Enzymes

A Level

Part A Enzyme overview

Enzymes are [ ] proteins that function as [ ] in biological reactions. Enzymes are essential for life because they [ ] the activation energy of fundamental reactions i.e. they allow these reactions to happen much [ ]. The complex tertiary/quaternary structure of enzymes ensures that enzymes are highly [ ] in terms of the reactions they catalyse.

Items:

faster **catalysts** **fibrous** **specific** **increase** **general** **globular** **substrates** **slower** **lower**

Part B Enzyme reactions

An enzyme catalyses a reaction by binding to the [ ] to form an [ ]. The part of the enzyme that binds is called the [ ]. After the reaction is complete, the [ ] releases the [ ]. The enzyme is then free to catalyse another reaction.

Items:

enzyme-substrate complex **product(s)** **active site** **substrate(s)** **enzyme-product complex**

Part C Models of enzyme action

[ ]: the [ ] of the enzyme perfectly matches the shape of the [ ], which ensures complete specificity.

[ ]: the [ ] of the enzyme changes shape in response to the [ ] binding, and only matches the shape after this initial binding.

Items:

Lock-and-key model **product** **substrate** **cofactor** **active site** **Induced-fit model**

Part D Limiting factors

Which of the following are potential limiting factors in **all** enzyme-controlled reactions? Select all that apply.

- [ ] temperature
- [ ] pH
- [ ] concentration of enzyme
- [ ] concentration of product
- [ ] concentration of substrate

Part E Enzyme examples

Enzyme	Reactant(s)	Product(s)
Amylases		
Proteases		
Lipases		
Catalase		

Items:

proteins **hydrogen peroxide** **fatty acids & glycerol** **maltose** **fats** **peptides/amino acids** **water & oxygen** **starch**

Part F Stopping an enzyme from working

What is the name given to a non-substrate molecule that binds to the active site of an enzyme, and thus prevents the substrate from binding?

What is the name given to a non-substrate molecule that binds to part of the enzyme that is **not** the active site, but in doing so causes the shape of the active site to change, such that the substrate can no longer bind?

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Enzyme Reactions

A Level

C C C

Part A Product formation over time

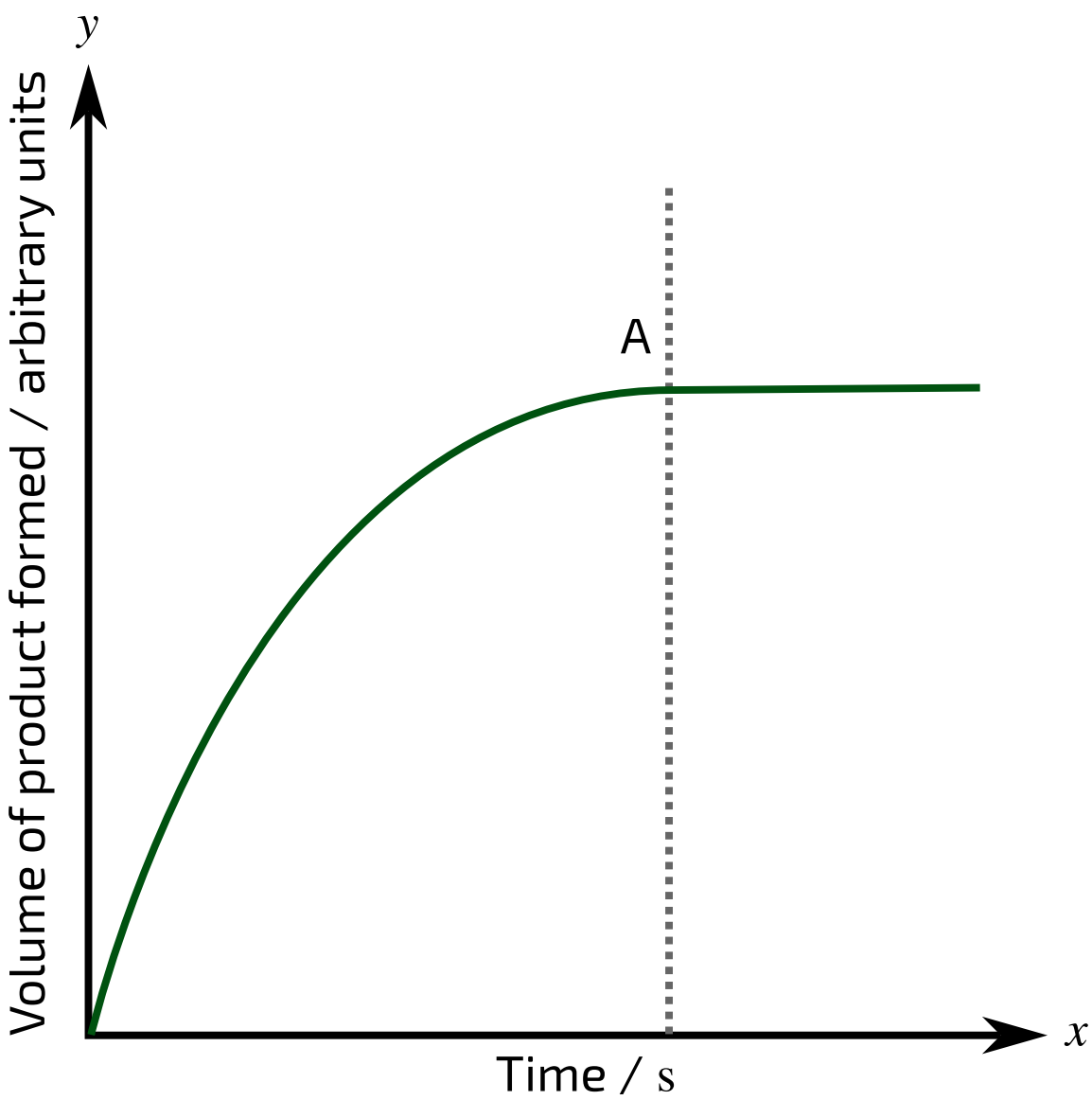

Figure 1: The volume of product formed over time for an enzyme-controlled reaction. Temperature and pH were kept constant throughout the reaction.

Which of the following could explain why no more product is being formed after point A in Figure 1? Select all that apply.

- [ ] The enzyme has become denatured
- [ ] The product is acting as a competitive inhibitor
- [ ] All of the enzyme has been used up in the reaction
- [ ] All of the substrate has been used up in the reaction
- [ ] The product is acting as a cofactor

Part B Reaction rate over temperature

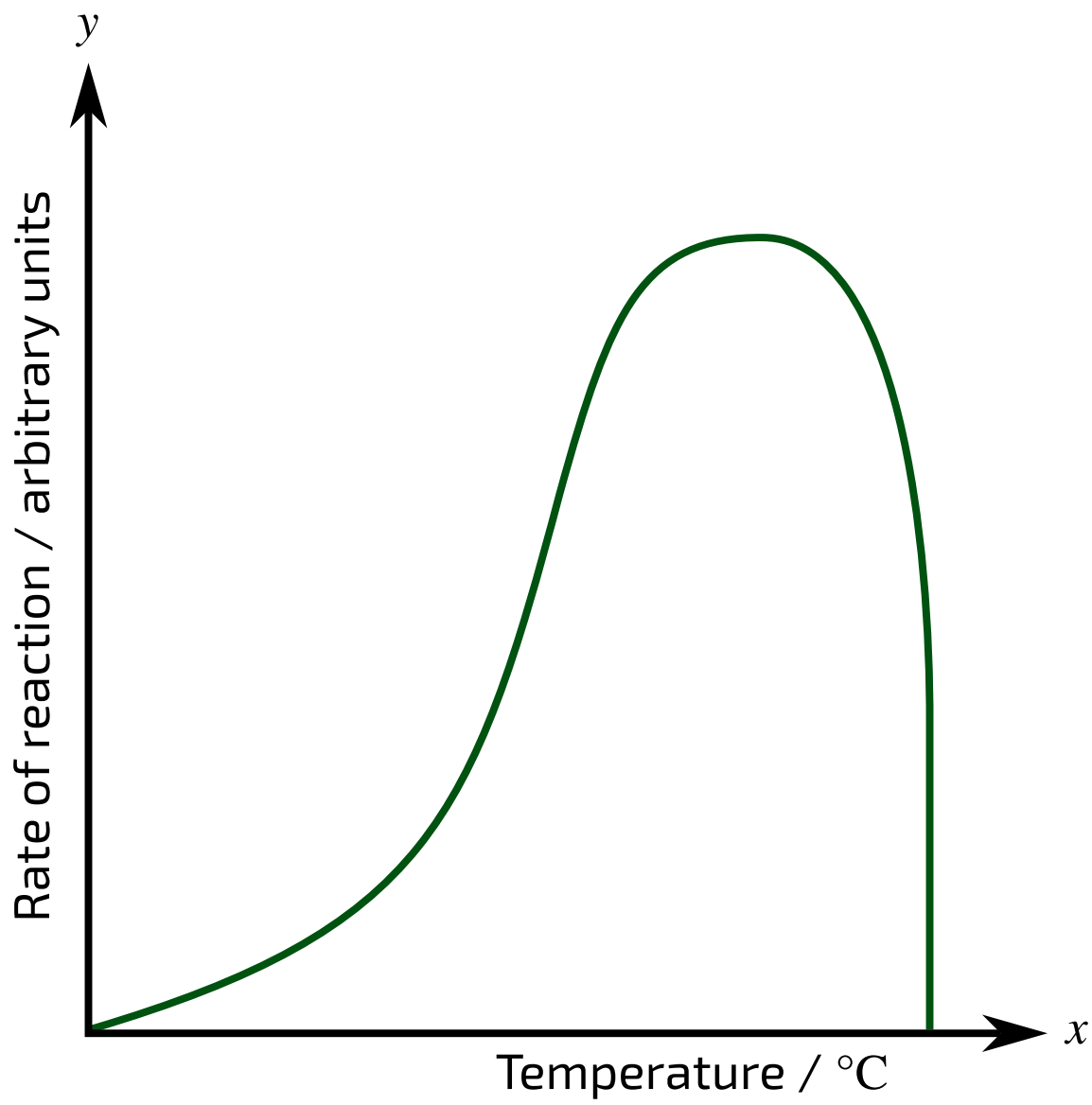

Figure 2: The reaction rate at different temperatures for an enzyme-controlled reaction.

Which of the following correctly describe the relationship shown in Figure 2?

- The rate of reaction positively correlates with temperature across the range of temperatures measured.
- The rate of reaction increases over time until all the substrate is used up, after which point the reaction stops.
- The rate of reaction increases with temperature up to the enzyme's optimal temperature, beyond which the enzyme is denatured and the reaction will not work.
- The rate of reaction increases over time until the product begins to act as a competitive-inhibitor, which slows the reaction down.

Question elements adapted with permission from NSAA 2021 Section 1 Q67

Gameboard:
STEM SMART Biology Week 4 - Enzymes

Enzyme Conditions

A Level

C C C

Part A Reaction rate

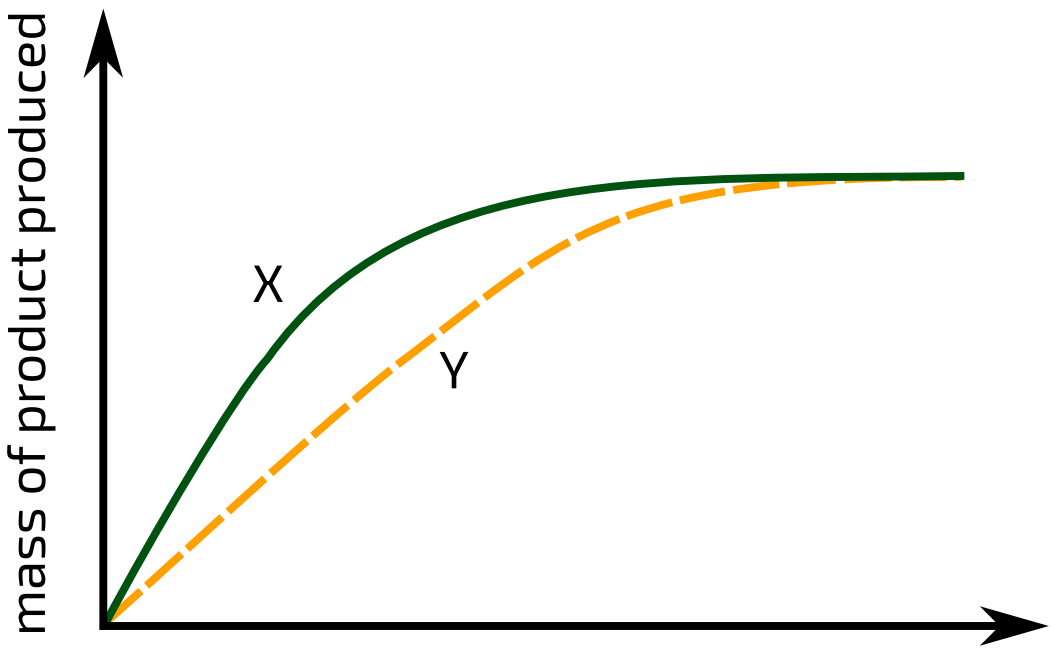

Figure 1: The graph shows the mass of product produced over time for an enzyme-controlled reaction in two different conditions: X and Y. All other variables were kept constant.

Which of the following could explain the differences between X and Y?

- [ ] Condition X has more substrate supplied than condition Y.
- [ ] Condition X has less substrate supplied than condition Y.
- [ ] Condition X is a higher pH than condition Y.
- [ ] Condition X is a lower pH than condition Y.

Part B Preferred pH

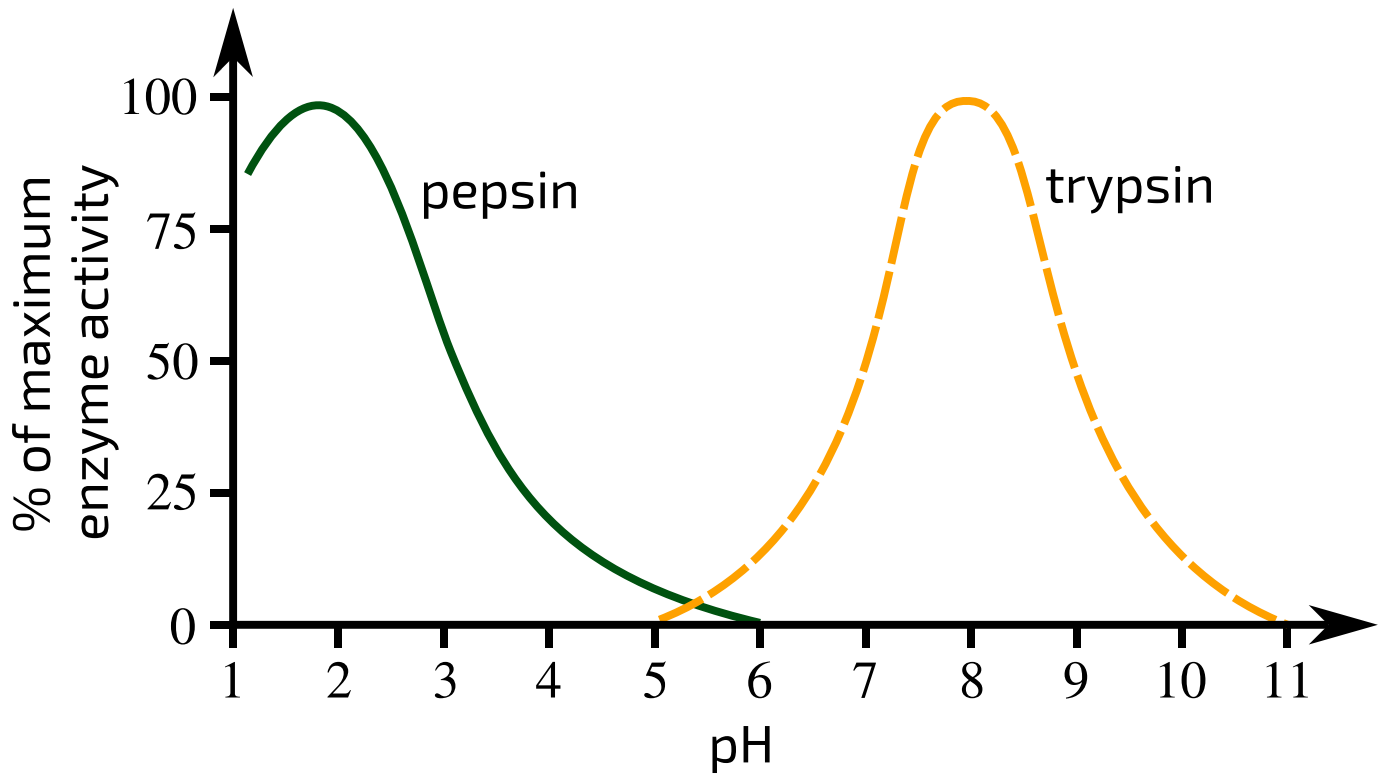

Figure 2: Pepsin and trypsin are both protease enzymes found in the human digestive system. The graph shows how the activity of both enzymes varies with pH.

Which of the following statements are correct, for the human digestive system?

- [ ] Trypsin would be inactive in the stomach.
- [ ] Pepsin is most active at low acidity and trypsin most active at high acidity.
- [ ] Pepsin could be a substrate for trypsin.
- [ ] Pepsin is most active in the stomach.

Question elements adapted with permission from NSAA 2020 Section 1 Q72 and NSAA 2020 Section 1 Q66

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Changing Substrate Concentrations

A Level

C C C

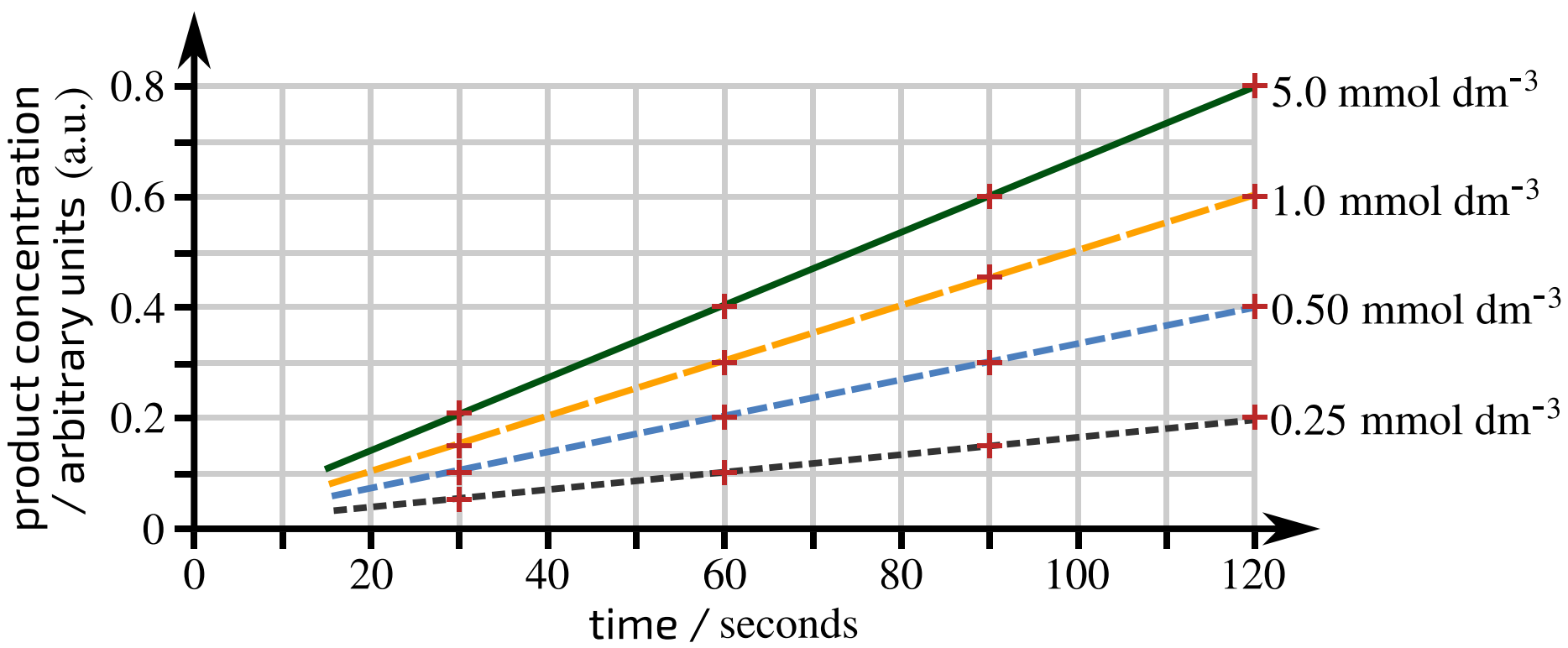

Figure 1: An investigation was carried out on the effect of substrate concentration on an enzyme-controlled reaction. Four different concentrations of substrate were tested. In each case, the concentration of product was measured at regular intervals following the introduction of the substrate. All other variables were kept constant.

Part A Reaction rate

What is the average rate of reaction for a substrate concentration of $1.0\,\mathrm{mmol\,dm^{-3}}$?

Part B Substrate statements

Which of the following statements are correct? Select all that apply.

- [ ] Doubling the substrate concentration always doubles the amount of product produced over $120\,\mathrm{s}$.
- [ ] Doubling the substrate concentration always doubles the rate of reaction.
- [ ] As substrate concentration increases, the time taken to produce 0.2 arbitrary units of product decreases.
- [ ] At substrate concentrations above $1.0\,\mathrm{mmol\,dm^{-3}}$, the relationship between substrate concentration and average reaction rate is non-linear.
- [ ] As substrate concentration increases, the time taken to produce 0.2 arbitrary units of product increases.

Adapted with permission from NSAA 2019 Section 1 Q71

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STEM SMART Biology Week 4 - Enzymes

Enzyme Experiment: pH Comparison

A Level

C C C

A student carried out an experiment to investigate the effect of pH on enzyme activity. The volume of product was measured over time in two separate experiments: one at $\mathrm{pH}\ 5$ and one at $\mathrm{pH}\ 7$. In both experiments, the temperature was kept constant at the optimum temperature for this enzyme. All other variables were kept constant. The results are shown below in **Figure 1**.

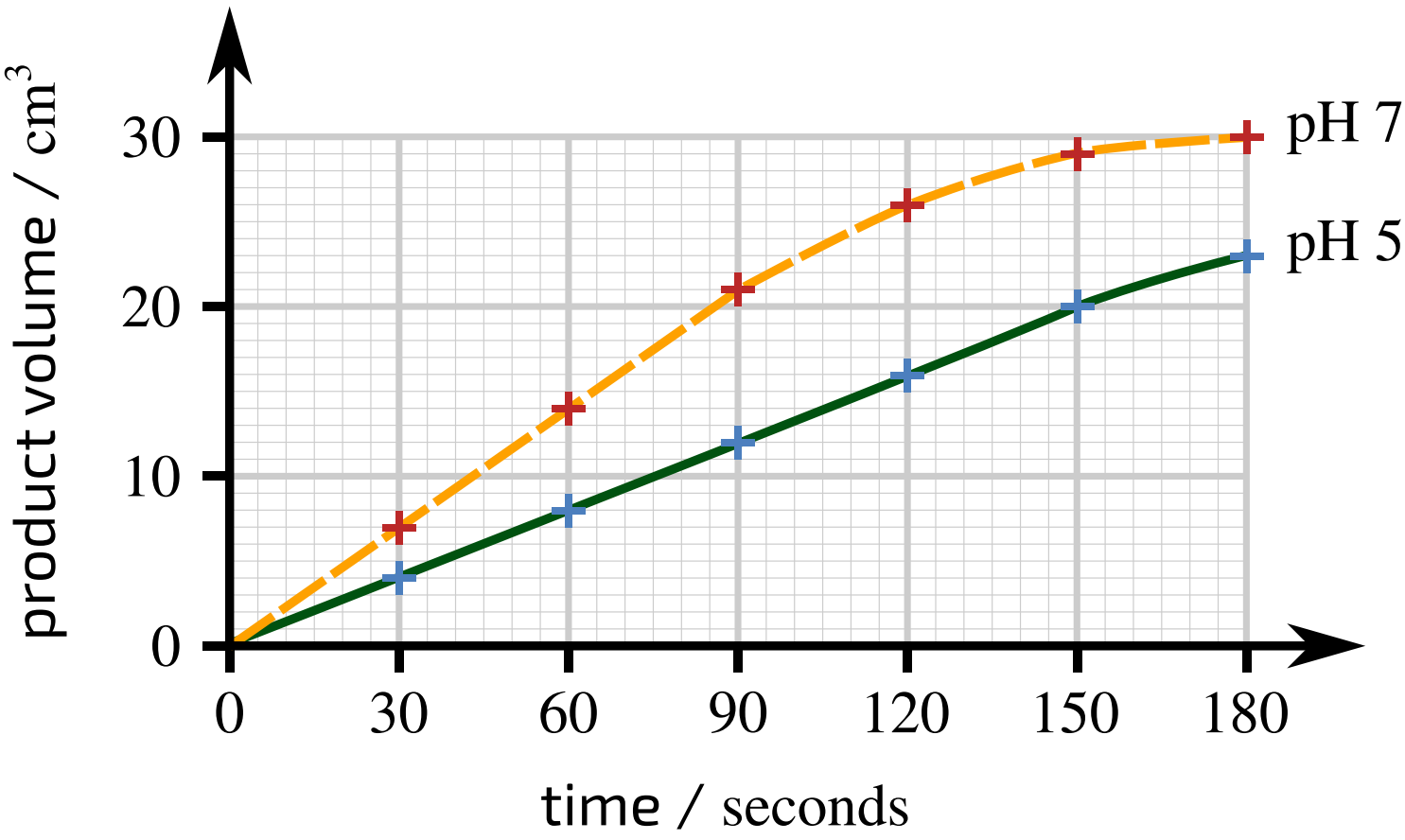

Figure 1: The volume of product over time for the same enzyme reaction carried out at two different pHs.

Part A Percentage increase from $30\ \mathrm{s}$ to $90\ \mathrm{s}$

Calculate the percentage increase in product volume from $30\ \mathrm{s}$ to $90\ \mathrm{s}$ for each pH. Give your answer to the nearest percent.

$\mathrm{pH}\ 5$: ____ %

$\mathrm{pH}\ 7$: ____ %

Part B Percentage increase from $120\,\mathrm{s}$ to $180\,\mathrm{s}$

Calculate the percentage increase in product volume from $120\,\mathrm{s}$ to $180\,\mathrm{s}$ for each pH. Give your answer to the nearest percent.

$\mathrm{pH}\ 5$: [ ] %

$\mathrm{pH}\ 7$: [ ] %

Part C Rate of reaction from $30\,\mathrm{s}$ to $90\,\mathrm{s}$

Calculate the average rate of reaction from $30\,\mathrm{s}$ to $90\,\mathrm{s}$ for each pH. Give your answer to 2 sf.

$\mathrm{pH}\ 5$: [ ]

$\mathrm{pH}\ 7$: [ ]

Part D Rate of reaction from $120\,\mathrm{s}$ to $180\,\mathrm{s}$

Calculate the average rate of reaction from $120\,\mathrm{s}$ to $180\,\mathrm{s}$ for each pH. Give your answer to 2 sf.

$\mathrm{pH}\ 5$: [ ]

$\mathrm{pH}\ 7$: [ ]

Part E pH 5 vs pH 7

Why is the average rate of reaction higher for $\mathrm{pH}\ 5$ than for $\mathrm{pH}\ 7$ from $120\,\mathrm{s}$ to $180\,\mathrm{s}$?

- In the $\mathrm{pH}\ 7$ experiment, the enzyme is starting to become denatured by this point in time.
- In the $\mathrm{pH}\ 7$ experiment, the reaction has almost finished, which means that the enzyme is almost used up.
- In the $\mathrm{pH}\ 7$ experiment, the reaction has almost finished, which means that the substrate is almost used up.
- The optimum pH for this enzyme is $\mathrm{pH}\ 5$.
- The $\mathrm{pH}\ 5$ experiment was carried out at the optimum temperature, whereas the $\mathrm{pH}\ 7$ experiment was not.

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Temperature and Catalase Activity

A Level

C C C

Catalase is an enzyme, found in the cells of most organisms, that breaks down hydrogen peroxide into water and oxygen.

A student carried out an experiment to investigate the effect of temperature on catalase activity. They placed the test tubes containing hydrogen peroxide solution at different temperatures, added sections of potato (a source of catalase) to each tube, and measured the total volume of oxygen produced over 60 seconds. For each temperature, there were three test tubes, which allowed the student to calculate a mean volume of oxygen produced for each temperature.

Part A Reaction equation

Catalase catalyses the breakdown of hydrogen peroxide into water and oxygen.

Write the balanced equation for this reaction. You do not need to include state symbols.

Part B Independent and dependent variables

Identify the independent variable and the dependent variable in this experiment.

Independent variable: [ ]

Dependent variable: [ ]

Items:

time **pH** **temperature** **volume of oxygen** **volume of hydrogen peroxide solution** **concentration of catalase** **concentration of hydrogen peroxide solution** **mass of potato sections**

Part C Control variables

Which of the following variables should be control variables in this experiment?

- [ ] time
- [ ] pH
- [ ] temperature
- [ ] volume of oxygen
- [ ] volume of hydrogen peroxide solution
- [ ] concentration of catalase
- [ ] concentration of hydrogen peroxide solution
- [ ] mass of potato sections

Part D Experimental data

Some of the student's data is shown in the table below. Fill in the missing values.

Temperature $(^\circ\mathrm{C})$	**Volume of oxygen produced** (cm^3)			
	Tube 1	Tube 2	Tube 3	Mean
0	4	2	3	3.0
10	7	5	9	
20	23	26		23.0
30	34	38	39	
40		17	13	14.0
50	2		1	2.0

Calculate an average rate of reaction for $30\,^\circ\mathrm{C}$ using the mean value in the table above. Give your answer to 2 sf.

Part E Catalase above $50\,^{\circ}\mathrm{C}$

Why does catalase stop working at temperatures above $50\,^{\circ}\mathrm{C}$? Select all that apply.

- [ ] The high temperatures break apart the bonds involved in the primary structure of catalase i.e. the protein is broken down into amino acids.
- [ ] The high temperatures break apart the bonds involved in the secondary, tertiary, and quaternary structures of catalase.
- [ ] The active site changes shape, which prevents hydrogen peroxide from binding to it.
- [ ] The active site changes shape, which prevents oxygen from binding to it.
- [ ] The active site changes shape, which prevents water from binding to it.

What word is used to describe an enzyme after this has occurred?
