Examine the chemical formula of water, H_2O.

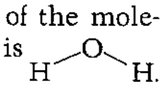
Question: What elements make up water?
Answer: H represents the element hydrogen. O represents the element oxygen. Water is made up of hydrogen and oxygen.

Question: What does the number 2 following H tell you?
Answer: The number 2 represents the number of atoms of hydrogen. A number, called a subscript, following a chemical symbol indicates the number of atoms of that particular element.

Question: Why does the oxygen symbol (O) not have a subscript?
Answer: There is only one atom.

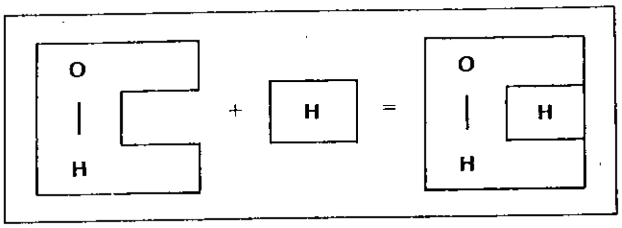
Question: How many molecules of water are represented by the formula H_2O?
Answer: One molecule is represented. The number of molecules is indicated by a number to the left of the formula. No number indicates one molecule.

Question: What is a molecular formula? What is the molecular formula of water?
Answer: A molecular formula shows the total number of atoms for each element in a molecule. The molecular formula of water is H_2O.

Question: What is a structural formula? What is the structural formula of water?
Answer: A structural formula attempts to show the three-dimensional organization of the molecule. The structural formula of water is 

Question: What do the lines between O and H in the structural formula of water represent?
Answer: These lines represent chemical bonds or points of attachment between the atoms.

Question: What is one way water can be represented as a paper model?
Answer: One way water may be represented is shown below. We will use this way of representing water throughout the study of different chemical compounds found in living systems.



Part B. Carbohydrate Models

There are three different groups of carbohydrates. They are called monosaccharides, disaccharides, and polysaccharides. "Saccharide" means sugar.

Group 1. Monosaccharides (single molecule sugars)

A single molecule sugar is called a monosaccharide. The prefix "mono-" means one. However, the one molecule can have different shapes due to a different arrangement of atoms. Three monosaccharides are glucose, fructose, and galactose.

- Examine the structural formulas of these three sugars (Figure 6-1) and answer questions 1 to 6.

1. What three chemical elements are present in the three monosaccharides shown? (NOTE: The letter "C" stands for carbon, "H" stands for hydrogen, and "O" stands for oxygen.)

____

2. How many atoms of carbon are present in a molecule of

glucose? ______________________________

fructose? ______________________________

galactose? ______________________________

3. Add subscripts to the following to indicate the proper molecular formula. Fill in the blanks by counting the total number of carbon, hydrogen, and oxygen atoms in each molecule.

glucose C__H__O__

fructose C__H__O__

galactose C__H__O__

4. Are there two times as many hydrogen atoms as oxygen atoms in a molecule of:

glucose? ______________________________

fructose? ______________________________

galactose? ______________________________

5. Are there two times as many hydrogen atoms as oxygen atoms in a molecule of water?

____

- Compare the structural formula of glucose to fructose.

6. (a) Are they exactly the same in shape?

____

(b) Are they both monosaccharides?

____

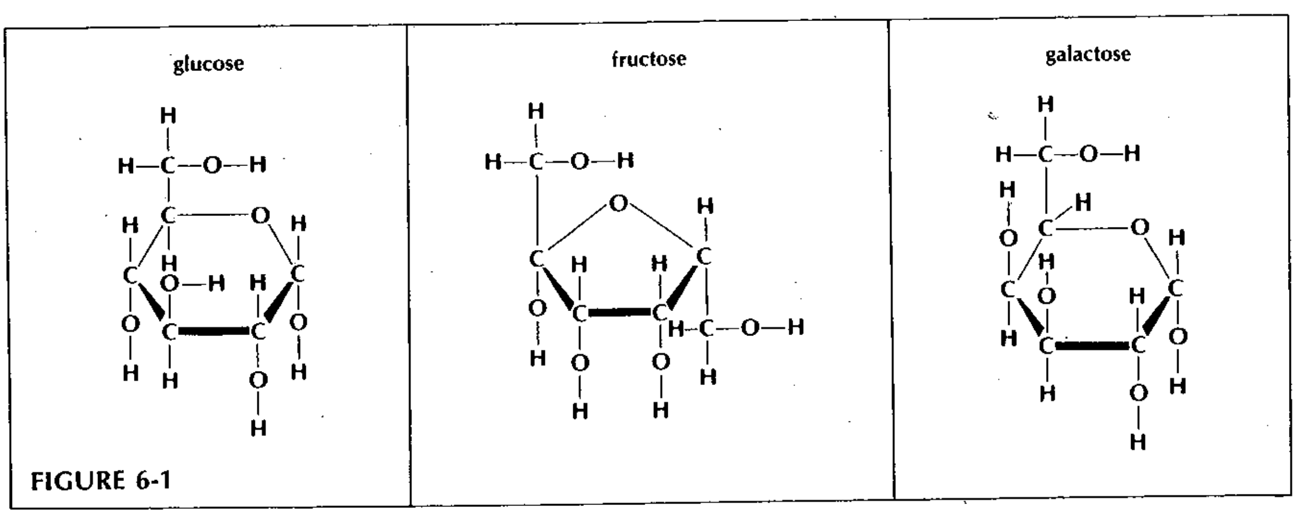


FIGURE 6-1

Group 2. Disaccharides (double molecule sugars) Two monosaccharide sugar molecules can join chemically to form a larger carbohydrate molecule called a double sugar, or disaccharide. The prefix "di-" means two. By chemically joining a glucose molecule with a fructose molecule, a double sugar called sucrose is produced.

Use the page of paper models given to you by your teacher to complete this section.

• Cut out a model of one glucose and one fructose molecule. **CAUTION:** *Always be extremely careful with scissors. Cut along solid lines only.* Attempt to join the two molecules like puzzle pieces.

7. Do the glucose and fructose fit together easily to form a sucrose molecule? ____________

• In order to join the molecules, remove an -OH end from one molecule and an -H end from another. Cut along dotted lines.

8. Does removing the -H and -OH ends now allow the molecules to fit together easily?

____

9. The -H and -OH ends that were removed can also fit together with each other to form a molecule. This new molecule has a molecular formula of ____________________ and is called ____________________.

10. Write the molecular formula for sucrose by adding together the molecular formulas for glucose and fructose and then subtracting water, H_2O. (Use structural formulas for this step, not the models.)

____

Different disaccharide molecules can be made by joining other monosaccharides in different combinations. By chemically joining a glucose molecule with another glucose molecule, a double sugar called maltose is formed.

• Cut out and attempt to join the two new glucose model molecules like puzzle pieces.

11. What must be removed from the glucose model molecules so that they easily fit together? ____________________

12. Write the molecular formula for maltose. (See question 10.) ____________________

13. (a) How does the molecular formula for sucrose compare to maltose? ____________

____

(b) Are there two times as many hydrogen atoms as oxygen atoms in a disaccharide?

____

(c) How many monosaccharide molecules are needed to form one sucrose molecule?

____

(d) How many monosaccharide molecules are needed to form one maltose molecule?

____

Group 3. Polysaccharides (many molecule sugars) Just as double sugars were formed from two single sugar molecules, polysaccharides are formed when many single sugars are joined chemically. The prefix "poly-" means many. Starch, glycogen, and cellulose are the three most common polysaccharides in biology. They consist of long chains of glucose molecules joined.

• Construct a starch molecule by joining three glucose molecules. This model will represent only a small part of a starch molecule because starch consists of hundreds of glucose molecules.

14. What must be removed from the glucose model molecules in order to have them easily fit together? ____________________

The molecular formula for a polysaccharide is written as $(C_6H_{10}O_5)_n$. The *n* equals the number of times the $C_6H_{10}O_5$ group is repeated. You can see this group as the middle glucose of your model. REMEMBER: The -H and -OH ends of the middle molecule are missing.

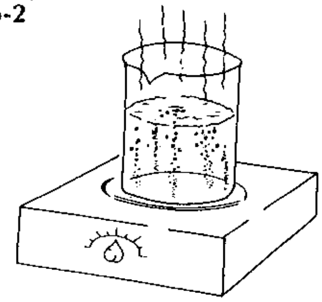
Part C. Identification of Carbohydrates

I. Chemical Tests on Known Carbohydrates

Benedict's Test

• Fill a 500 mL beaker half full of water. Bring the water to a boil on a hot plate. The boiling water is called a hot water bath (Figure 6-2). **CAUTION:** *Water is very hot.*

FIGURE 6-2



• Number three clean test tubes one to three. Using Figure 6-3 as a guide and a clean dropper for each tube, add the following:
Tube 1—30 drops of monosaccharide solution
Tube 2—30 drops of disaccharide solution
Tube 3—30 drops of polysaccharide solution

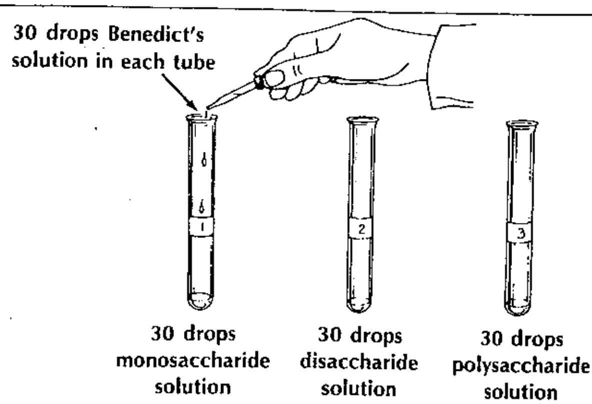


FIGURE 6-3 BENEDICT'S TEST

• Add 30 drops of Benedict's solution to each tube.

CAUTION: *If Benedict's solution spillage occurs, rinse with water and call your teacher.*

• Place the three test tubes into the hot water bath for five minutes.

• Use a test tube holder to remove the tubes from the hot water bath.

CAUTION: *Water and test tubes are very hot. Handle test tubes only with a test tube holder.*

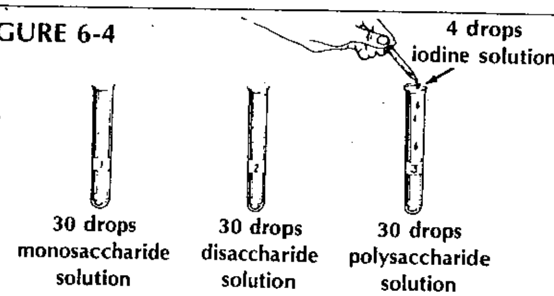
• Observe any color changes in the solutions. NOTE: A color change may or may not occur when Benedict's solution is added to a carbohydrate and then heated. A change from blue to green, yellow, orange, or red occurs if a monosaccharide is present. The original blue color will remain after heating if a disaccharide or polysaccharide is present.

• Record in Table 6-1 the color of the solutions in the tubes in the column marked "Benedict's Color After Heating."

Iodine Test

Number three clean test tubes one to three. Using Figure 6-4 as a guide and a clean dropper for each tube, add the following:
Tube 1—30 drops of monosaccharide solution
Tube 2—30 drops of disaccharide solution
Tube 3—30 drops of polysaccharide solution

FIGURE 6-4



IODINE TEST

• Add 4 drops of iodine solution to each tube. **CAUTION:** *If iodine spillage occurs, rinse with water and call your teacher immediately.*

• Mix the contents of each tube by gently swirling.

• Record in Table 6-1 the color of the solutions in the three tubes in the column marked "Iodine color." NOTE: A color change may or may not occur when iodine solution is added to a carbohydrate. A change from its original rust color to deep blue-black occurs if a polysaccharide is present. The original color of the carbohydrate remains if a disaccharide or monosaccharide sugar is present.

TABLE 6-1. RESULTS OF TESTS WITH KNOWN CARBOHYDRATES

TUBE NUMBER	CARBOHYDRATE TYPE	BENEDICT'S COLOR AFTER HEATING	IODINE COLOR
1	Monosaccharide		
2	Disaccharide		
3	Polysaccharide		

Name Date

II. Chemical Tests on Unknown Carbohydrates

Having tested known carbohydrates, you are now ready to test some unknown substances. By comparing results of the Benedict's and iodine tests in Table 6-1, you should be able to classify known substances as either monosaccharides, disaccharides, or polysaccharides.

- Number five clean test tubes 1 to 5. Using Figure 6-5 as a guide and a clean dropper for each tube, add the following:

tube 1—20 drops of honey
tube 2—20 drops of liquid oats
tube 3—20 drops of table sugar solution
tube 4—20 drops of apple juice
tube 5—20 drops of powdered sugar solution

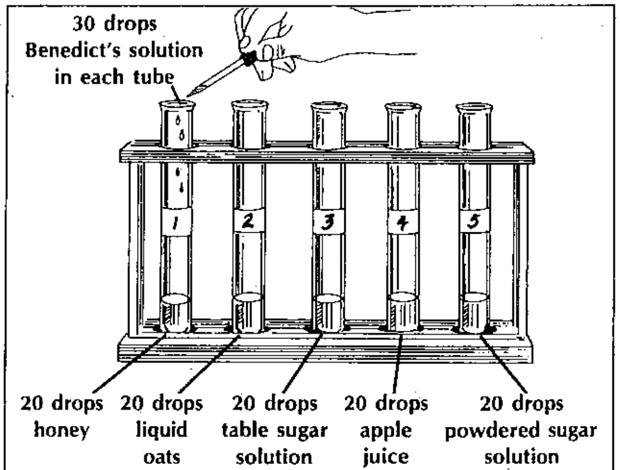


FIGURE 6-5 BENEDICT'S TEST

- Add 30 drops of Benedict's solution to each test tube.
- Place all five test tubes into a hot water bath for five minutes.
- Remove the test tubes from the bath with a test tube holder and note any color changes. Record the color of the solutions in Table 6-2.
- Using Figure 6-6 as a guide, prepare five more test tubes containing the same substances just used (honey, oats, and so on). *Do not add Benedict's solution.*

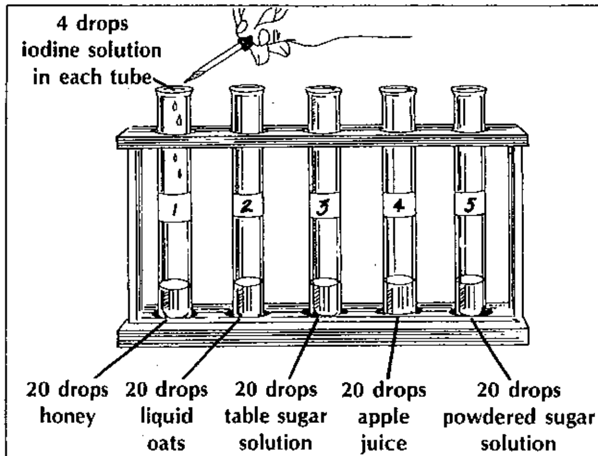


FIGURE 6-6 IODINE TEST

- Add 4 drops of iodine solution to each tube and mix by swirling.
- Note any color changes and record in Table 6-2.

On the basis of your results, classify each carbohydrate as a monosaccharide, disaccharide or polysaccharide and record answers in Table 6-2.

TABLE 6-2. RESULTS OF TESTS WITH UNKNOWN CARBOHYDRATES

CARBOHYDRATE	BENEDICT'S COLOR	IODINE COLOR	TYPE OF CARBOHYDRATE
Honey			
Oats			
Table sugar			
Apple			
Powdered sugar			

Analysis

Use your results from Parts A and B to answer questions 1 to 5.

1. Name the three categories of carbohydrates studied in this investigation. ______

______

2. What three elements are present in all carbohydrates?

______

3. Give two examples each of sugars that are

   (a) monosaccharides. ______

   (b) disaccharides. ______

   (c) polysaccharides. ______

4. (a) How many times larger is the number of hydrogen atoms than oxygen atoms in all carbohydrates?

   ______

   (b) In water? ______

5. "Mono-" means one, "di-" means two, and "poly-" means many. Why are these terms used in describing the three types of sugars? ______

______

Use your results from Part C to answer questions 6 to 9.

6. How can you tell by using Benedict's and iodine solutions if a sugar is a

   (a) monosaccharide? ______

   (b) disaccharide? ______

   (c) polysaccharide? ______

7. A certain sugar has no change in color when tested with Benedict's solution.

   (a) Can you tell what type of saccharide it is? ______

   (b) Explain: ______

   ______

8. A certain sugar has a color change in Benedict's solution.

   (a) Can you tell what type of saccharide it is? ______

   (b) Explain: ______

   ______

9. Give an example of a food that is a

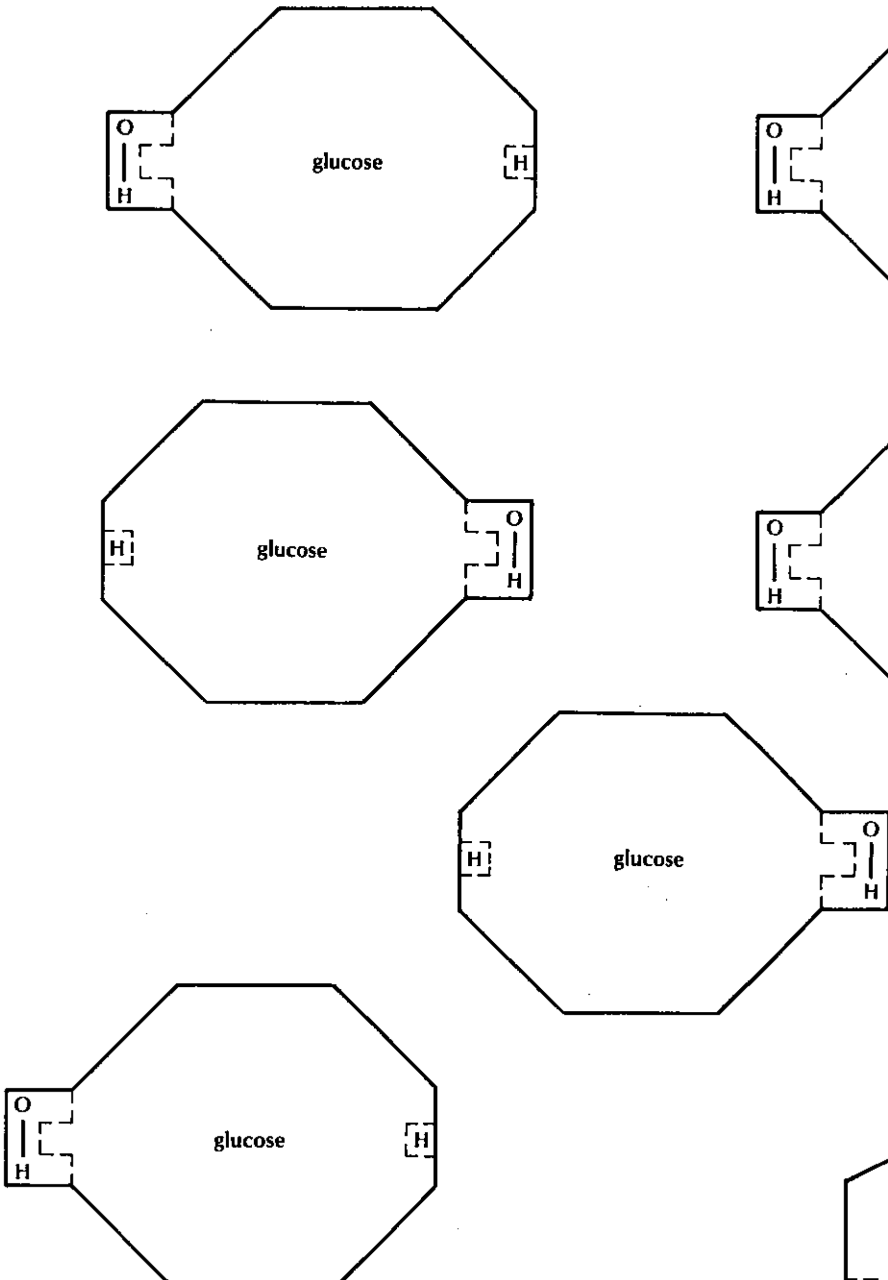
   (a) monosaccharide. ______

   (b) disaccharide. ______

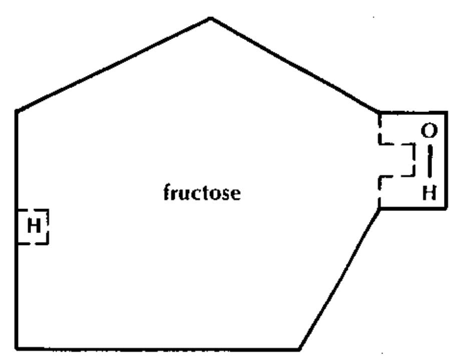
   (c) polysaccharide. ______

MODELS FOR INVESTIGATION 6, "CARBOHYDRATES: CHEMISTRY AND IDENTIFICATION"

models of glucose



model of fructose



(only end atoms of hydrogen and oxygen are shown in models)