ASPECt
Assessing Students' Progress on the Energy Concept

Eclipse & Trees: AP34-6

High school – Energy and Chemical Reactions

TASK OVERVIEW

Students are presented with data collected during an eclipse. The data includes the amount of carbon dioxide taken in by a tree and the amount of energy from the sun absorbed by the tree during the eclipse. They are asked to describe the patterns in the data and identify the relationship between carbon dioxide uptake and the amount of energy absorbed by the tree. Students are then provided with a molecular model of the chemical reaction happening inside the tree involving carbon dioxide and asked to use the model to explain the correlation in the data.

Data used in this task were modified from Haeberle, K H, Reiter, I, Patzner, K, Heyne, C, & Matyssek, R. (2001). Switching the light off: a break in photosynthesis and sap flow of forest trees under total solar eclipse. *Meteorologische Zeitschrift, 10*(3), 201 – 206, doi:10.1127/0941-2948/2001/0010-0201.

TARGETED DCIs, SEPs, AND CCCs

Disciplinary core ideas

- PS1.A-H.4: A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.

- LS1.C-H.1: The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.
- PS1.B-H.1: Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.

Science & engineering practices

- SEP2-H.8: Use a model to predict the relationships between systems or between components of a system.
- SEP4-M.1: Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.
- SEP6-H.2: Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future

Crosscutting concepts

- CC1-M.4: Graphs, charts, and images can be used to identify patterns in data.
- CC2-H.1: Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- CC2-H.2: Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.

Related Performance Expectations

- HS-LS1-5. Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy. [*Clarification Statement*: Emphasis is on illustrating inputs and outputs of matter and the transfer and transformation of energy in photosynthesis by plants and other photosynthesizing organisms. Examples of models could include diagrams, chemical equations, and conceptual models.] [*Assessment Boundary*: Assessment does not include specific biochemical steps.]

- HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. [*Clarification Statement*: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [*Assessment Boundary*: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]

TASK PERFORMANCE EXPECTATION

Summarize patterns and *identify relationships in data* involving the reactants of a chemical reaction and the energy required for the chemical reaction to occur. *Use a model of a chemical reaction system to explain how* relationships in data are caused by smaller scale chemical mechanisms within the system.

LINK TO ONLINE VERSION

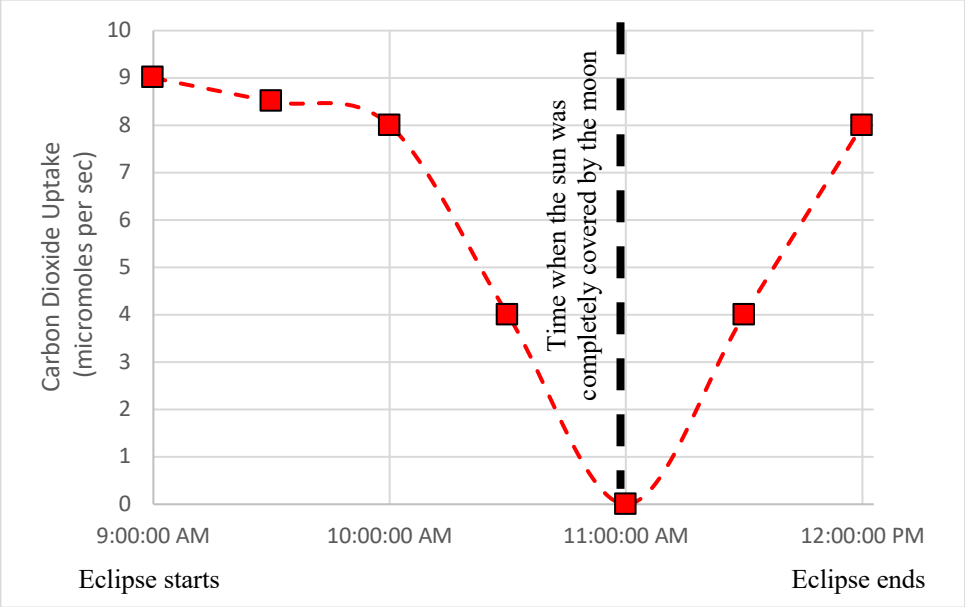
http://assess.bscs.org/i/test/598

Task

Photo of a 2017 solar eclipse taken by NASA/Aubrey Gemignani

A solar eclipse occurs when the moon moves in front of the sun to block sunlight from reaching the Earth. Scientists have noticed that during a solar eclipse there is a decrease in the amount of carbon dioxide (CO_2) that trees take in.

A graph of the amount of carbon dioxide that was taken in during a solar eclipse is shown below. The eclipse lasted from approximately 9:00 AM to 12:00 PM, with the sunlight being completely blocked at 11:00 AM.

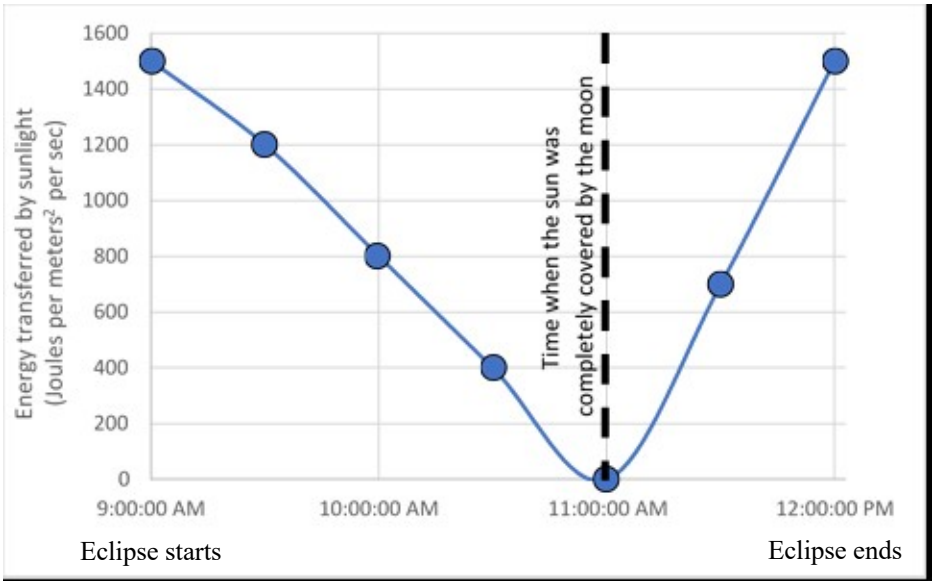


(data adapted from Häberle et al., 2001)

---

1. Describe how the amount of carbon dioxide that was taken in by the leaves of the trees changed from the start of the eclipse (9:00 AM) to the end of the eclipse (12:00 PM).

The scientists also measured the amount of energy that was transferred to the leaves of the trees by sunlight during this time.



2. Describe how the amount of energy that was transferred to the trees by sunlight changed from the start of the eclipse (9:00 AM) to the end of the eclipse (12:00 PM).

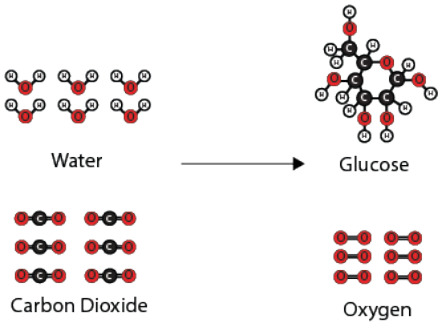
3. Using the data from both graphs, which of the following best describes the relationship between the amount of carbon dioxide that was taken in by the trees and the amount of energy that was transferred to the trees by sunlight during the eclipse?

   A. The amount of carbon dioxide that was taken in by the trees **increased** as the amount of energy transferred to the trees **increased**.

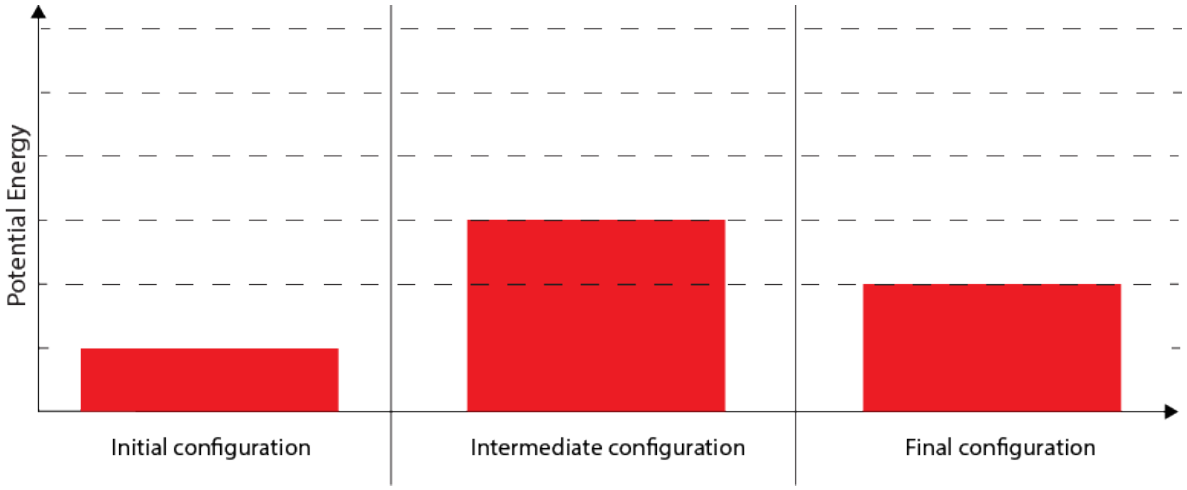
   B. The amount of carbon dioxide that was taken in by the trees **increased** as the amount of energy transferred to the trees **decreased**.

   C. The amount of carbon dioxide that was taken in by the trees **increased** as the amount of energy transferred to the trees **stayed the same**.

The scientists want to explain the changes in carbon dioxide uptake they observed during the solar eclipse. They know that the carbon dioxide that was taken in by the leaves of trees reacts with water to form glucose and oxygen. Below is a molecular model showing this reaction.



The potential energy of this chemical reaction system changes during the reaction as the configuration of the atoms and molecules changes. Below is a model showing the potential energy associated with the initial, intermediate, and final configurations of the atoms and molecules in the system. The intermediate configuration represents when bonds are breaking and forming and the potential energy is the highest.



4. How is the amount of energy that was transferred to the tree by sunlight represented in the model?

   A. The height of the bar for the initial configuration

   B. The height of the bar for the intermediate configuration

   C. The height of the bar for final configuration

   D. The difference in the heights for the bars of the initial and final configurations

   E. The difference in the heights for the bars of the initial and intermediate configurations

   F. The difference in the heights for the bars of the intermediate and final configurations

5. Does the model show that a net amount of energy was taken in or released during the overall chemical reaction?
    A. Taken in
    B. Released
    C. Neither taken in nor released

6. Explain how changes in the amount of energy that was transferred to the trees during the eclipse caused the amount of carbon dioxide that was taken in by the trees to change. You should support your explanation using:
    - the scientists' potential energy model
    - what you know about the energy associated with breaking and making bonds

Alignment to Targeted DCIs, SEPs, and CCCs and Scoring Rubrics

QUESTION 1

Describe how the amount of carbon dioxide that was taken in by the leaves of the trees changed during the eclipse.

LEARNING GOAL

Learning Performance

- Analyze data in graphs showing the change in carbon dioxide intake during an eclipse and describe the pattern in the data.

Targeted DCIs, SEP, and CCC

- CC1-M.4: Graphs, charts, and images can be used to identify patterns in data.

- SEP4-M.1: Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.

SCORING RUBRIC

Ideal Response

The amount of carbon dioxide taken in by the leaves started to decrease at the start of the eclipse, reached a minimum when the sun was completely covered, and started to increase after the sun was no longer completely covered.

Elements of a Correct Response

Categories	Elements
Student describes the pattern in the data	• Carbon dioxide intake first decreases (until the sun was completely blocked by the moon) and then begins to increase (after the sun was no longer completely covered). Note: The important thing here is the pattern. Students should describe the change in carbon dioxide intake throughout the eclipse.

Sample Student Responses

Student response	Scoring description
"When the sun was fully covered by the moon the carbon dioxide dropped"	Score = 0 The response does not describe the full pattern.
"At 9:00AM the leaves were taking in 9 mps and went down to 0 mps at 11:00AM then it went back up to 8 mps at 12:00PM"	Score = 1 The response describes the correct pattern.

QUESTION 2

Describe how the amount of energy that was transferred to the trees by sunlight changed during the eclipse.

LEARNING GOAL

Learning Performance

- Analyze data in graphs showing the change in the amount of energy transferred to trees during a solar eclipse and describe the pattern in the data.

Targeted DCIs, SEP, and CCC

- CC1-M.4: Graphs, charts, and images can be used to identify patterns in data.
- SEP4-M.1: Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.

SCORING RUBRIC

Ideal Response

The energy transferred to the trees started decreasing at the start of the eclipse, had a minimum when the sun was completely covered, and started increasing after the sun was no longer completely covered.

Elements of a Correct Response

Categories	Elements
Student describes the pattern in the data	• The amount of energy transferred to the trees first decreases (until the sun was completely blocked by the moon) and then begins to increase (after the sun was no longer completely covered). Note: The important thing here is the pattern. Students should describe the change in energy transferred throughout the eclipse.

Sample Student Responses

Student response	Scoring description
"The amount of energy decease because the sun was covered."	Score = 0 The response does not describe the correct pattern.

"The amount of energy that was transferred to the trees by sunlight started to go down at the beginning until it hit zero when the sun was fully blocked by the moon then it slowly went back up after the moon fully blocked the sun."	Score = 1 The response describes the correct pattern.

QUESTION 3

Using the data from both graphs, which of the following best describes the relationship between the amount of carbon dioxide that was taken in by the trees and the amount of energy that was transferred to the trees by sunlight during the eclipse?

A. The amount of carbon dioxide that was taken in by the trees **increased** as the amount of energy transferred to the trees **increased**.

B. The amount of carbon dioxide that was taken in by the trees **increased** as the amount of energy transferred to the trees **decreased**.

C. The amount of carbon dioxide that was taken in by the trees **increased** as the amount of energy transferred to the trees **stayed the same**.

LEARNING GOAL

Learning Performance

- Identify the relationship between the amount of carbon dioxide intake and the amount of energy transferred based on data in graphs plotting the change in these two variables as a function of time.

Targeted DCIs, SEP, and CCC

- SEP4-M.1: Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.

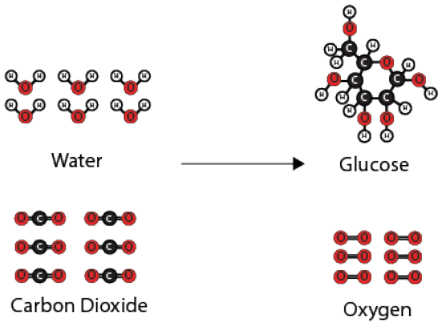
SCORING RUBRIC

Elements of a Correct Response

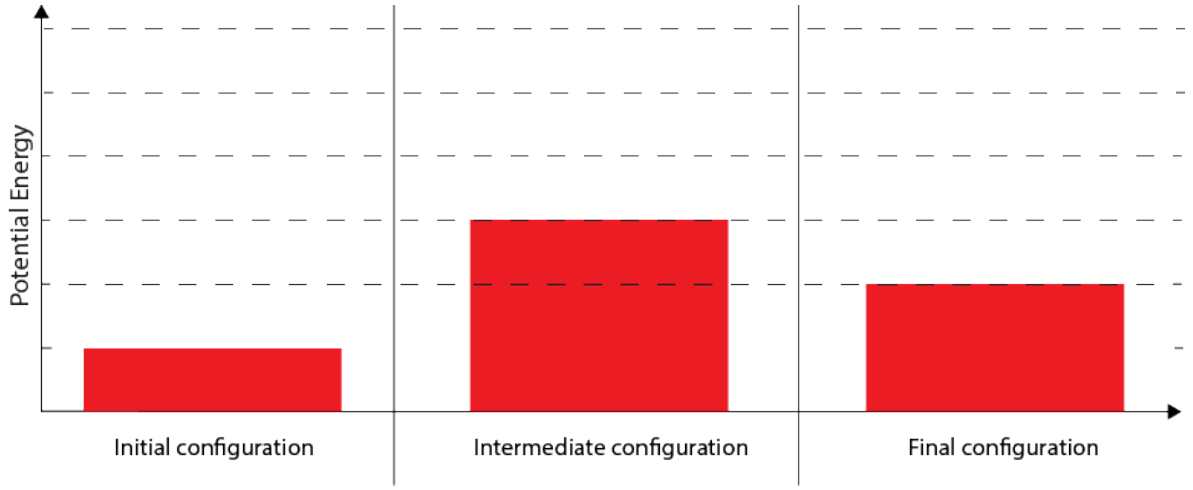
Categories	Elements
Student selects the correct multiple-choice answer	A. The amount of carbon dioxide that was taken in by the trees increased as the amount of energy transferred to the trees increased.

QUESTION 4

The scientists want to explain the changes in carbon dioxide uptake they observed during the solar eclipse. They know that the carbon dioxide that was taken in by the leaves of trees reacts with water to form glucose and oxygen. Below is a molecular model showing this reaction.



The potential energy of this chemical reaction system changes during the reaction as the configuration of the atoms and molecules changes. Below is a model showing the potential energy associated with the initial, intermediate, and final configurations of the atoms and molecules in the system. The intermediate configuration represents when bonds are breaking and forming and the potential energy is the highest.



How is the amount of energy that was transferred to the tree by sunlight represented in the model?

A. The height of the bar for the initial configuration
B. The height of the bar for the intermediate configuration
C. The height of the bar for final configuration
D. The difference in the heights for the bars of the initial and final configurations
E. The difference in the heights for the bars of the initial and intermediate configurations
F. The difference in the heights for the bars of the intermediate and final configurations

---

LEARNING GOAL

Learning Performance

- Students identify which parts of a model represent the energy transferred to the tree from the sun.

Targeted DCIs, SEP, and CCC

- PS1.A-H.4: A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.
- SEP2-H.8: Use a model to predict the relationships between systems or between components of a system.

SCORING RUBRIC

Elements of a Correct Response

Categories	Elements
Student selects the correct multiple-choice answer	E. The difference in the heights for the bars of the initial and intermediate configurations

QUESTION 5

Does the model show that a net amount of energy was taken in or released during the overall chemical reaction?

A. Taken in

B. Released

C. Neither taken in nor released

LEARNING GOAL

Learning Performance

- Use a model to identify whether a chemical reaction takes in or releases energy.

Targeted DCIs, SEP, and CCC

- PS1.B-H.1: Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.
- SEP2-H.8: Use a model to predict the relationships between systems or between components of a system.

SCORING RUBRIC

Elements of a Correct Response

Categories	Elements
Students select the correct multiple-choice answer	A. Taken in

---

QUESTION 6

Explain how changes in the amount of energy that was transferred to the trees during the eclipse caused the amount of carbon dioxide that was taken in by the trees to change. You should support your explanation using:

- the scientists' potential energy model
- what you know about the energy associated with breaking and making bonds

---

LEARNING GOAL

Learning Performance

- Explain the cause of a pattern in data using a chemical reaction energy model.

Targeted DCIs, SEP, and CCC

- PS1.A-H.4: A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.
- PS1.B-H.1: Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.
- LS1.C-H.1: The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.

- SEP6-H.2: Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future
- CC2-H.2: Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.

SCORING RUBRIC

Ideal Response

The energy transferred to the tree from the sun is used to break the bonds between the carbon dioxide molecules during photosynthesis. When the eclipse started, the amount of energy transferred to the trees decreased. The decrease in the amount of energy being transferred resulted in fewer bonds of carbon dioxide being broken and, therefore, less carbon dioxide being used by the trees to make food. As the eclipse ended and the amount of energy transferred to the trees increased, more bonds of carbon dioxide and water were broken, resulting in an increased amount of carbon dioxide being used by the trees to make food.

Elements of a Correct Response

Categories	Elements
Student cites evidence	• The molecular model shows that carbon dioxide is a reactant of the energy-requiring chemical reaction occurring in the trees (i.e., carbon dioxide is a reactant). ○ Note: Explicitly stating that this is from the model is not required. It is more that they are stating that the carbon dioxide is a reactant in the chemical reaction. • The potential energy model shows that the intermediate and/or final configurations are higher in energy than the initial configuration.
Student states or uses a general science idea	• Energy is required to break bonds between the atoms of the reactant molecules (i.e., energy from the sun is used to break the bonds between the carbon and oxygen atoms). [*links energy and bond breaking*]

	• The process of photosynthesis converts light energy to stored chemical energy (i.e., photosynthesis requires an input of energy from the sun to occur.) [*photosynthesis is energy-requiring*]

Student uses reasoning to link the evidence to the science ideas	• Having less energy transferred from the sun to the tree results in fewer few bonds being broken because an input of energy is required to break the bonds of the reactant. This means less carbon dioxide will be taken up by the tree because carbon dioxide is a reactant in this reaction.
	  ○ Note: If a student uses the phrase "activation energy" and they are using it as a proxy for the energy needed to break bonds, they can receive this point. Additionally, if the student uses the phrase "break and make bonds" as in "there will be less energy to break and make bonds", that is ok for this point.
	• Having less energy transferred from the sun to the tree results in less photosynthesis occurring because an input of energy is required for photosynthesis to occur. If less photosynthesis occurs, less carbon dioxide will be taken up by the tree because carbon dioxide is a reactant.
	  ○ Note: This line of reasoning is at a middle school level as opposed to the first bullet which is at a high school level.
	Note: Students receive one or the other reasoning point. If they use the "bond breaking requires energy" reasoning, they get that point.

Sample Student Responses

Student response	Scoring description
"Since the eclipse was out the trees cant get as much carbon because there is no sunlight."	Score = 0 The response describes the correlation but does not explain it.

"The trees use sunlight to do chemical reactions and make food for themselves but without sunlight they can t do this so no energy can be released if none is coming in, so as the eclipse gets closer and less energy is being consumed the less energy is released."	Score = 1 The response includes the idea that photosynthesis is an energy requiring reaction but does not explain what happens to the amount of carbon dioxide being used to make food.
"When the energy was absorbed by the trees, it broke bonds and raised the potential energy as shown in the bar graphs."	Score = 2 The response uses the potential energy graphs as evidence and includes idea that bond breaking requires energy but does not explain what happens to the amount of carbon dioxide being used to make food.
"During the solar eclipse, the amount of available energy from sunlight decreases as more of the sunlight is being blocked by the moon. Because there is less available energy from sunlight, photosynthesis reactions become less frequent as sunlight becomes a limiting factor of the reaction. Because carbon dioxide is also a reactant, the amount of carbon dioxide being absorbed decreases as well."	Score = 3 The response uses the middle school level line of reasoning described in the rubric.
"Based on the potential energy model, it is evident that, to start off, the initial configuration has little potential energy. This is due to the lack of sunlight being absorbed by the trees, therefore, a lack of energy to use in photosynthesis and a decreased amount of carbon dioxide taken in. In order to break and make bonds, a considerable amount of energy is needed, however, due to this lack of provided energy, less bonds are broken and made than if there was sufficient sunlight and, therefore, sufficient carbon dioxide."	Score = 3 The response uses the high school level line of reasoning, i.e., bond breaking, described in the rubric.

The research reported here was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305A180512 to BSCS Science Learning. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.