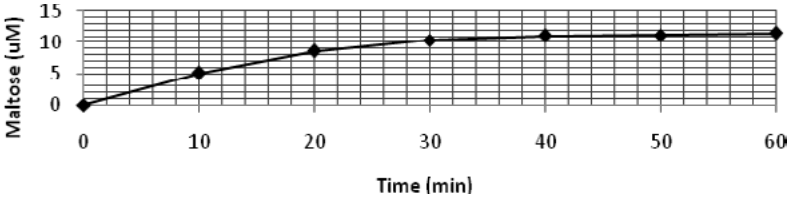
AP® BIOLOGY
2010 SCORING GUIDELINES

Question 2

An experiment was conducted to measure the reaction rate of the human salivary enzyme α-amylase. Ten mL of a concentrated starch solution and 1.0 mL of α-amylase solution were placed in a test tube. The test tube was inverted several times to mix the solution and then incubated at 25°C. The amount of product (maltose) present was measured every 10 minutes for an hour. The results are given in the table below.

Time (minutes)	Maltose Concentration (μM)
0	0
10	5.1
20	8.6
30	10.4
40	11.1
50	11.2
60	11.5

(a) **Graph** the data on the axes provided and **calculate** the rate of the reaction for the time period 0 to 30 minutes. **(4 points maximum)**



Graph 1 point each (3 points maximum)	Calculation (1 point maximum)
• Correct orientation of the independent (time) and dependent (maltose) variables. • Correct display of units and intervals **(scale and labels)**. • Correct graphing of **all** data points on a properly scaled and oriented graph **(0–60 minutes)**.	• Correct setup **or** rate calculation (0.3–0.4 μM/min or, e.g., 1μM/3 min, 10.4 μM/30 min or 10.4–0.0 /30–0 μM/min), **with units**. (No points if setup is incorrect or if calculated number is wrong and contradicts a correct setup.)

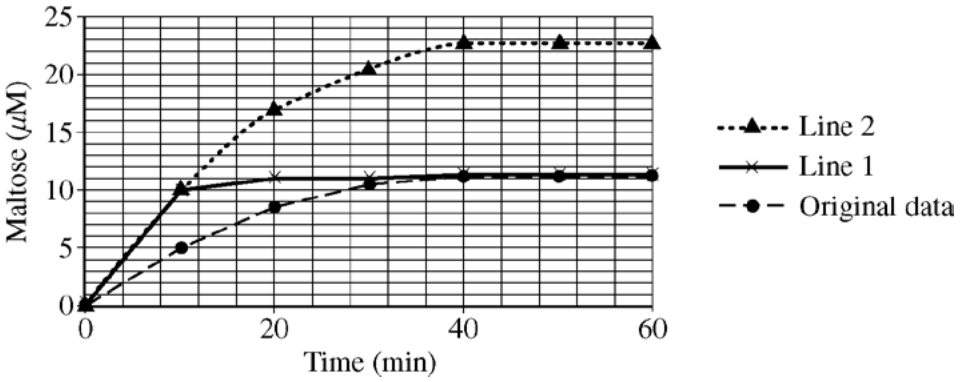
AP® BIOLOGY
2010 SCORING GUIDELINES

Question 2 (continued)

(b) **Explain** why a change in the reaction rate was observed after 30 minutes. **(2 points maximum)**

Change (1 point maximum)	Explanation of change (1 point maximum)
• Reaction rate slows/levels off.	• Rate slows as substrate concentration declines (substrate used). • Enzyme inactive by about 40 minutes — enzyme loses activity over time (labile enzyme). • Product inhibition.

(c) **Draw** and **label** another line on the graph to predict the results if the concentration of α-amylase was doubled. **Explain** your predicted results. **(2 points maximum)**



Drawing and labeling point (1 point maximum)	Explanation point (1 point maximum)
• Drawing and labeling of new line showing appropriate prediction (increased initial rate). o **Draw either line 1 OR line 2.**	• Line 1: Substrate is consumed more quickly because twice as much enzyme is present, but overall final product concentration remains the same. • Line 2: More product is formed at each time point because twice as much enzyme is present; product formation levels off as enzyme loses activity.

AP® BIOLOGY
2010 SCORING GUIDELINES

Question 2 (continued)

(d) **Identify** TWO environmental factors that can change the rate of an enzyme-mediated reaction. **Discuss** how each of those two factors would affect the reaction rate of an enzyme. **(4 points maximum including elaboration point)**

Identification point (1 point maximum)	**Discussion points (3 points maximum)**
• Identification of **TWO** environmental factors. (e.g., temperature, pH, salinity, inhibitors, stirring/mixing, pressure, O_2, light).	• Temperature factor — temperature ↑, rate ↑; temperature ↓, rate ↓; high temperature causes denaturation. • Other factors — how that factor changes the rate of the enzymatic reaction. • Detailed explanation point — description of temperature denaturation (improper folding, change of active site), altered kinetics (temperature alters rate of collisions) or pH inactivation or ionic (salinity) inactivation (active site charge changes).

2. An experiment was conducted to measure the reaction rate of the human salivary enzyme α-amylase. Ten mL of a concentrated starch solution and 1.0 mL of α-amylase solution were placed in a test tube. The test tube was inverted several times to mix the solution and then incubated at 25°C. The amount of product (maltose) present was measured every 10 minutes for an hour. The results are given in the table below.

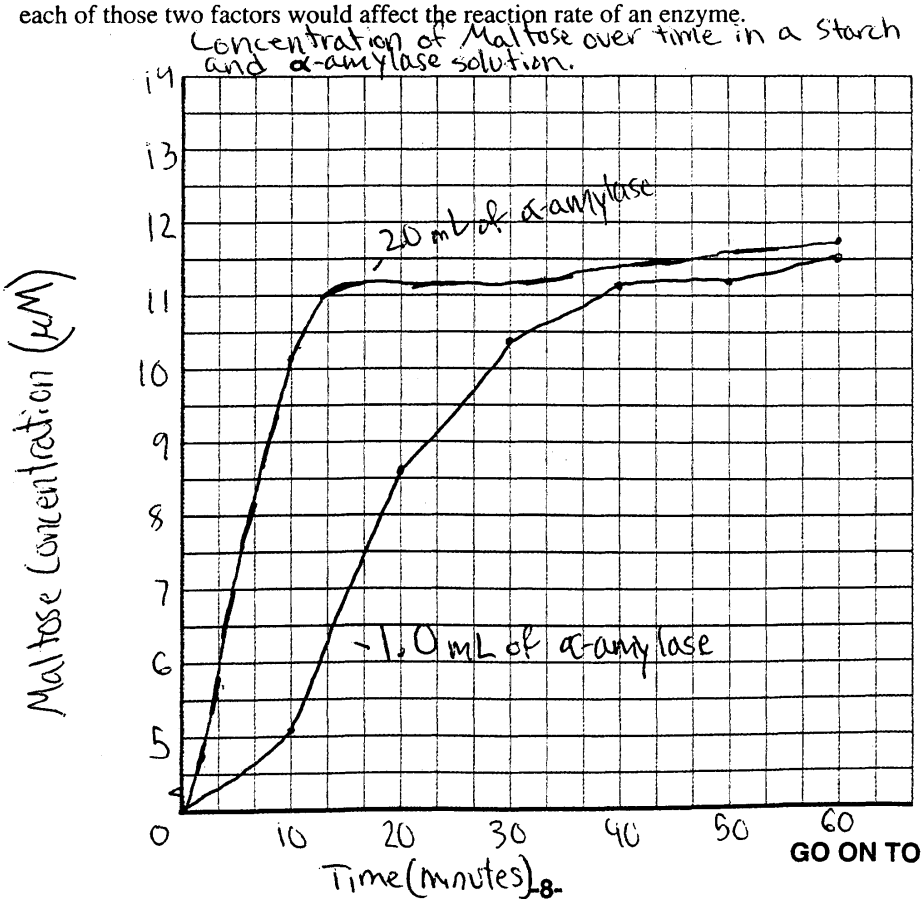
Time (minutes)	Maltose Concentration (μM)
0	0
10	5.1
20	8.6
30	10.4
40	11.1
50	11.2
60	11.5

(a) **Graph** the data on the axes provided and **calculate** the rate of the reaction for the time period 0 to 30 minutes.

(b) **Explain** why a change in the reaction rate was observed after 30 minutes.

(c) **Draw** and **label** another line on the graph to predict the results if the concentration of α-amylase was doubled. **Explain** your predicted results.

(d) **Identify** TWO environmental factors that can change the rate of an enzyme-mediated reaction. **Discuss** how each of those two factors would affect the reaction rate of an enzyme.



GO ON TO THE NEXT PAGE.

ADDITIONAL PAGE FOR ANSWERING QUESTION 2

a) rate of reaction for 0 to 30 minutes: $\frac{10.4}{10} = \frac{104}{100} = \frac{26}{25}$

b) A change in the reaction rate was observed after 30 minutes because the reaction rate levels off after 30 minutes. The rate of reaction most likely levels off after 30 minutes because the substrate, which in this case is the starch has been exhausted by the enzyme. This means that the enzyme has already broken down most of the starch, so the chance of the enzyme and substrate encountering eachother to form an enzyme-substrate complex is very low. after 30 min. So the effectiveness of the enzyme should be measured during the first 30 minutes while the substrate is still abundant.

c) If the concentration of α-amylase was doubled, the starch would by broken down twice as fast during the first 10 minutes. Since the starch would be broken down faster, the concentration of maltose would double as well because the rate of reaction is being doubled. However, the rate of reaction would level off much sooner because the substrate (starch) would be exhausted sooner, and the enzyme and substrate would only have a small chance of colliding to create an enzyme-substrate complex.

d) Temperature is one environmental factor that can change the rate of an enzyme-mediated reaction. As temperature increases, the enzymes and substrates will move around faster causing them to

2A 3

collide and form and enzyme-substrate complex which leads to the product. However, if the temperature becomes too high, the proteins that make up the enzyme will become denatured and the enzyme will be ineffective. In summary, temperature increases the rate of reaction up until the temperature is too high and the ~~enzymes~~ enzymes are denatured, resulting in no reactions at all.

Another environmental factor that would affect the rate of an enzyme mediated reaction is the pH of the environment. Certain enzymes work better at specific pHs, and may not work at all at other pH levels, due to denaturization.

2. An experiment was conducted to measure the reaction rate of the human salivary enzyme α-amylase. Ten mL of a concentrated starch solution and 1.0 mL of α-amylase solution were placed in a test tube. The test tube was inverted several times to mix the solution and then incubated at 25°C. The amount of product (maltose) present was measured every 10 minutes for an hour. The results are given in the table below.

2B 1

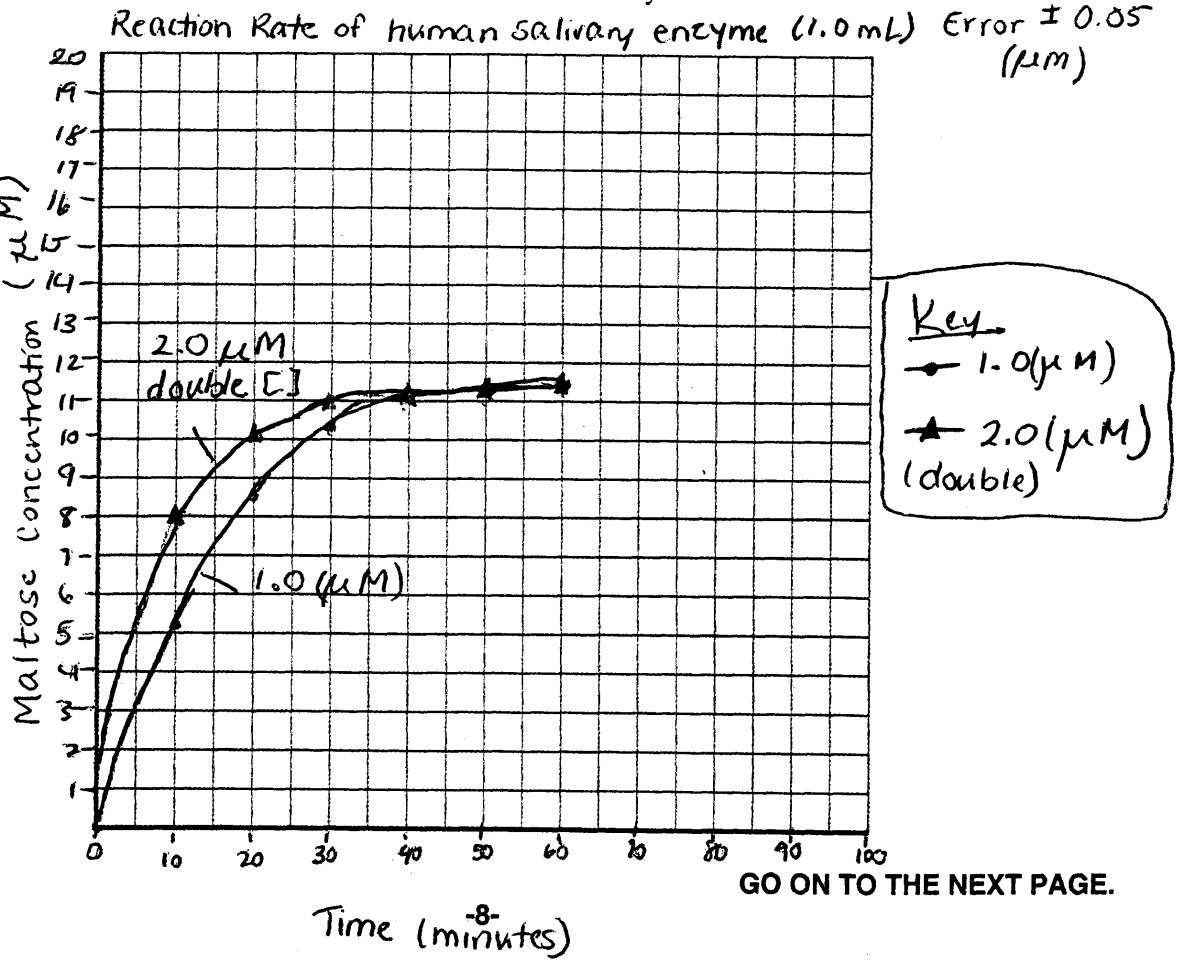
Time (minutes)	Maltose Concentration (μM)
0	0
10	5.1
20	8.6
30	10.4
40	11.1
50	11.2
60	11.5

(a) **Graph** the data on the axes provided and **calculate** the rate of the reaction for the time period 0 to 30 minutes.

(b) **Explain** why a change in the reaction rate was observed after 30 minutes.

(c) **Draw** and **label** another line on the graph to predict the results if the concentration of α-amylase was doubled. **Explain** your predicted results.

(d) **Identify** TWO environmental factors that can change the rate of an enzyme-mediated reaction. **Discuss** how each of those two factors would affect the reaction rate of an enzyme.



2B 2

2a) In this graph the rate of reaction of the break down of carbohydrated was graphed. Human salivary ~~enz~~ enzyme a-amylase is ~~found~~ found in the mouth of the human ~~do~~ body digestive system. It is secreated by salivary glands in the mouth. The first step in digestion is mechanical digestion by the teeth. Then the food it broken down into smaller particles by enzymes like a-amylase. This amylase breaks down carbohydrates into sugars like maltose which is a form of sugar. So when the food is broken down by the amylase there are a greater number of carbohydrates so from the 0-30 minute time span the maltose concentration is going to increase rapidly because of all the carbohydrates that are needed to be broken down. The 30-60 minute time span the concentration of maltose only increases slightly because of the decrease in carbohydrates.

The rate of the reaction from 0-30 minutes is 0.3466.

$r = \frac{10.4}{30}$ $r = 300\sqrt{104}$

0.3466

10

1040

900

1400

1200

2000

1800

2000

2b) When looking at the graph and data table there is a change in reaction rate ~~it~~ because the amount of carbohydrates available to be broken down has decreased because most of it is already broken down to maltose. There is an increase concentration of maltose byt decrease concentration of carbs.

GO ON TO THE NEXT PAGE.

2B3

2c) The line with the triangular points represents the concentration when the amalyse concentration is doubled. The concentration of maltose would increase suddenly from 0-30 minutes with a higher reaction rate than the 1.0 μM amalyse. Then after the 30 minutes it would level of to be the same same as the 1.0 μM ~~as~~ ~~or~~ amalyse because the amount of starch in both solutions would remain the same amount. So the [] of maltose would not be higher than 11.5 at 60 minutes.

2d) Two environmental factors would be salinity and pH. Temperature also makes a significant difference on the nature of the enzyme. If the salinity were to increase then the enzyme could be denatured. Salinity and pH go hand in hand. Temperature would effect the nature of the enzyme as well if it were to increase or decrease drastically it would effect the ~~str~~ Shape of the enzyme changing it which causes the enzyme to be denatured. The rate of the enzyme would increase if the pH were to decrease and vice versa. The rate of the enzyme would decrease if the temperature were to decrease, and ~~or~~ vice versa. The salitiy would effect the rate in which if it were to increase the rate would increase.

GO ON TO THE NEXT PAGE.

2C1

2. An experiment was conducted to measure the reaction rate of the human salivary enzyme α-amylase. Ten mL of a concentrated starch solution and 1.0 mL of α-amylase solution were placed in a test tube. The test tube was inverted several times to mix the solution and then incubated at 25°C. The amount of product (maltose) present was measured every 10 minutes for an hour. The results are given in the table below.

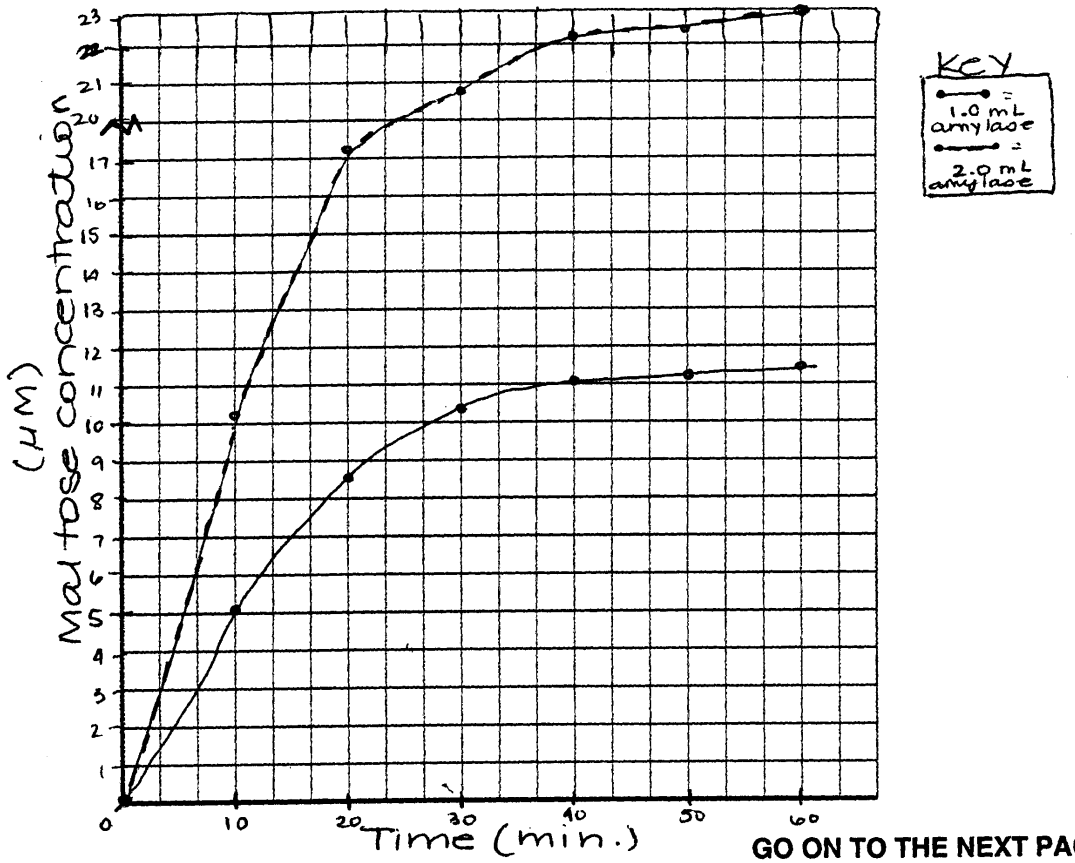
Time (minutes)	Maltose Concentration (μM)
0	0
10	5.1
20	8.6
30	10.4
40	11.1
50	11.2
60	11.5

(a) **Graph** the data on the axes provided and **calculate** the rate of the reaction for the time period 0 to 30 minutes.

(b) **Explain** why a change in the reaction rate was observed after 30 minutes.

(c) **Draw** and **label** another line on the graph to predict the results if the concentration of α-amylase was doubled. **Explain** your predicted results.

(d) **Identify** TWO environmental factors that can change the rate of an enzyme-mediated reaction. **Discuss** how each of those two factors would affect the reaction rate of an enzyme.



GO ON TO THE NEXT PAGE.

ADDITIONAL PAGE FOR ANSWERING QUESTION 2

a. $\frac{5.1+3.5+1.8+.7+.1+.3}{6} = 1.92^{\mu M}/min$

b. The change in the reaction rate was observed because the amylase had reached its maximum potential. The and broken down all the starch graph begins to level because the reaction has been completed and no more maltose can be produced from the provided starch solution and α-amylase.

c. The rate at which maltose is produced would double when 2.0mL of α-amylase is used, but it would still level off at the same rate because no added starch was used. Therefore the amylase is consuming starch at a faster rate, being [illegible] but still leveling off when all starch is broken down.

GO ON TO THE NEXT PAGE.

AP® BIOLOGY
2010 SCORING COMMENTARY

Question 2

Overview

In this question data were provided based on an experiment on the reaction rate of the human salivary enzyme α-amylase. The amount of product (maltose) and the time intervals over which it was measured were given. In part (a) students were instructed to construct a graph and to calculate the reaction rate for the time period of 0 to 30 minutes. In the graph students were expected to include the correct placement of the dependent (*x*-axis) and independent (*y*-axis) variables, proper labeling and scaling of the axes, and the precise placement of the data points on the curve. The correct calculation of the reaction rate over 30 minutes demonstrated an understanding of how data are used to obtain a kinetic rate for enzymatic reactions. Use of correct units of measurement was expected. Part (b) requested an explanation of the change in reaction rate after 30 minutes. Students were expected to demonstrate an ability to analyze data and make appropriate conclusions. Part (c) instructed students to predict and label a line on the graph that represented a doubling of the amount of the enzyme (α-amylase). Students were asked to explain their predicted results. Students were expected to demonstrate an understanding of how enzymes function and to use that understanding to make an appropriate prediction based on increased availability of the enzyme. Part (d) instructed students to list two environmental factors that can alter the rate of enzyme-mediated reactions. Students were asked to discuss how each of the two factors they selected would affect the reaction rate. Students were expected to demonstrate an understanding of how environmental variables control an enzyme's function.

Sample: 2A
Score: 10

For part (a) the graph contains the proper orientation of the dependent and independent variables and axes that are correctly scaled and labeled (with the correct units). The data are properly graphed on a correctly scaled and oriented graph. The predicted line, required for part (c), is labeled and displays the appropriate prediction, an increase in initial rate. The rate calculation is incorrectly set up and calculated, however, so that point was not earned. The responses for part (a) thus earned 3 points and the graphing point of part (c).

In part (b) the response notes a leveling off of the rate after 30 minutes and earned 1 point. A further explanation notes that the leveling off of the rate is due to substrate exhaustion, earning 1 point.

The response in part (c) indicates that the rate of reaction is doubled (noting the rate increase) and that the leveling off of the rate would occur much faster due to substrate exhaustion. This response earned 1 point as it notes the initial rate increase followed by the rate reduction due to substrate limitation. The other point in part (c), for graphing, was tallied above under part (a).

The first section of part (d) describes the effect of increased temperature on kinetic motion, leading to an increased reaction rate, and earned 1 point for the detailed explanation. The student then explains that too much heat results in denaturation, earning 1 point. pH is then discussed, completing the identification of two environmental factors, earning 1 point. The description of the enzyme not working well outside of its optimum would have earned a point, but the response had already earned the maximum 10 points.

Question 2 (continued)

Sample: 2B
Score: 8

For part (a) the graph contains the proper orientation of the dependent and independent variables and axes that are correctly scaled and labeled (with the correct units). The data are properly graphed on a correctly scaled and oriented graph. The predicted line, required for part (c), is labeled and displays the appropriate prediction, an increase in initial rate. The responses for part (a) thus earned 3 points and the graphing point of part (c). The rate calculation did not earn a point as it lacks units.

At the end of part (a) and the beginning of part (b), the response notes a slowing of the rate and earned 1 point. The student further describes the decrease in carbohydrates (starch), earning 1 point.

In part (c) the description of an increased maltose concentration with a doubling of the enzyme concentration and the attainment of the same final product concentrations earned 1 point.

In part (d) salinity and pH are identified as environmental factors, earning 1 point. No point for the identification of temperature was awarded as it is the third factor noted. No point for the pH discussion was earned as it lacks a description of how an increase or decrease in pH results in an increase or decrease of activity. No point for the discussion of salinity was earned as the first discussion of salinity notes increased salinity as inactivating (denaturing) the enzyme, whereas the second cites an increase in activity (which is a contradiction of the same point).

Sample: 2C
Score: 6

For part (a) the graph contains the proper orientation of the dependent and independent variables and axes that are correctly scaled and labeled (with the correct units). The data are properly graphed on a correctly scaled and oriented graph. The predicted line, required for part (c), is labeled and indicates an increased rate, earning 1 point. The rate calculation is incorrectly set up and calculated, earning no point. The responses for part (a) thus earned 3 points plus the graphing point of part (c).

In part (b) the response notes a leveling off of the reaction rate, earning 1 point.

The response in part (c) describes an increase (doubling) and a leveling off of the rate, earning 1 point. No point was earned for noting that the starch had been broken down because it is not tied to a slowing of the rate. No points were earned for the identification and discussion of environmental factors as they are not discussed.