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AP[®]

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AP[®] Biology

Sample Student Responses and Scoring Commentary

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Question 3: Scientific Investigation**4 points**

Fireflies emit light when the enzyme luciferase catalyzes a reaction in which its substrate, D-luciferin, reacts to form oxyluciferin and other products (Figure 1). In order to determine the optimal temperature for this enzyme, scientists added ATP to a solution containing D-luciferin, luciferase, and other substances needed for the reaction. They then measured the amount of light emitted during the first three seconds of the reaction when it was carried out at different temperatures.

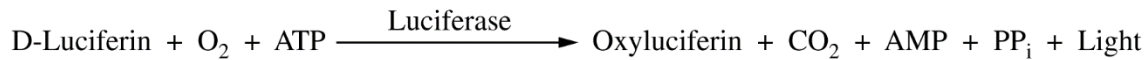


Figure 1. Light is emitted as a result of the reaction catalyzed by luciferase.

(a)	Describe a characteristic of the luciferase enzyme that allows it to catalyze the reaction. Accept one of the following: <ul style="list-style-type: none"> • It has <u>an active site/a shape</u> that <u>can bind with the substrate(s)/brings reactants together</u>. • It has a charge that is compatible with the substrate(s). 	1 point
(b)	Identify the dependent variable in the experiment. <ul style="list-style-type: none"> • The amount of light emitted 	1 point
(c)	State the null hypothesis for the experiment. <ul style="list-style-type: none"> • Temperature has no effect on the amount of light emitted. 	1 point
(d)	A student claims that, as temperature increases, there will be an increase in the amount of light given off by the reaction in the first three seconds. Support the student's claim. Accept one of the following: <ul style="list-style-type: none"> • Higher temperature increases the frequency of <u>collisions/interactions</u> between molecules, resulting in an increase in reaction rate. • The higher temperature results in a change to the active site that enhances substrate binding. 	1 point
Total for question 3		4 points

BEGIN Question 3

Begin your response to **QUESTION 3** on this page. Do not skip lines.

- a.) A characteristic of the luciferase enzyme that allows it to catalyze the reaction is its specific active site. The enzyme's amino acids & their R-groups interact in such a way that gives luciferase its unique structure & active site so that its substrate fits into that active site & luciferase can catalyze the reaction by lowering its activation energy.
- b.) The dependent variable is the amount of light emitted during the first three seconds of the reaction.
- c.) The null hypothesis is that temperature has no impact on the amount of light emitted by the reaction.
- d.) With an increase in temperature, substrate molecules have more kinetic energy, so they move around more & faster, making it more likely that a substrate molecule will bump into or get pushed into the luciferase enzyme, bind to the enzyme's active site, undergo the reaction, & reactants emit light.

BEGIN Question 3

Begin your response to **QUESTION 3** on this page. Do not skip lines.

- a) Luciferase is an enzyme with an active site that perfectly fits its substrate, D-luciferin. The active site holds the substrate in a position which lowers the activation energy of the reaction and catalyzes it.
- b) The amount of light emitted during the first 3 seconds of the reaction.
- c) Temperature has no statistically significant effect on the activity of the luciferase enzyme.
- d) An increase in temperature increases the kinetic energy of the reactant molecules, which means they will collide more often and D-luciferin will enter the active site of luciferase more often. Therefore, the reaction speed will increase, producing more products in the first 3 seconds. Since light is a product, more light will be given off at a higher temperature.

BEGIN Question 3

Begin your response to **QUESTION 3** on this page. Do not skip lines.

a) Luciferase is able to catalyze the reaction because it causes a reaction from its substrate D-Luciferin. b) The dependent variable in this experiment is the amount of light emitted during the first three seconds of the reaction. c) The temperature has no effect on the amount of light emitted in the first three seconds. d) As the temperature increases the amount of light emitted will as well because it will cause molecules to move more rapidly.

Question 3

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

Question 3 described the chemical reaction that produces light in fireflies and presented the chemical equation. The stimulus also described a scientific investigation designed to determine the effect of temperature on the reaction in a solution containing ATP, the substrate D-luciferin, and the enzyme luciferase.

Responses to part (a) were expected to describe that luciferin has an active site compatible with its substrate (Learning Objective ENE-1.D).

Responses to part (b) were expected to identify the amount of light emitted as the dependent variable (Science Practice 3.C).

Responses to part (c) were expected to state the null hypothesis of the experiment (Science Practice 3.B).

Responses to part (d) were expected to support the claim that increased temperature results in an increase in light emitted by demonstrating an understanding that, as molecular movements increase, more collisions between the substrate and enzyme will occur (Learning Objective ENE-1.G).

Sample: 3A

Score: 4

The response earned 1 point in part (a) for describing that the enzyme has a “specific active site ... so that its substrate fits into that active site.” The response earned 1 point in part (b) for identifying the dependent variable as “the amount of light emitted.” The response earned 1 point in part (c) for stating “that temperature has no impact on the amount of light emitted.” The response earned 1 point in part (d) for supporting that higher temperatures will give molecules “more kinetic energy ... making it more likely that a substrate molecule will bump into ... the enzyme.”

Sample: 3B

Score: 3

The response earned 1 point in part (a) for describing that the luciferase enzyme has an active site that “perfectly fits ... and holds the substrate” and allows it to catalyze the reaction. The response earned 1 point in part (b) for identifying the dependent variable as the “amount of light emitted.” The response did not earn a point in part (c) because it states an “effect on the activity of the luciferase enzyme” instead of on the amount of light emitted. The response earned 1 point in part (d) for supporting the claim by stating that higher temperatures will make the reactant molecules “collide more often” and therefore “the reaction speed will increase.”

Sample: 3C

Score: 2

The response did not earn a point in part (a) because it does not describe an active site or a shape of the enzyme that can bind with the substrate. The response earned 1 point in part (b) for identifying the dependent variable as “the amount of light emitted.” The response earned 1 point in part (c) for stating the “temperature has no effect on the amount of light emitted.” The response did not earn a point in part (d) because it does not connect the increased rapidity of molecule movement with increasing the frequency of collisions.