Hydrolysis and Dehydration Synthesis

Topic

Ball-and-stick models can demonstrate hydrolysis and dehydration synthesis in carbohydrates.

Introduction

Living things are made up of both *inorganic* and *organic compounds*. Generally, inorganic compounds are those that do not contain the element carbon. Water is the most important inorganic compound in organisms. Organic compounds are based on carbon, an element that is perfect for its central role in living things. Carbon has four electrons in its outer *valence shell*, giving it the ability to form four *covalent bonds*. These bonds can occur between carbon atoms or between carbon and other elements. For this reason, carbon easily forms long chains, as shown in Figure 1, as well as rings and other structures.

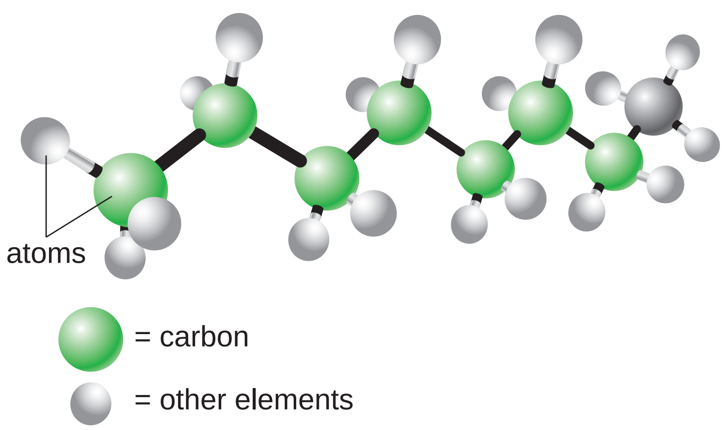


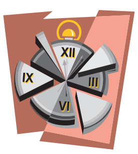
Figure 1

Ball-and-stick model of carbon chain

There are four basic groups of organic compounds: carbohydrates, lipids, proteins, and nucleic acids. The first three are important parts of our diets. Carbohydrates include sugars and starches, which are made up of carbon, oxygen, and hydrogen. Carbohydrates are classified by size and solubility. The smallest carbohydrates are *monosaccharides* (mono means "one," saccharide denotes "sugar"). Monosaccharides are small enough to pass through a cell membrane, so they can travel from the blood into cells. *Glucose* is the most important monosaccharide in living things because cells can break down this simple sugar to make energy in the form of *ATP*. Others monosaccharides include fructose and galactose, which are different forms of glucose, as well as deoxyribose and ribose, sugars found in DNA and RNA respectively.

Two monosaccharides can join in the chemical reaction of *hydrolysis* to form a *disaccharide* ("two sugars"). Disaccharides include sucrose, which is also known as table sugar, and lactose, milk sugar. Disaccharides cannot pass through a cell membrane so they must be broken down into monosaccharides to be useful to the body. The breakdown of a disaccharide into two monosaccharides requires water and the process is called *hydrolysis*.

Several monosaccharides can form chains called polysaccharides ("many sugars"). Although monosaccharides dissolve easily in water, polysaccharides do not. Generally, the larger a carbohydrate molecule, the harder it is for that molecule to dissolve in water. This insolubility makes polysaccharides excellent storage molecules. Three important polysaccharides are *starch*, *glycogen,* and *cellulose*. Starch, a plant product, is found in foods like corn and potatoes. When we eat these foods, our bodies digest them and convert the carbohydrate molecules into glucose that our cells can use. Cellulose is also made by plants, but humans cannot digest it. Cellulose is important in the diet as fiber or bulk because it helps move digested foods through the intestines. Glycogen is a polysaccharide that stores glucose molecules in animal tissue. If blood levels of glucose get high, the body stores some as glycogen. If blood levels of glucose drop to low levels, the body breaks down some glycogen and circulates it in the blood. In this experiment, you will use models to show how glucose molecules participate in two chemical reactions, hydrolysis and dehydration synthesis.



Time Required

55 minutes for part A
55 minutes for part B

Materials

- ball-and-stick models (or gumdrops and toothpicks)
- colored pencils
- access to the Internet
- science notebook

Safety Note **Please review and follow the safety guidelines.**

Procedure, Part A

1. Access the Internet and carry out a search to find the ring structure of a glucose molecule. Draw the ring structure in your science notebook. Color the hydrogen atoms blue, the oxygen atoms red, and the carbon atoms green.
2. Search the Internet to find out what happens to glucose molecules when they undergo dehydration synthesis. Draw the process of two glucose molecules undergoing dehydration synthesis in your science notebook.
3. Continue your search to find what happens to a disaccharide when it undergoes hydrolysis. Draw the process of a disaccharide undergoing hydrolysis in your science notebook.

Procedure, Part B

1. Using ball-and-stick models (or gumdrops and toothpicks), create models of two glucose molecules. Refer to the drawings in your science notebook. Use blue balls (or gum drops) for hydrogen atoms, red balls (or gum drops) for oxygen atoms, and green balls (or gum drops) for carbon atoms.
2. Use your models of glucose molecules to show what happens when they undergo dehydration synthesis.
3. Use the model you created in step 2 to show what happens during hydrolysis.

Analysis

1. Explain the difference between organic and inorganic compounds.
2. Why is carbon able to form so many types of molecules?
3. Define *dehydration synthesis*.
4. Define *hydrolysis*.
5. During dehydration synthesis, one molecule of glucose loses an OH. What does the other molecule of glucose lose?
6. What do H and OH form?
7. During hydrolysis, two joined molecules of glucose are broken apart. In the process, one molecule of glucose gains an H. What does the other molecule of glucose gain?

What's Going On?

The ring structure of glucose is made of five carbon atoms and one oxygen atom joined to form a ring. The sixth carbon atom is attached to the carbon to the left of the oxygen atom (see Figure 2). Five hydroxyl groups (OH) are added to all of the carbon atoms except the one to the left of the oxygen, as shown in Figure 3. Seven hydrogen atoms are added at the positions shown in Figure 3.

When two glucose molecules join, the chemical reaction is called dehydration synthesis. This is an important process in making disaccharides and polysaccharides. During dehydration synthesis, the OH on one glucose molecule and H on another are removed, exposing the bonding sites of the two molecules (see Figure 4). The process gets its name from the fact that the two glucose molecules lose water (dehydration) to form a new molecule (synthesis).

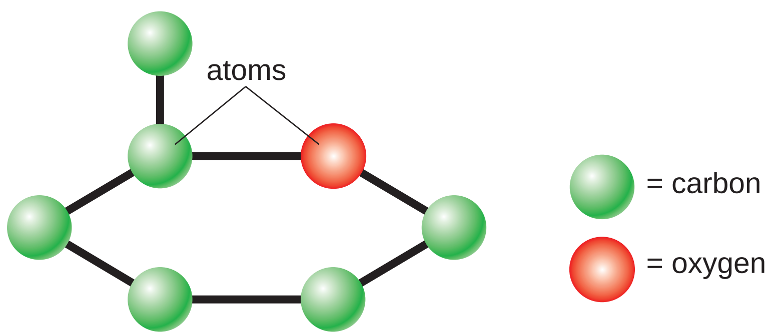


Figure 2

Ball-and-stick model of glucose

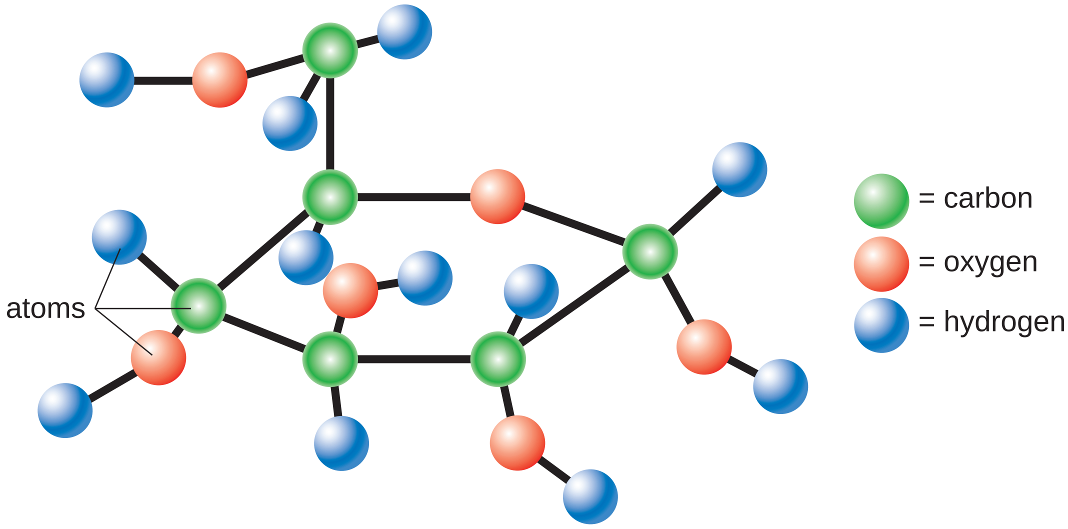


Figure 3

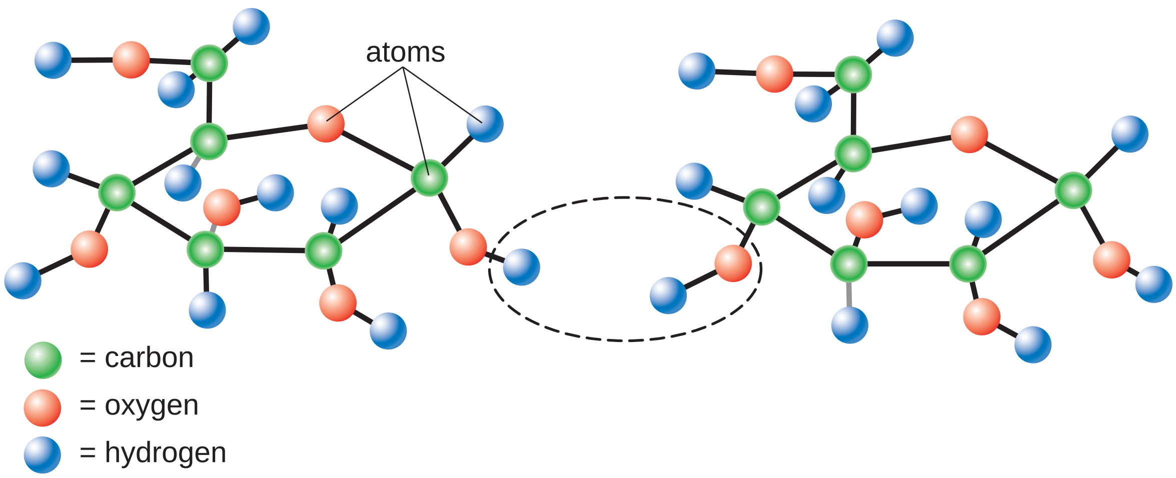


Figure 4

The reverse reaction occurs when the disaccharide breaks down into two glucose molecules. Hydrolysis (splitting with water) is the breakdown of a molecule by the addition of water. During hydrolysis of a disaccharide, hydrogen is added to one glucose molecule and hydroxide (OH) is added to the other to produce two complete molecules.

Connections

Carbohydrates are only one of the important organic compounds found in living things. The other three are proteins, lipids, and nucleic acids.

Proteins are long molecules made up of *amino acids*. There are 20 different amino acids, but they all have the same basic amine structure (NH_2) on one end and organic acid group (COOH) on the other. The differences among amino acids are due to their unique side groups, also known as the R group. When two amino acids join together, they do so by the process of dehydration synthesis. The bond between two amino acids is called a *peptide bond*. Like carbohydrates, they break apart by the process of hydrolysis.

Lipids are large molecules made of chains of fatty acids and glycerol molecules. They include fats and oils (triglycerides) that protect the body and store energy, phospholipids found in cell membranes, and steroids in cholesterol. Lipids do not dissolve in water, but will dissolve in organic solvents like ether and alcohol. The largest molecules in living things are nucleic acids, which are made up of carbon, hydrogen, oxygen, nitrogen, and phosphorus. Nucleic acids are made up of long chains of nucleotides. The two types of nucleic acids are DNA and RNA.

Want to Know More?

See Our Findings.

OUR FINDINGS

HYDROLYSIS AND DEHYDRATION SYNTHESIS

Idea for class discussion: Point out that water is essential for life. One of the reasons living things need water is to make chemical reactions possible. Explain that water is involved in combining atoms to make molecules and in breaking apart molecules.

Analysis

1. Organic molecules contain carbon; inorganic molecules do not.
2. because carbon has four valence electrons
3. Dehydration synthesis is a chemical reaction that joins two molecules by removing a molecule of water.
4. Hydrolysis is a chemical reaction that breaks apart a molecule into two molecules by adding water.
5. H
6. water
7. OH

SAFETY PRECAUTIONS

Review Before Starting Any Experiment

Each experiment includes special safety precautions that are relevant to that particular project. These do not include all the basic safety precautions that are necessary whenever you are working on a scientific experiment. For this reason, it is absolutely necessary that you read and remain mindful of the General Safety Precautions that follow. Experimental science can be dangerous, and good laboratory procedure always includes following basic safety rules. Things can happen very quickly while you are performing an experiment. Materials can spill, break, or even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following the basic safety guidelines during the entire experiment, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual experiments. For one reason, we want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical.

Read the safety precautions here and at the beginning of each experiment before performing each lab activity. It is difficult to remember a long set of general rules. By rereading these general precautions every time you set up an experiment, you will be reminding yourself that lab safety is critically important. In addition, use your good judgment and pay close attention when performing potentially dangerous procedures. Just because the book does not say “Be careful with hot liquids” or “Don’t cut yourself with a knife” does not mean that you can be careless when boiling water or using a knife to punch holes in plastic bottles. Notes in the text are special precautions to which you must pay special attention.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking an unnecessary risk can be avoided by practicing safety procedures and being alert while conducting experiments. Be sure to check the individual experiments in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone. When you are working off-site, keep in groups with a minimum of three students per groups, and follow school rules and state legal requirements for the number of supervisors required. Ask an adult supervisor with basic training in first aid to carry a small first-aid kit. Make sure everyone knows where this person will be during the experiment.

PREPARING

- Clear all surfaces before beginning experiments.
- Read the instructions before you start.
- Know the hazards of the experiments and anticipate dangers.

PROTECTING YOURSELF

- Follow the directions step by step.
- Do only one experiment at a time.
- Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eyewash, and first-aid kit.
- Make sure there is adequate ventilation.
- Do not horseplay.
- Keep floor and workspace neat, clean, and dry.
- Clean up spills immediately.
- If glassware breaks, do not clean it up; ask for teacher assistance.
- Tie back long hair.
- Never eat, drink, or smoke in the laboratory or workspace.
- Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult.

USING EQUIPMENT WITH CARE

- Set up apparatus far from the edge of the desk.
- Use knives or other sharp-pointed instruments with care.

- Pull plugs, not cords, when removing electrical plugs.
- Clean glassware before and after use.
- Check glassware for scratches, cracks, and sharp edges.
- Clean up broken glassware immediately.
- Do not use reflected sunlight to illuminate your microscope.
- Do not touch metal conductors.
- Use alcohol-filled thermometers, not mercury-filled thermometers.

USING CHEMICALS

- Never taste or inhale chemicals.
- Label all bottles and apparatus containing chemicals.
- Read labels carefully.
- Avoid chemical contact with skin and eyes (wear safety glasses, lab apron, and gloves).
- Do not touch chemical solutions.
- Wash hands before and after using solutions.
- Wipe up spills thoroughly.

HEATING SUBSTANCES

- Wear safety glasses, apron, and gloves when boiling water.
- Keep your face away from test tubes and beakers.
- Use test tubes, beakers, and other glassware made of Pyrex™ glass.
- Never leave apparatus unattended.
- Use safety tongs and heat-resistant gloves.
- If your laboratory does not have heat-proof workbenches, put your Bunsen burner on a heat-proof mat before lighting it.
- Take care when lighting your Bunsen burner; light it with the airhole closed, and use a Bunsen burner lighter in preference to wooden matches.

- Turn off hot plates, Bunsen burners, and gas when you are done.
- Keep flammable substances away from flames and other sources of heat.
- Have a fire extinguisher on hand.

FINISHING UP

- Thoroughly clean your work area and any glassware used.
- Wash your hands.
- Be careful not to return chemicals or contaminated reagents to the wrong containers.
- Do not dispose of materials in the sink unless instructed to do so.
- Clean up all residues and put them in proper containers for disposal.
- Dispose of all chemicals according to all local, state, and federal laws.

BE SAFETY CONSCIOUS AT ALL TIMES!