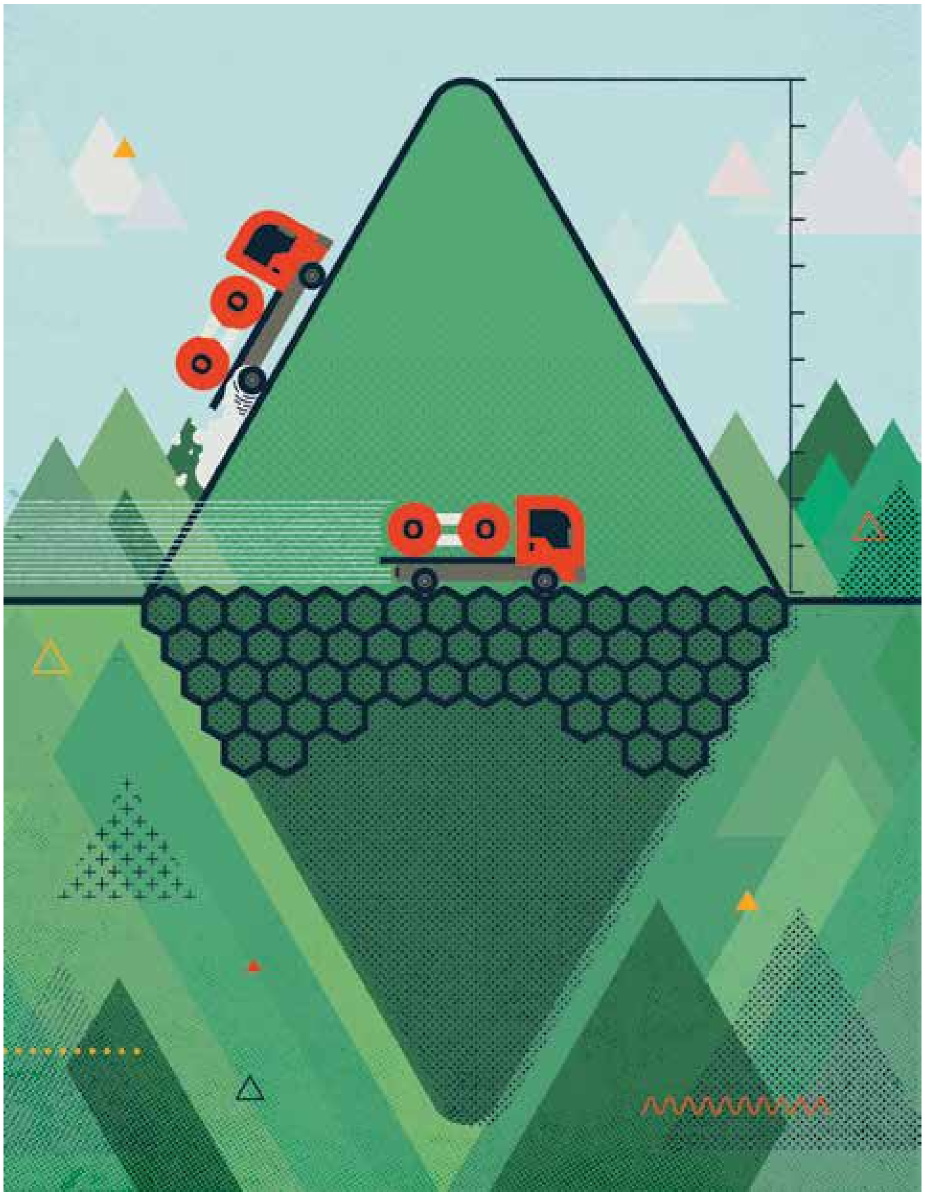
Science News

IN HIGH SCHOOLS | EDUCATOR GUIDE



©JAMES PROVOST

March 4, 2017

Built for Speed

SOCIETY FOR SCIENCE & THE PUBLIC

SN EDUCATOR GUIDE

March 4, 2017
Built for Speed

About this Issue

The article “Built for speed” (10.8 readability score) discusses how catalysts make a wide range of chemical reactions possible, and how scientists are developing improved catalysts that would be less expensive, more efficient or have other advantages. Students can focus on details in the article, follow connections to earlier articles about catalysts, explore cross-curricular connections to other major science topics and conduct their own experiments to demonstrate the ability of catalysts. *Science News for Students* provides an explainer titled “What is a catalyst?” as an additional student resource.

Want to introduce your students to an interesting STEM career related to this article? Check out Cool Jobs: Chemistry: Green and clean by *Science News for Students*.

Connections to Curricula

- Catalysts
- Enzymes
- Chemical reactions
- Activation energy
- Crystalline structure
- Engineering
- Biochemistry
- Nanomaterials
- Fuel cells

What’s in this Guide?

- **Article-Based Observation:** These questions focus on reading and content comprehension by drawing on information found in the article “Built for speed.” Questions focus on the use of catalysts in common industrial reactions and new research on alternatives to the precious metals currently used as catalysts.
- **Quest Through the Archives:** With Internet access and your school’s digital access to *Science News*, your students can use this short section to explore the history of catalytic material technology as reported by *Science News* since 1922.
- **Cross-Curricular Discussion:** These questions and extension prompts connect to the article “Built for speed” and encourage students to think in more detail about scientific areas related to the articles. The section is subdivided roughly by science subdiscipline for educators who would like to focus on one particular topic area. The extension prompts are either more topic-specific or more conceptually advanced. **Chemistry** questions address the basics of chemical catalysts and the chemical reactions that they facilitate. **Other Physical Sciences** questions explore the energies and other physical properties of catalysts, with extensions to the catalysis of nuclear reactions. **Biological Sciences** questions focus on enzymes as biological catalysts in living organisms. **Engineering and Experimental Design** questions probe various applications of catalysts and the efficiency of their designs. A crowd-pleasing demonstration titled Elephant’s Toothpaste, found at the beginning of this section, can start the catalysts discussion. This demonstration uses a catalyst to drastically increase hydrogen peroxide’s rate of decomposition.

- **Activities**: This section includes two student experiments based on catalysts. **Illuminating Catalysts** has students test different types of catalysts and conditions for the light-producing luminol reaction. In **From Lactose to Glucose**, students test the effect of different conditions on lactase, an enzyme that catalyzes the conversion of lactose (milk sugar) to glucose (simple sugar).

Standards Alignment

Next Generation Science	Common Core
Matter and Its Interactions: HS-PS1-1, HS-PS1-2, HS-PS1-4, HS-PS1-5, HS-PS1-6, HS-PS1-8	ELA Standards: Reading Informational Text (RI): 1, 2, 4, 5, 7
Motion and Stability: HS-PS2-6	ELA Standards: Writing (W): 1, 2, 3, 4, 6, 7, 9
Energy: HS-PS3-1, HS-PS3-2, HS-PS3-3	ELA Standards: Speaking and Listening (SL): 1, 2, 4, 6
From Molecules to Organisms: Structures and Processes: HS-LS1-5, HS-LS1-6, HS-LS1-7	ELA Standards: Reading for Literacy in Science and Technical Subjects (RST): 1, 2, 3, 4, 5, 7, 8, 9
Earth's Place in the Universe: HS-ESS1-1, HS-ESS1-3	ELA Standards: Writing Literacy in History/Social Studies and Science and Technical Subjects (WHST): 1, 2, 4, 6, 7, 9
Earth's Systems: HS-ESS2-2, HS-ESS2-4, HS-ESS2-6	
Engineering Design: HS-ETS1-1, HS-ETS1-2	

March 4, 2017
Built for Speed

Article-Based Questions

Directions: Read the article "Built for speed" and then answer these questions:

1. **Pick out your favorite metaphor used by the author to describe a catalyst. Use it to explain the purpose of a catalyst in a chemical reaction.**

2. **Liming Dai and other scientists are engineering new materials that have a catalytic power similar to platinum. Why is there a need for new catalytic materials?**

3. **Carbon might be an alternative to platinum and other precious metals used as catalysts. Chemist Huixin He notes that carbon structures alone aren't catalytically active. What alterations are made to carbon structures so that they can serve as catalysts?**

4. **Huixin He's team is working with phytic acid as an alternative catalytic material. How are the researchers transforming phytic acid into a catalyst and what are the advantages of using it?**

5. **Explain the advantages and disadvantages of using enzymes as catalysts for industrial purposes.**

6. **Rather than finding alternatives to catalytic metals, chemist Younan Xia is researching ways to minimize platinum waste. What structures are Xia and his team developing and why are they effective catalytically?**

7. **Briefly explain why "Built for speed" is a fitting title for this article.**

March 4, 2017
Built for Speed

Responses to Article-Based Observation

1. **Pick out your favorite metaphor used by the author to describe a catalyst. Use it to explain the purpose of a catalyst in a chemical reaction.** Possible student response: The author describes a catalyst as a "molecular matchmaker." During a chemical reaction, molecular bonds are broken and new bonds are formed between different atoms. Catalysts help increase the rate of a reaction by bringing reactant atoms or molecules together, which changes the reaction pathway. Though they help lower the activation energy needed to start the reaction, catalysts aren't chemically altered or used up during the reaction.

2. **Liming Dai and other scientists are engineering new materials that have a catalytic power similar to platinum. Why is there a need for new catalytic materials?** Possible student response: Platinum and other precious metals are often used as catalysts in clean energy technologies. Developing cheaper, more abundant and sustainable substitutes for these metal catalysts could allow clean energy technologies to compete with fossil fuels.

3. **Carbon might be an alternative to platinum and other precious metals used as catalysts. Chemist Huixin He notes that carbon structures alone aren't catalytically active. What alterations are made to carbon structures so that they can serve as catalysts?** Possible student response: One carbon structure that researchers are working with is graphene, a chicken wire–like sheet of carbon atoms bonded in hexagonal rings. Rolled up sheets of graphene, known as carbon nanotubes, have also been used as the base of carbon catalysts. To make graphene or the nanotubes catalytically active, researchers have also been replacing some of the carbon atoms in the ring with nitrogen or other atoms. The specific application for these catalysts will determine the type of atom impurity and the carbon structure needed.

4. **Huixin He's team is working with phytic acid as an alternative catalytic material. How are the researchers transforming phytic acid into a catalyst and what are the advantages of using it?** Possible student response: Phytic acid is a substance composed of carbon, oxygen and phosphorus. He's team is microwaving liquid phytic acid to form a sooty black powder. The energy of the microwaves heats up and rearranges the atoms to form an amorphous structure of carbon and phosphorus atoms. The main advantage of this phytic acid–derived catalyst is that it is very easy to make. It has sped up reactions that produce fuel from hard-to-use molecular reactants found in plant cellulose.

5. **Explain the advantages and disadvantages of using enzymes as catalysts for industrial purposes.** Possible student response: Inside living things, enzymes assist with everything from copying genetic information to processing nutrients. Enzymes are specific to a reaction and don't expend much energy catalyzing unwanted side reactions. Another advantage is that they can be easily altered for a particular set of reactants. A disadvantage is that they are often too fragile to use in industrial manufacturing.

6. **Rather than finding alternatives to catalytic metals, chemist Younan Xia is researching ways to minimize platinum waste. What structures are Xia and his team developing and why are they effective catalytically?** Possible student response: Xia and his team are developing platinum "nanocages." To create the nanocages, palladium cubes are coated with a thin layer of platinum. The palladium inside is chemically removed, leaving a hollow platinum skeleton. Since only the top layer of a catalyst interacts with the reactants, the structure maximizes the surface area of the platinum to reduce the amount of unused platinum.

7. **Briefly explain why "Built for speed" is a fitting title for this article.** Possible student response: Scientists are using many different methodologies to build the most effective, cost-efficient catalysts possible. Catalysts allow important industrial reactions, such as the reactions in a fuel cell, to occur at a much faster rate.

SN
IN HIGH SCHOOLS

March 4, 2017
Built for Speed

Quest Through the Archives

Directions: After reading the article "Built for speed," use the archives at www.sciencenews.org to answer these questions:

1. **Search for an article that discusses the use of catalysts in developing new energy technologies. Explain the article.**

2. **Search for an article that discusses alternatives to platinum in catalytic converters. Describe the alternative and how it works.**

3. **Search for the earliest published article about catalytic action. What anecdotal story demonstrates catalytic action?**

Responses to Quest Through the Archive

1. **Search for an article that discusses the use of catalysts in developing new energy technologies. Explain the article.** Possible student response: "Hydrogen made using sunlight, cheap materials," published 9/16/2014, discusses the use of chemical catalysts to produce hydrogen and oxygen from water and energy derived from sunlight. Using sunlight to produce hydrogen as a fuel source would be a clean, efficient way to store the sun's energy.

2. **Search for an article that discusses alternatives to platinum in catalytic converters. Describe the alternative and how it works.** Possible student response: "Building a cheaper catalyst," published on 4/24/2010, discusses using perovskite as an alternative to platinum catalytic converters in diesel vehicles. Wei Li at General Motors' Global Research and Development branch replaced a platinum-based catalyst with one made of manganese-based perovskite. The resulting reaction rate was faster than the rate using platinum.

3. **Search for the earliest published article about catalytic action. What anecdotal story demonstrates catalytic action?** Possible student response: "A table trick and what it teaches," published on 6/28/1924, tells the story of a dinner trick explained by the science of "catalysis." The story describes the end of a dinner where someone remarks that you can't light sugar on fire with a match. Attempts are made, without success. A guest takes the challenge and succeeds by using the ash from a cigar, which lowers the ignition point of sugar. The chemicals in the ash act as catalysts.

Cross-Curricular Discussion

After students have had a chance to review the article "Built for speed," lead a classroom discussion based on the questions that follow. You can copy and paste only the questions that apply to your classroom into a different document for your students. As an introduction to catalysts, and to get your students' attention, consider performing the well-known "elephant toothpaste" demonstration. This activity can lead off a general discuss of catalysts by showing students the rate of decomposition of hydrogen peroxide with and without a catalyst. Suggested links with demonstration instructions and materials are listed below. Please note that appropriate safety precautions should be used when handling hydrogen peroxide.

"Elephant toothpaste" demonstration resources

- Using 3% H_2O_2
  - Steve Spangler Science: Kid-Friendly Elephant's Toothpaste
  - Science Bob: Fantastic Foamy Fountain
- Using 30% H_2O_2
  - North Carolina State University Demonstration: Elephant's Toothpaste
  - University of Utah Chemistry Demonstration: Elephant's Toothpaste

CHEMISTRY

Discussion Questions:

1. What is a catalyst? What are some examples of common catalysts? [*A catalyst is a substance that helps a chemical reaction happen at a faster rate, but it is not used up by that reaction. The same catalyst can go on to help more reactions. Common examples of catalysts include: Platinum in automobile catalytic converters, which convert unburned gasoline into carbon dioxide. Iodide catalyzes the decomposition of hydrogen peroxide to create water and oxygen gas.*]

2. What precious metals are effective catalysts? Where are these metals located on the periodic table, and based on their location, how are they similar? [*Platinum, palladium, iridium, ruthenium and gold are effective metal catalysts. These metals are inert, or unreactive, in many systems and therefore won't be used up in side reactions unrelated to the reaction they are supposed to catalyze. All of these metals are located in the d-block of the periodic table and are considered transition metals. Based on this similarity, they should have similar reactivity.*]

Extension Prompts:

3. Refer to the diagram on Page 22 of "Built for speed" titled "Carbon and then some" (also on Blackline Master 3) to answer the following questions: What is graphene and what is it composed of? What types of chemical bonds does it contain, and what is the bond hybridization? [*Graphene is a single sheet of graphite. It is composed of one layer of carbon atoms bonded covalently in a repeating hexagonal

shape. All of the interior carbon atoms in graphene are sp^2 hybridized.]

4. What elements are used to enhance, or dope, carbon structures such as graphene to make potentially viable catalysts? Why do these particular elements create a more catalytically active carbon-based material? [*Nitrogen and phosphorus have both been used to replace carbon atoms in graphene, for example. These elements are rich in electrons (have one more valence electron than a carbon atom), therefore they create an unequal charge distribution throughout the material.*]
5. What is autocatalysis? [*A product of one reaction serves as a catalyst to facilitate more reactions. Examples include neutron-induced chain reactions in fission reactors and conversion of normal proteins to pathogenic prions in mad cow disease.*]

Chemistry Question Bank

What is a catalyst? What are some examples of common catalysts?

What precious metals are effective catalysts? Where are these metals located on the periodic table, and based on their location, how are they similar?

Refer to the diagram on Page 22 of "Built for speed" titled "Carbon and then some" (also on Blackline Master 3) to answer the following questions. What is graphene and what is it composed of? What types of chemical bonds does it contain, and what is the bond hybridization?

What elements are used to enhance, or dope, carbon structures such as graphene to make potentially viable catalysts? Why do these particular elements create a more catalytically active carbon-based material?

What is autocatalysis?

OTHER PHYSICAL SCIENCES

Discussion Questions:

1. What is the activation energy of a reaction? [*The minimum amount of energy that molecules must have to start a particular reaction.*]
2. Refer to the diagram on Page 21 of "Built for speed" titled "A lesser effort" (also on Blackline Master 3) to answer the following questions. How does a catalyst affect the activation energy? On the y-axis, label the reactant energy and product energy. With a vertical line, label the overall energy for both the catalyzed and uncatalyzed reaction curves. What do you notice about this amount of energy? Why does this make sense? [*A catalyst lowers the activation energy. The short horizontal line at the beginning of the curve represents the energy of the reactants and the short horizontal line at the end of the curve represent the energy of the products. The overall energy of each reaction is represented by a vertical line connecting the reactant and product energies on the y-axis. This amount of energy is the same for both the catalyzed and uncatalyzed reaction. Catalysts do not change the overall reaction, they just change the pathway of the reaction.*]
3. How does a catalyst help a reaction occur at a faster rate? [*Getting the molecules to go through the reaction involves getting them over the activation energy hump. When a catalyst is introduced into a system,*

the activation energy is lowered, which means that a greater percentage of reactants will chemically react in a given amount of time, increasing the rate of the reaction.]

4. Why is surface area important for a catalytic material? [*Reactions that require a catalyst occur when reactants come in contact with the catalytic material. When more surface area of a catalyst is available for contact, more reactants can form products.*]

Extension Prompts:

5. Define a transition state. At what point does the transition state occur during a chemical reaction? How does a catalyst interact with the transition state of a reaction? [T*he configuration of the reactants with the highest potential energy is the transition state of a reaction. It occurs at the top of the potential energy curve. Catalysts stabilize the transition state, lowering the activation energy of the reaction.*]

6. How can muons catalyze nuclear reactions? [*Negatively charged muons, heavier than electrons but with the same charge, orbit very closely around positively charged nuclei, allowing the nuclei to snuggle up close to one another to undergo fusion or other nuclear reactions.*]

7. How can carbon-12 catalyze nuclear fusion reactions in stars? [*A carbon-12 nucleus captures a proton to start a series of reactions. The series of reactions result in the production of a carbon-12 nucleus and a helium nucleus. Since a carbon-12 nucleus initiates the cycle and is regenerated in the last reaction, it is considered a catalyst for the whole cycle. For a more detailed explanation, visit the* **CNO Cycle page by Swinburne University**]

Other Physical Sciences Question Bank

What is the activation energy of a reaction?

Refer to the diagram on Page 21 of "Built for speed" titled "A lesser effort" (also on Blackline Master 3) to answer the following questions. How does a catalyst affect the activation energy? On the y-axis, label the reactant energy and product energy. With a vertical line, label the overall energy for both the catalyzed and uncatalyzed reaction curves. What do you notice about this amount of energy? Why does this make sense?

How does a catalyst help a reaction occur at a faster rate?

Why is surface area important for a catalytic material?

Define a transition state. At what point does the transition state occur during a chemical reaction? How does a catalyst interact with the transition state of a reaction?

How can muons catalyze nuclear reactions?

How can carbon-12 catalyze nuclear fusion reactions in stars?

BIOLOGICAL SCIENCES

Discussion Questions:

1. What is an enzyme? What kind of molecule is an enzyme? Give examples of biological processes that use enzymes. [*An enzyme is a biological molecule that serves as a catalyst to help biochemical reactions. The vast majority of enzymes are proteins, although other types of molecules such as RNA can serve as enzymes for certain reactions. Enzymes can help in processes such as copying genetic material and breaking down food and nutrients.*]

2. "Built for speed" states that enzymes "can evolve." For an organism, what are the advantages of having evolvable catalysts? [*Catalysts reduce the amount of energy required to start a reaction, so an organism will expend less energy on a chemical reaction when a catalyst is present. Over time, enzymes can evolve to be more specialized. The more specialized an enzyme is for a reaction, the less likely it is to expend unnecessary effort catalyzing side reactions. Vital reactions supporting an organism's growth, reproduction and survival would occur more quickly with an effective catalyst.*]

3. What is an inhibitor? How does it interact with a catalyst? [*An inhibitor is a molecule that can prevent enzyme-substrate interaction or lower an enzyme's catalytic ability. For example, a competitive inhibitor is a molecule that blocks an enzyme's active site but does not chemically react the same way as the substrate. Therefore, the inhibitor prevents other substrate molecules from interacting with the catalyst. Many pharmaceutical drugs are inhibitors.*]

Extension Prompts:

4. How are enzymes important for DNA synthesis? How are they important for RNA synthesis? [*Enzymes such as DNA polymerases are involved in polymerizing or linking together individual DNA nucleotides to form a new strand of DNA, using an existing DNA strand as a template. A number of enzymes such as RNA polymerases are involved in polymerizing individual RNA nucleotides to form a strand of RNA, generally using an existing DNA strand as a template (or RNA as a template in some viruses).*]

5. Explain how enzymes are involved in protein synthesis. [*Lots of enzymes assemble amino acids one step at a time from more basic building blocks. Then ribosomes—enzymes that are part protein and part RNA — together with other enzymes polymerize individual amino acids to form a protein.*]

6. How are enzymes important for cellular respiration? [*Numerous enzymes—especially in or near the mitochondria in eukaryotic cells—break down molecules such as sugars containing carbon (C), hydrogen (H) and oxygen (O) one step at a time, and combine them with oxygen (O_2) to produce water (H_2O), carbon dioxide (CO_2) and energy. This energy is stored in the form of adenosine triphosphate, or ATP, and the enzyme ATP synthase is essential for its creation.*]

7. How are enzymes important for photosynthesis? [*Enzymes involved in photosynthesis—especially in or near the chloroplasts in plant cells—absorb energy from sunlight (using chlorophyll molecules) and use that energy to break up water (H_2O) and carbon dioxide (CO_2) and combine their components one step at a time to produce sugars (containing C, H and O) and oxygen (O_2). Thus photosynthesis is basically respiration running backward, but the enzymes are slightly different.*]

Biological Sciences Question Bank

What is an enzyme? What kind of molecule is an enzyme? Give examples of biological processes that use enzymes.

"Built for speed" states that enzymes "can evolve." For an organism, what are the advantages of having evolvable catalysts?

What is an inhibitor? How does it interact with a catalyst?

How are enzymes important for DNA synthesis? How are they important for RNA synthesis?

Explain how enzymes are involved in protein synthesis.

How are enzymes important for cellular respiration?

How are enzymes important for photosynthesis?

ENGINEERING AND EXPERIMENTAL DESIGN

Discussion Questions:

1. What practical applications could catalysts be used for? [*Fuel cells to produce electricity from chemical reactions; artificial photosynthesis to convert solar energy into stored chemical energy.*]
2. What applications outside the ones that occur in the body could enzymes be used for? [*Proteases to tenderize your steak; proteases, lipases and other enzymes to remove stains from clothes; enzymes for making cheese.*]

Extension Prompts:

3. What research steps would you need to carry out to develop catalysts or enzymes for those applications? [*Answers will vary.*]
4. Using the information learned from "Built for speed," design the most effective, cost-efficient shape of platinum catalyst possible. If time and supplies permit, try to build a model of your catalyst. [*Answers will vary but should include a design trying to achieve the maximum possible surface area of platinum using the minimum possible mass of platinum.*]

Engineering and Experimental Design Question Bank

What practical applications could catalysts be used for?

What outside the body applications could enzymes be used for?

What research steps would you need to carry out to develop catalysts or enzymes for those applications?

Using the information learned from "Built for speed," design the most effective, cost-efficient shape of platinum catalyst possible. If time and supplies permit, try to build a model of your catalyst.

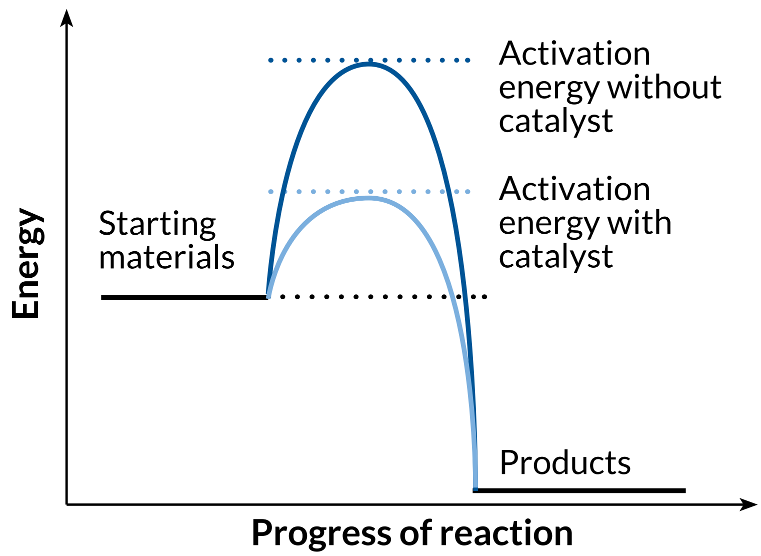
March 4, 2017
Built for Speed

Cross-Curricular Discussion

Directions: Use the diagrams from “Built for speed” to answer the related discussion questions assigned by your teacher.

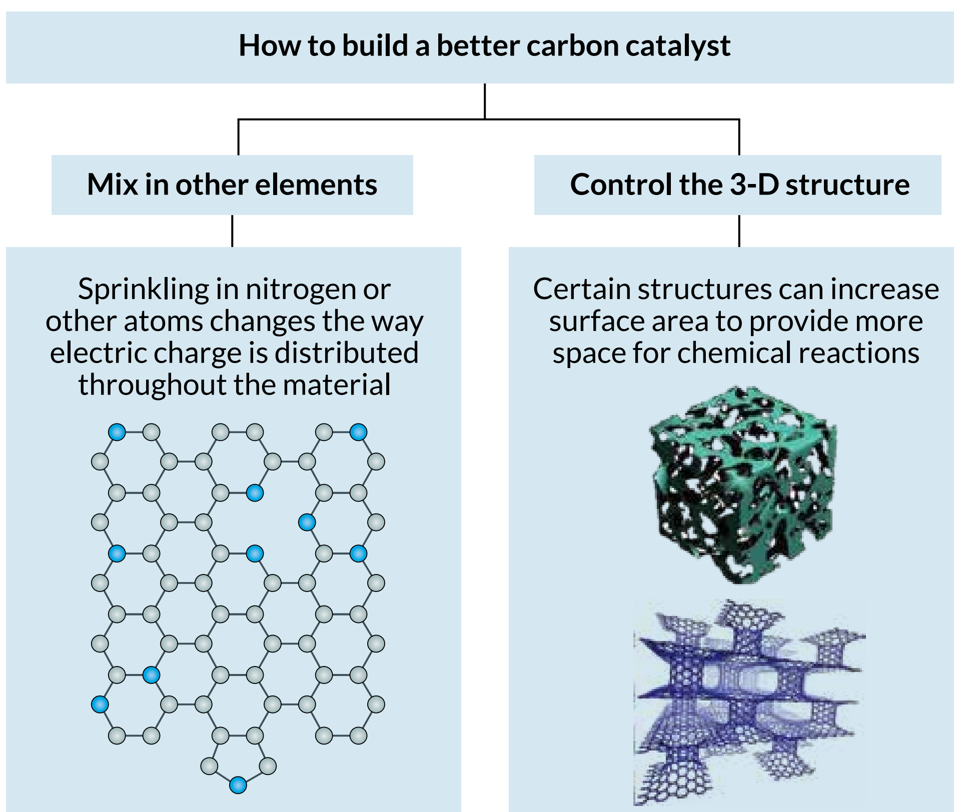
A lesser effort

Catalysts lower the amount of energy needed to make a chemical reaction run. The starting materials and ending products are the same, but the catalyst offers an easier route to get between the two.



Carbon and then some

By itself, carbon is not a great catalyst. But mixing in other elements (left) or changing its 3-D structure (right) gives it new powers. Scientists can vary these parameters to design carbon catalysts suited to different situations.



Teacher Guide for Illuminating Catalysts

Class time: 30-50 minutes

Purpose: Testing different catalysts and conditions for the light-producing luminol reaction.

Notes to the teacher: This Teacher Guide is intended to provide an outline of an experiment. You can adapt this activity depending on the level of the students, the amount of available class time and the resources available. For this activity, it is easiest to buy several Cool Blue Light Experiment Kits, ideally one for each group of students working together during the experiment. Each kit contains 5 grams of luminol, 5 grams of perborate, 2 grams of copper sulfate, a small scoop for measuring out the chemicals and a few other accessories. You can also buy the chemicals separately and use common lab equipment.

Luminol and perborate will react in water to produce luminescence, but that reaction is greatly aided by a catalyst. Depending on your preference, students can test different catalysts or they can use the same catalyst but vary other conditions to optimize the reaction.

Students will need light to set up experiments, but dark to see how well the experiments work. Plan to do a lot of flipping of the light switch or have two adjacent rooms, one light and one dark.

Materials:

- Cool Blue Light Experiment Kit at Home Science Tools (currently $9.95) or the chemicals included in the kit: luminol mixture, perborate mixture and copper sulfate
- Disposable clear plastic cups or small beaker (about 150 ml)
- Camera without a flash (cell phone cameras will work well)
- Thermometers for each group
- Hot and cold water
- Colorimetric pH indicator strips
- Household acids and bases such as vinegar, lemon juice, ammonia, water with baking soda or laboratory acids and bases with varying pH
- A sheet of instructions outlining the experimental design of your choosing
- Gloves

Directions:

1. Each student lab group should get one Cool Blue Light Experiment Kit (or related chemicals); additional small clear cups or beakers; and various catalysts (see Step 4 below) or other conditions to test such as amount of catalyst used for a specific amount of reactants, temperature of reactants or the effect of pH on reaction rate (see Step 5 and Step 6 below).

2. Students can set up several small clear cups, each with one small scoop of luminol, one small scoop of perborate and a half-filled small cup of water. If your students are taking a more quantitative route to this experiment, have them measure and record the mass of the reactants.
3. Decide on a general procedure that students should use to determine the effect of a catalyst, or help your students determine a sound experimental technique of their own. They need to mix and stir all materials with a catalyst and determine the catalyst's effect. For example, students can use their cell phones to take photos (without the flash) of the luminescent reactions in the dark so they can compare the relative brightness of the reactions afterward. Be sure to use the same exposure settings for each photo with the phone camera and do not auto-adjust the cameras to the brightness.
4. If you would like students to test different catalysts, provide them with a number of options, such as:
    - Copper sulfate crystals
    - Shiny copper (pennies)
    - Corroded copper (pennies left in water for a day in advance)
    - Shiny iron or steel (paperclips, bolts, etc.)
    - Rusted iron
    - Blood from raw meat or chicken (the iron ions act as a catalyst)
    - Zinc (zinc washers, etc.)
    - Aluminum (foil)
    - Magnesium sulfate (Epsom salts)
    - Other metals or chemical solutions that contain metal ions
5. If you would like students to test the effects of different temperatures on the catalytic reaction, they can use the same small number or mass of copper sulfate crystals for each cup, but different water temperatures. Provide sinks or other sources of hot and cold water, as well as thermometers. (Generally the hotter the water is, the faster the reaction will proceed.)
6. If you would like students to test the effects of different pH on the catalytic reaction, they can use the same small number of copper sulfate crystals for each cup but use a variety of solutions ranging from acid to neutral to alkaline instead of using water. Provide colorimetric pH indicator strips and chemical solutions or household acids and bases such as vinegar, lemon juice, ammonia, water with baking soda or laboratory acids and bases with varying pH. (An alkaline solution with a pH around 11 should work best, and acidic solutions should suppress the reaction.) Have students measure the pH of each solution before beginning their experiment.

Teacher Guide for From Lactose to Glucose

Class time: 30-50 minutes

Purpose: Testing the effects of different conditions on lactase, an enzyme that catalyzes the conversion of lactose (milk sugar) to glucose (simple sugar).

Notes to the teacher: You can adapt this activity depending on the number and the level of the students, as well as the amount of available class time.

Materials:

- URS-1G-100 Teco glucose assay strips from www.testyourselfathome.com (currently $9.95 for 100 strips)
- Scissors (to cut glucose strips in half lengthwise, so one strip will become two)
- Lactaid or similar generic chewable lactase tablets (available at drug stores and in the pharmacy section of grocery stores, Walmart and Target)
- Pliers (to crunch lactase tablets to powder) or a mortar and pestle
- Milk (any type except Lactaid milk that has already been treated with lactase)
- Test tubes
- Test tube racks
- Beakers or cups
- Thermometers
- Balances
- Weigh paper
- Crackers (if time permits for this part of the experiment)
- Stop watches or timers
- Gloves

Directions:

1. Assign students to lab groups, each with a rack of test tubes, a bottle of glucose test strips and the other supplies.
2. Have milk and water available for the whole class. Milk should ideally be in a beaker so it can be easily poured into test tubes.
3. Let the students conduct the lactase reactions with different conditions. Hand out Blackline Master 4 and have students record their results.
4. Have the students graph their results.

5. If you have the time, allow your students to experiment with their own saliva (and make sure that they dispose of it properly when finished). Saliva contains amylase, an enzyme that breaks down starch into glucose. Have them crumble a cracker in water in a cup. Then they should chew another cracker for 30 seconds, spit it into a second cup and test both cups for glucose. Even the test strips rely on the enzymes glucose oxidase and peroxidase.

SN IN HIGH SCHOOLS March 4, 2017
Built for Speed

Student Guide for From Lactose to Glucose

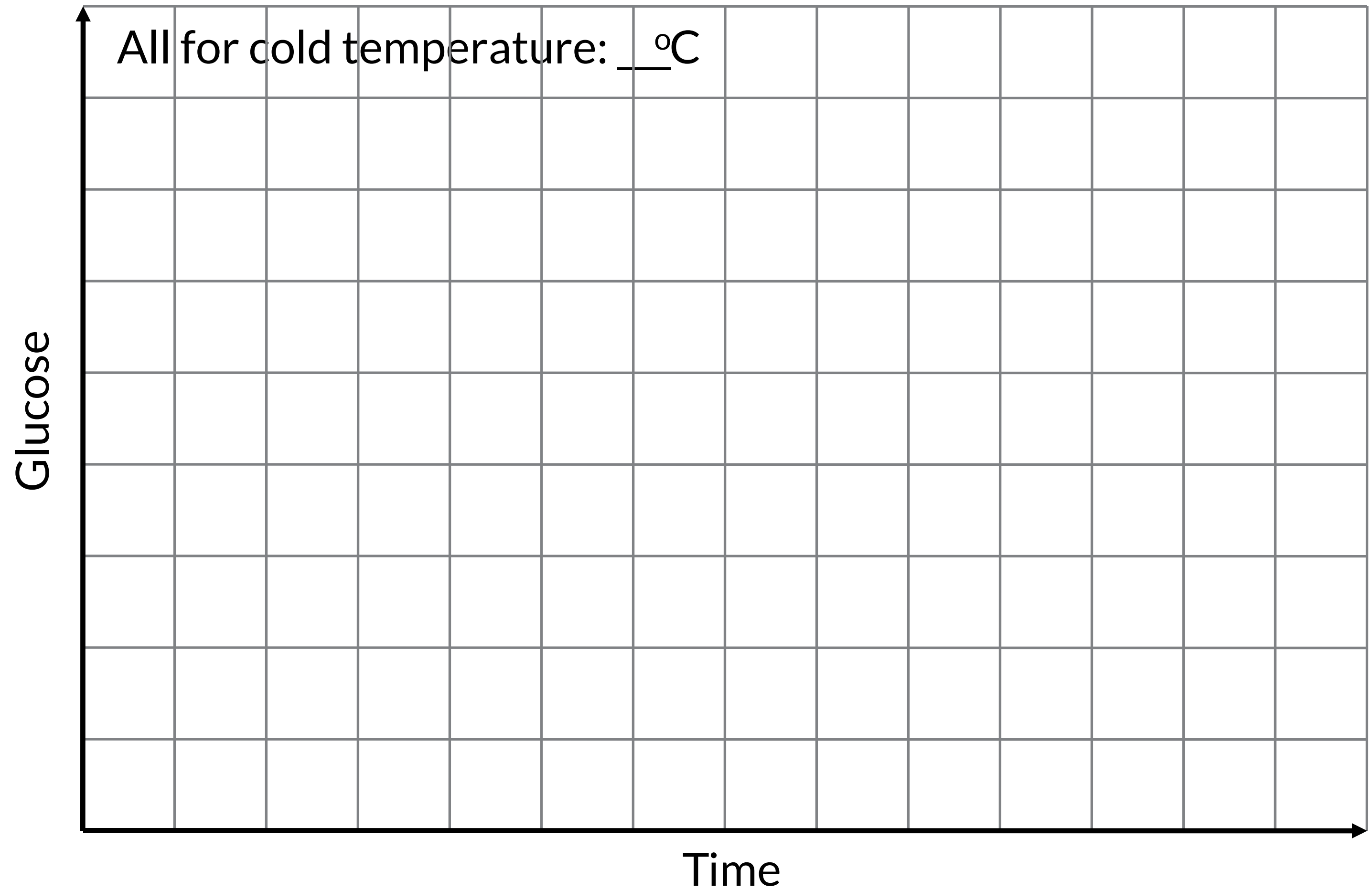
Enzymes are catalysts that do certain jobs inside you. Your body can easily use simple sugars like glucose as energy sources. However, milk mainly contains lactose, two simple sugars (glucose and galactose) bonded together. Therefore, your body (especially when you are young) makes the enzyme lactase, which breaks lactose into its two parts. If people don't have enough lactase, milk can upset their stomachs. But there's a solution: Lactase tablets provide the enzyme, and Lactaid milk comes with all the lactose already broken down.

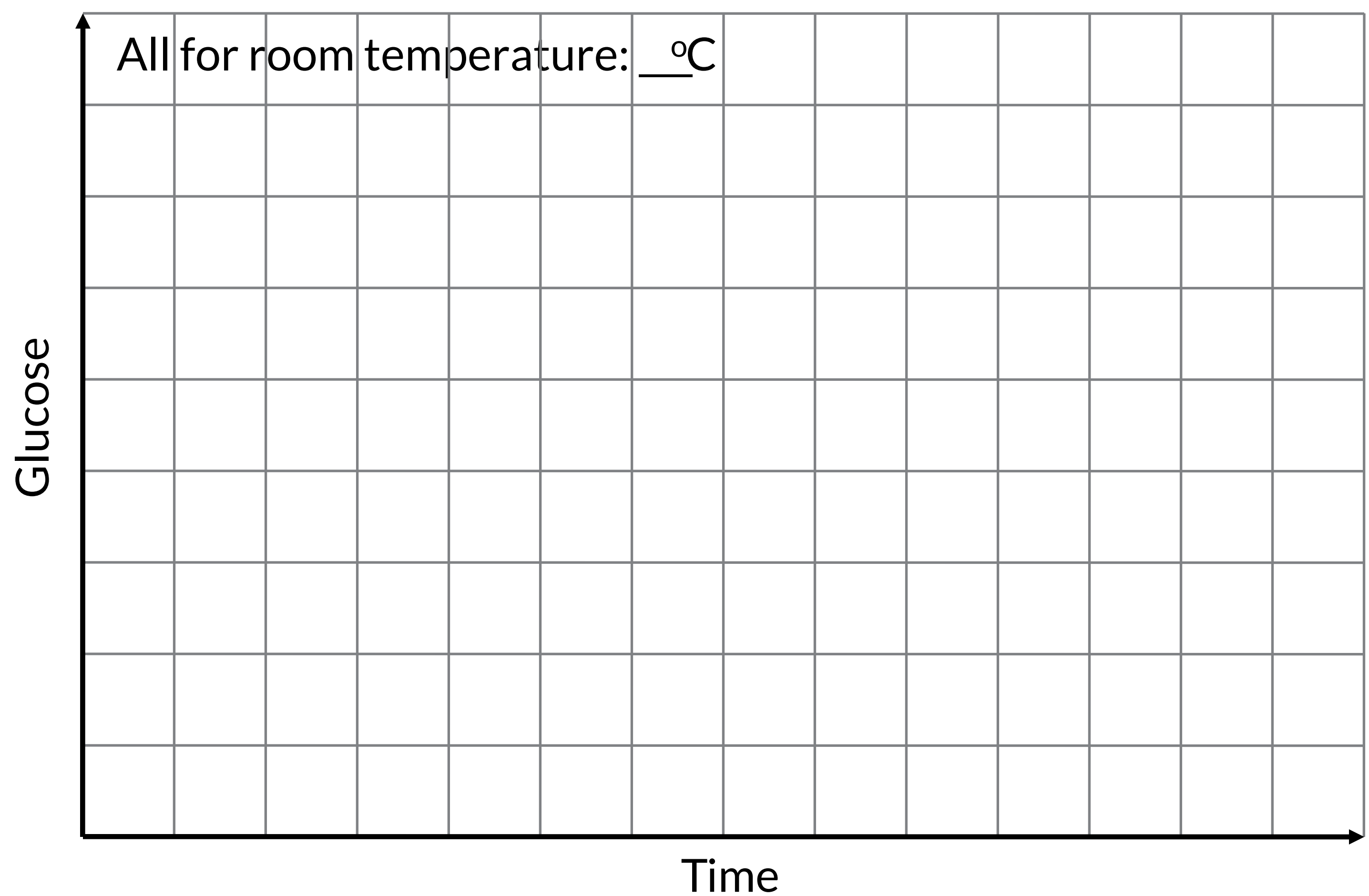
1. Cut the glucose test strips in half lengthwise so you can do two tests with one strip.
2. Fill three test tubes approximately half full with milk.
3. Briefly dip a glucose test strip into each tube of milk, then let the strip dry on the table for a minute or two. Compare the color of the strip with the color code on the side of the bottle of test strips. How much glucose is in the milk? Record your data on the accompanying sheets.
4. According to the thermometer, what is room temperature?
5. Fill a beaker most of the way with hot water. Record the water temperature.
6. Fill a beaker most of the way with cold water. Record the water temperature.
7. Use pliers or a mortar and pestle to crunch a Lactaid (lactase enzyme) tablet into powder. Put the powder on weigh paper on the scale. Record the mass of the powder.
8. Add the lactase powder to the test tubes of milk (1/3 tablet of powder per tube). Mix each tube by putting your gloved thumb over the top and shaking gently (or use a stopper if provided).
9. Set or hold one milk tube in the beaker of hot water, one in the beaker of cold water and one at room temperature (in no water).
10. After 1 minute, test the milk in each tube with new glucose test strips. How much glucose is in the milk? Record your data on the accompanying data table.
11. After 2 minutes, test the milk in each tube with new glucose test strips. Record your data.
12. Repeat the testing and recording procedure on each minute until you test and record the amount at 7 minutes.
13. Graph your data for the cold temperature on the accompanying sheets (add appropriate units to the axes).
14. Graph your data for room temaperature on the accompanying sheets (add appropriate units to the axes).

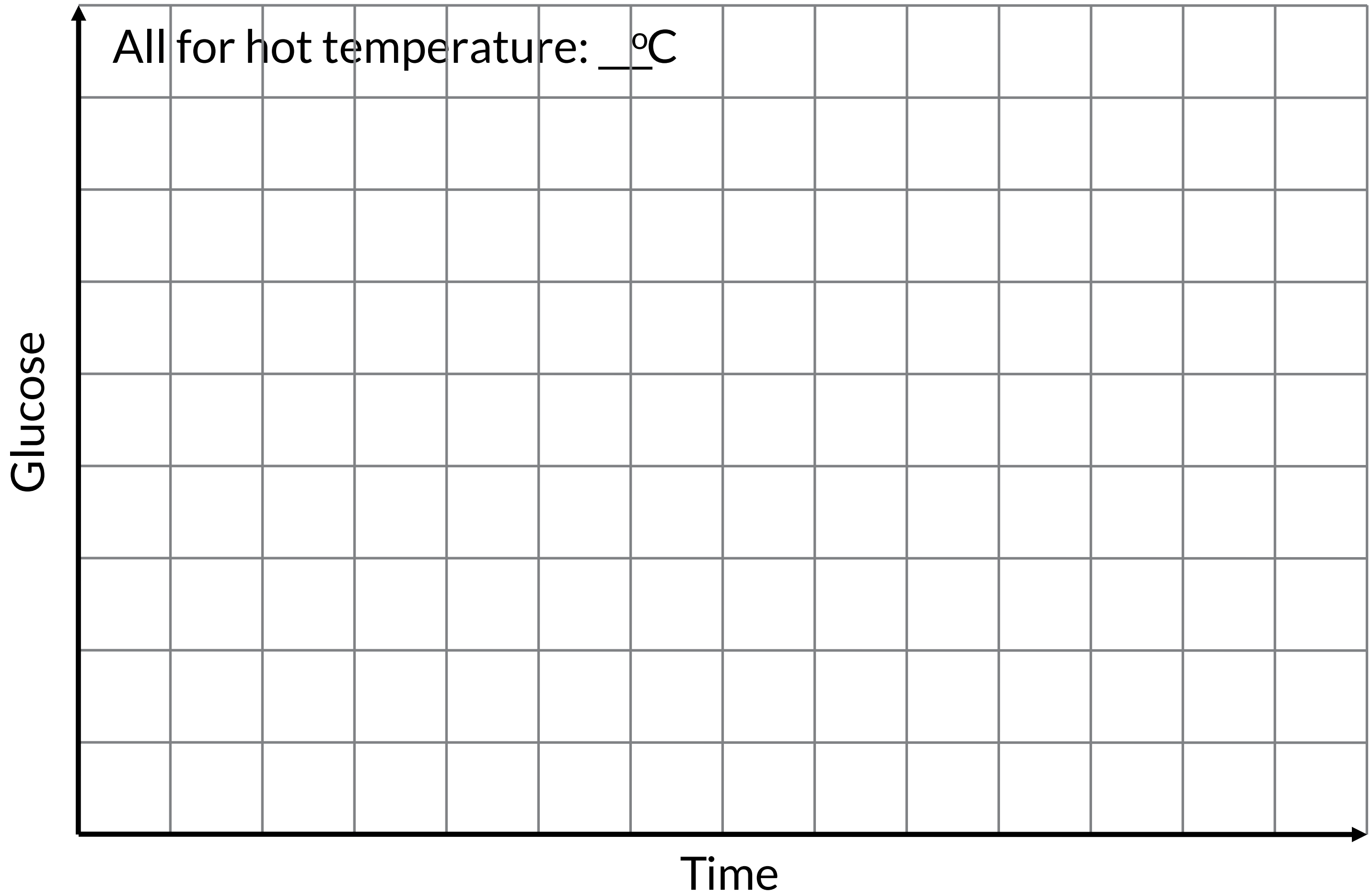
15. Graph your data for the hot temperature on the accompanying sheets (add appropriate units to the axes).
16. Pick one length of time (for example, 4 minutes) and graph the results for temperature versus glucose (add appropriate units to the axes). Mix hot and cold water to create two water baths with new, unique temperatures. For the length of time previously chosen (for example, 4 minutes), repeat steps 7 through 9 for the two new water baths. Make sure you use the same mass of lactase as you did in the first three test tubes, and make sure that the lactase is crushed to the same degree. Plot your results on the same temperature versus glucose graph.
17. Test and graph the results for different amounts of milk per tube (measure and record the amount of milk in each tube with a graduated cylinder or ask your teacher for specific instructions), with the same length of time, same temperature and same lactase mass for all tubes. Add appropriate units to the axes.
18. Test and graph the results for different masses of lactase per tube, with the same amount of time, same temperature and same milk amount for all tubes.
19. Once you have collected all of your data, answer the following questions. Explain your answers by using specific evidence from your graphs.
    - How does time affect the amount of glucose produced at a specific temperature? Explain.
    - How does temperature affect the amount of glucose produced after a specific amount of time? Explain.
    - What temperature gives the most glucose? What might happen to the lactase enzyme at high temperatures? Explain.
    - How does the amount of milk affect the amount of glucose produced by the reaction in a specific amount of time? Because glucose is a product, what does this tell you about how the amount of milk affects the rate of the chemical reaction? Is there a maximum or minimum amount of milk above which or below which this relationship no longer exists? If so, why might this "amount of milk limit" exist?
    - What is the relationship between the amount of lactase used and the amount of glucose produced for a given amount of time and a specific temperature? What does this tell you about how the amount of lactase affects the rate of the chemical reaction? Based on your knowledge of catalysts, explain why this might be the case.

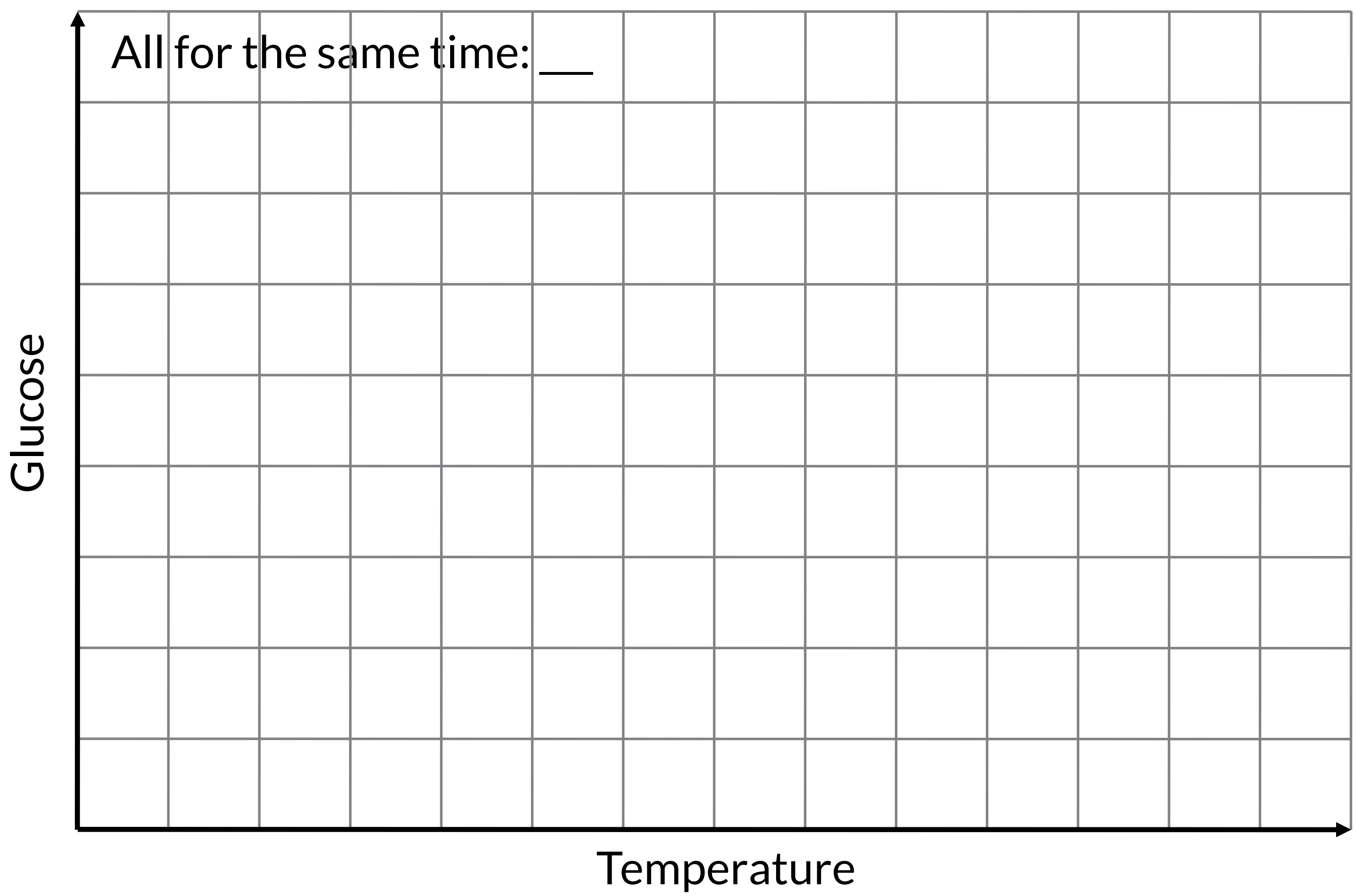
Lab: Lactase Enzyme Activity Name: _______________

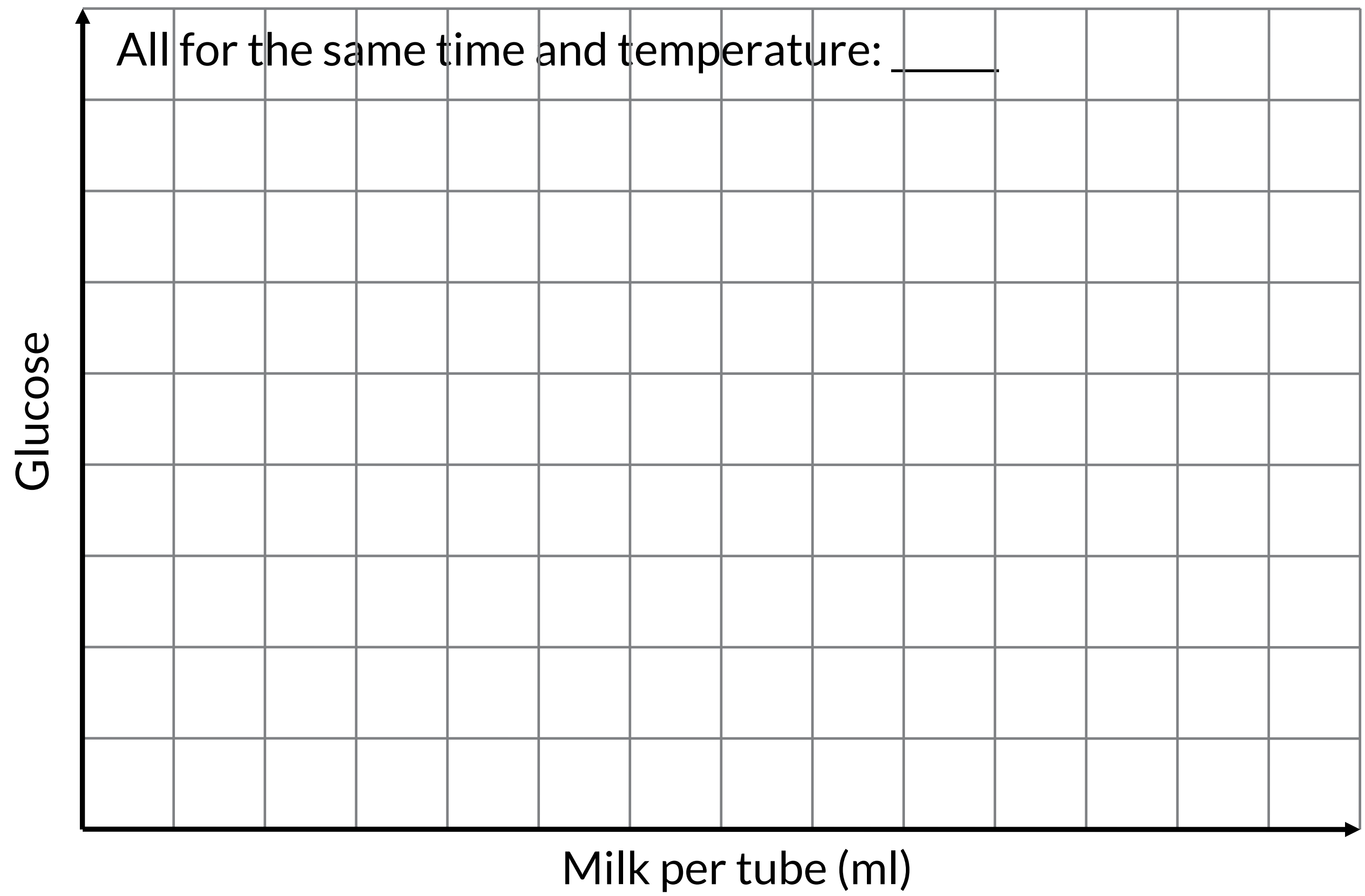
Cold water bath temperature:	**Room temperature:**	**Hot water bath temperature:**
Time: 0 Glucose:	Time: 0 Glucose:	Time: 0 Glucose:
Time: Glucose:	Time: Glucose:	Time: Glucose:
Time: Glucose:	Time: Glucose:	Time: Glucose:
Time: Glucose:	Time: Glucose:	Time: Glucose:
Time: Glucose:	Time: Glucose:	Time: Glucose:
Time: Glucose:	Time: Glucose:	Time: Glucose:
Time: Glucose:	Time: Glucose:	Time: Glucose:
Time: Glucose:	Time: Glucose:	Time: Glucose:

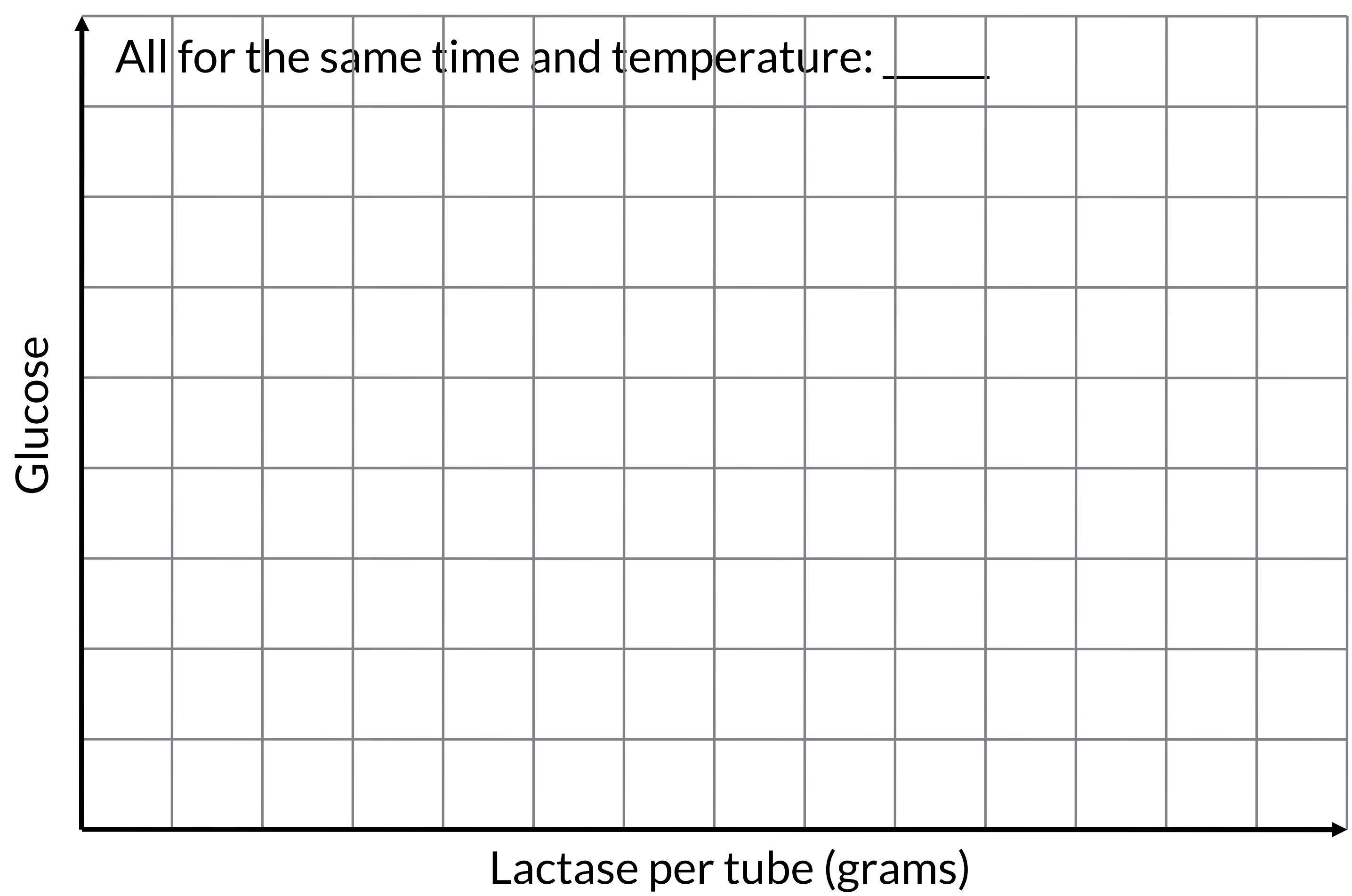

All for cold temperature: __ºC
Glucose
Time


All for room temperature: __ºC
Glucose
Time


All for hot temperature: __ºC
Glucose
Time


All for the same time: __
Glucose
Temperature


All for the same time and temperature: _____
Glucose
Milk per tube (ml)


All for the same time and temperature: _____
Glucose
Lactase per tube (grams)