Carbohydrates

Performance Goals

D-glucose

- 33-1 Perform tests on various types of carbohydrates.
- 33–2 Identify an unknown carbohydrate.

CHEMICAL OVERVIEW

Carbohydrates are a class of organic compounds composed of carbon, hydrogen, and oxygen. Carbohydrates include polyhydroxyaldehydes (aldoses) and polyhydroxyketones (ketoses) or more complex molecules that can be broken down to yield these compounds. Many of our most common foods, such as rice, bread, potatoes, and fruits, are rich in carbohydrates.

The formulas of carbohydrate molecules can be represented by openchain structures or by ring structures (Figure 33.1). All simple sugars in their open-chain form contain either an aldehyde group, —CHO, or a carbonyl group, —C=O. Glucose contains six carbons and has a —CHO group in its open-chain form; therefore, it is classified as an **aldohexose**. Fructose is a **ketose** since it contains a ketone (carbonyl) group. Because fructose has six carbon atoms it is referred to as a **ketohexose**. The predominant forms of glucose and fructose in solution are the ring structures.

$$C = O$$
 $C = O$
 $C =$

Figure 33.1 *Open-chain and ring structures of glucose*

α-D-glucopyranose

Further classification of carbohydrates is based on the number of simplest molecules (monosaccharides) present. Disaccharides, so-called "double sugars," are the result of the combination of two monosaccharides. Common examples of disaccharides are lactose (milk sugar), sucrose (table sugar), and maltose. Polysaccharides, such as starch and cellulose, are very large molar mass polymers composed of many monosaccharide units.

Disaccharides and polysaccharides can be broken down to smaller units by hydrolysis (reaction with water). Sucrose and starch can be hydrolyzed under strongly acidic conditions or by using a biological catalyst called an enzyme.

Many spot tests are available that allow identification of major carbohydrates. In this experiment we will be using the following tests:

1. Fehling's test. This test is used to determine if sugars containing free aldehyde or ketone groups are present. These sugars, called **reducing** sugars, can react with mild oxidizing agents, such as Cu^{2+} in Fehling's solution, to yield Cu_2O , a red-orange solid.

$$Cu^{2+}$$
 + reducing sugar $\rightarrow Cu_2O(s)$ + oxidized sugar (*Red-orange*)

- **2. Iodine test.** Polysaccharides, such as starch, produce a characteristic blue color when they react with a solution containing iodine. It is believed that a complex is formed that varies in intensity and shade of color depending on the size of the molecule, the concentration of iodine, and the temperature.
- **3. Seliwanoff's test.** This test is used to differentiate between an aldohexose and a ketohexose. The *quick* appearance of a deep red color is a positive indication of a ketohexose, such as fructose. Aldohexoses react much more slowly.
- **4. Barfoed's test.** The difference in reaction rate between reducing monosaccharides and reducing disaccharides with cupric acetate solution is the basis for this test. The smaller the sugar, the faster the reaction rate.

SAFETY PRECAUTIONS AND DISPOSAL METHODS

The reagents used in this experiment contain fairly concentrated acids, bases, and organic compounds that may cause burns or irritation to skin. Avoid contact with all solutions and wear eye protection while performing the experiment. Also, be careful when handling the boiling-water bath.

Collect all your solutions in a waste container or as directed by your instructor.

PROCEDURE

A boiling-water bath is required for some of the tests in this experiment. Pour about 200 mL of deionized water into a 400-mL beaker and heat it to

boiling. Maintain it at that temperature, replenishing the water from time to time as it becomes necessary.

1. Fehling's Test

Prepare the reagent for this test by mixing 20 mL of Fehling's solution A with 20 mL of Fehling's solution B. Add 1 mL of 1% solution of glucose, fructose, sucrose, lactose, and starch to separate, labeled test tubes, and then add 5 mL of the mixed Fehling's reagent to each test tube. Heat the test tubes in the boiling-water bath for 5 minutes and record your observations on the work page.

2. lodine Test

Add 1 mL of 1% solution of glucose, fructose, sucrose, lactose, and starch to separate, labeled test tubes, and then add 3 drops of dilute iodine solution to each. Prepare a sixth test tube with 1 mL of deionized water and 3 drops of iodine solution. Compare the colors observed and record them in the report sheet.

3. Seliwanoff's Test

Dilute the fructose and glucose solutions available to 0.5% (2 mL sugar solution + 2 mL deionized water). Add 1 mL of each into separate test tubes, prepare a third one with 1 mL of deionized water. Add 10 mL of Seliwanoff's reagent to each test tube and place it into a boiling-water bath. Using a stopwatch (or second hand on your watch), record the time required for a color change to occur. Use the deionized water as a blank. Discontinue the heating after 10 minutes.

4. Barfoed's Test

Add 2 mL of 1% solution of fructose, glucose, and lactose to three separate, labeled test tubes. Add 5 mL of Barfoed's reagent to each test tube, mix, and place the test tubes into a boiling-water bath. Observe the time when a reaction becomes apparent (solution becomes cloudy or changes color). Discontinue heating after 15 minutes. Record your observations.

5. Analysis of an Unknown

Obtain an unknown solution from your instructor that may contain one of the following carbohydrates: fructose, glucose, sucrose, lactose, or starch. Using the tests you performed above, determine which compound is present in your solution. Remember, fructose and glucose are monosaccharides, sucrose is a nonreducing disaccharide, lactose is a reducing disaccharide, and starch is a polysaccharide. Be sure to record your unknown number!

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Name	Date	Section

Experiment 33

Advance Study Assignment

1. Complete the table below:

	Fehling	g's Test	Iodine	e Test	Seliwano	off's Test	Barfoed	l's Test
Substance	Yes	No	Yes	No	Yes	No	Fast	Slow
Glucose								
Fructose								
Sucrose					X	Х		
Lactose					X	Х		
Starch					Х	Х	Х	Х

2. What group of compounds gives a positive iodine test? Give an example.

3. (Optional) Sucrose is a disaccharide of glucose and fructose. Honey is a mixture of glucose and fructose. Explain why honey is a quicker energy source than table sugar (sucrose).

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Experiment 33

Work Page

Part 1—Fehling's Test

Substance	Test Tube	Yes	No
Glucose	1		
Fructose	2		
Sucrose	3		
Lactose	4		
Starch	5		
Unknown			

Part 2—Iodine Test

Substance	Test Tube	Color
Glucose	1	
Fructose	2	
Sucrose	3	
Lactose	4	
Starch	5	
H ₂ O	6	
Unknown		

Part 3—Seliwanoff's Test

Substance	Test Tube	Yes	No	Time
Fructose	1			
Glucose	2			
H ₂ O	3			
Unknown				

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Part 4—Barfoed's Test

Substance	Test Tube	Time
Fructose	1	
Glucose	2	
Lactose	3	
Unknown		

Part 5—Analysis of an Unknown	
Unknown number	Compound present

Name	Date	Section

Experiment 33

Report Sheet

Part 1—Fehling's Test

	0		
Substance	Test Tube	Yes	No
Glucose	1		
Fructose	2		
Sucrose	3		
Lactose	4		
Starch	5		
Unknown			

Part 2—Iodine Test

Substance	Test Tube	Color
Glucose	1	
Fructose	2	
Sucrose	3	
Lactose	4	
Starch	5	
H ₂ O	6	
Unknown		

Part 3—Seliwanoff's Test

Substance	Test Tube	Yes	No	Time
Fructose	1			
Glucose	2			
H ₂ O	3			
Unknown				

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Part 4—Barfoed's Test

Substance	Test Tube	Time
Fructose	1	
Glucose	2	
Lactose	3	
Unknown		

Part 5—Analysis of an Unknown		

Unknown number	Compound present
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