C.1.1 Enzymes [131 marks]

1. [Maximum mark: 1]
What is a common feature of enzymes?

A. They all react with substrates.

B. They all decrease the rate of reaction.

C. They are all secreted from cells in vesicles.

D. They all bind to the active site of their substrate. [1]

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2. [Maximum mark: 15]
Various mechanisms can lead to inhibition in biological systems. A toxin is a substance capable of disrupting metabolic processes in organisms.

(a) Describe how toxins such as DDT might concentrate in the bodies of birds. [4]

(b) Toxins often act as inhibitors. Compare and contrast competitive and non-competitive enzyme inhibition. [7]

(c) Rotenone is a naturally occurring toxin that blocks the electron transport chain in insects and fish. Outline the consequences of exposure to a toxin like rotenone for cell respiration. [4]

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3. [Maximum mark: 15]

Biological systems are sensitive to temperature changes, so they have mechanisms to resist temperature changes.

(a) Explain the mechanisms involved in thermoregulation in humans. [7]

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(b) Explain the relationship between temperature and the activity of enzymes. [4]

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(c) Distinguish between the thermal properties of air and water as they relate to the habitat of animals. [4]

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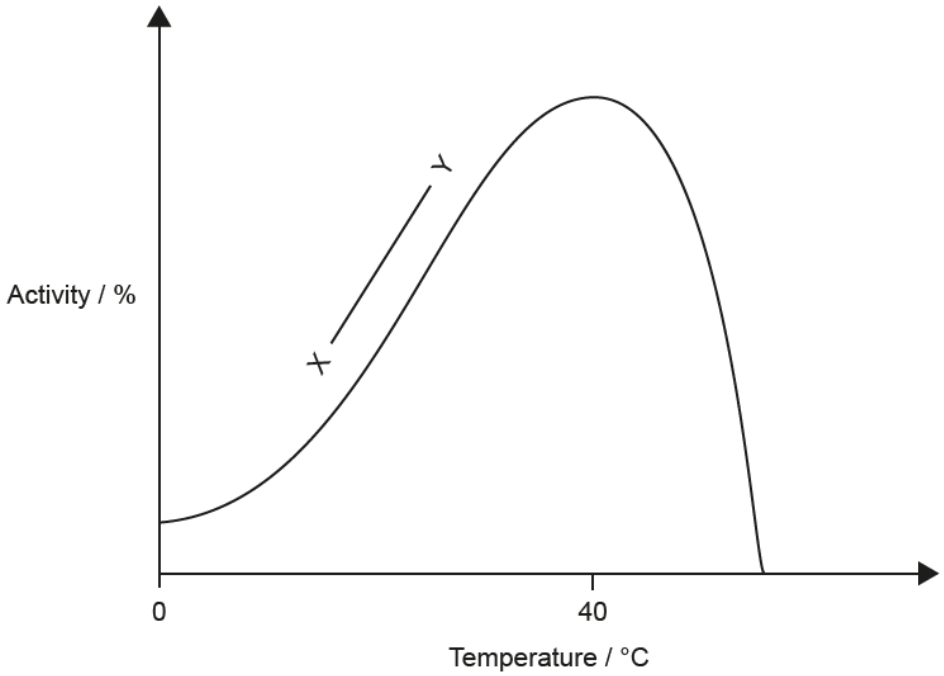
4. [Maximum mark: 1]

The graph shows the activity of an enzyme as temperature increases.



[Source: Gal m, 2007. Enzyme-temperature. [image online] Available at: https://commons.wikimedia.org/wiki/File:Enzyme-temperature.png. Licensed under the Creative Commons Attribution 3.0 Unported license: https://creativecommons.org/licenses/by/3.0/deed.en. [Accessed 7 June 2024]. Source adapted.]

What explains the change in enzyme activity between X and Y? [1]

A. The enzyme is denaturing as the active site changes shape.

B. Increased collisions occur as molecules are moving faster.

C. Increased product concentration speeds up the reaction.

D. An inhibitor has been added, reducing the number of active sites.

5. [Maximum mark: 1]

What is an example of an intracellular enzyme-catalysed reaction?

A. Chemical digestion in the gut

B. Glycolysis in cellular respiration

C. Blood clotting in the circulatory system

D. Recycling of acetylcholine in a synapse [1]

6. [Maximum mark: 1]
Which process is an example of catabolism?

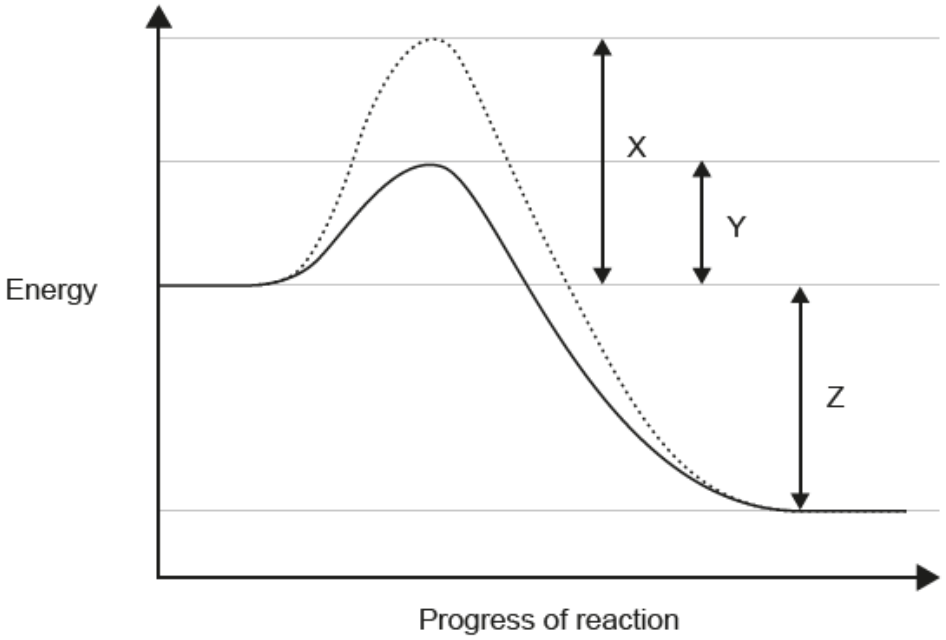
A. Protein synthesis

B. Photosynthesis

C. Oxidation of substrates in respiration

D. Glycogen formation [1]

7. [Maximum mark: 1]
The graph shows energy changes during a reaction both with and without an enzyme present.



Which statement correctly identifies two of the regions labelled X, Y and Z in the graph?

A. X is the activation energy with an enzyme and Z is the net energy released from the reaction. [1]

B. X is the energy released from the reaction and Y is the activation energy with an enzyme.

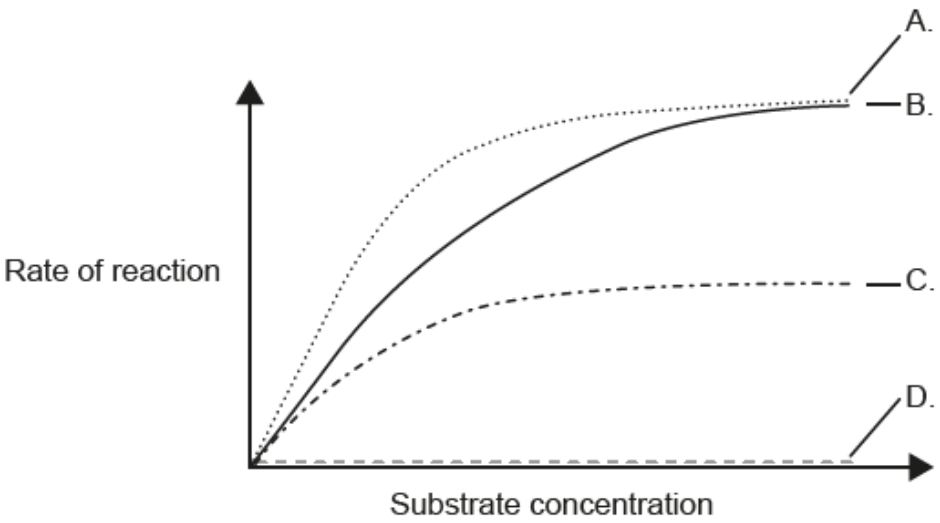
C. Y is the energy released with an enzyme and Z is the energy released when bonds are broken.

D. Y is the activation energy with an enzyme and Z is the net energy released.

8. [Maximum mark: 1]

The graph illustrates how enzyme-catalysed reactions can be affected by inhibitors. Which curve shows the effect of statins on the rate of

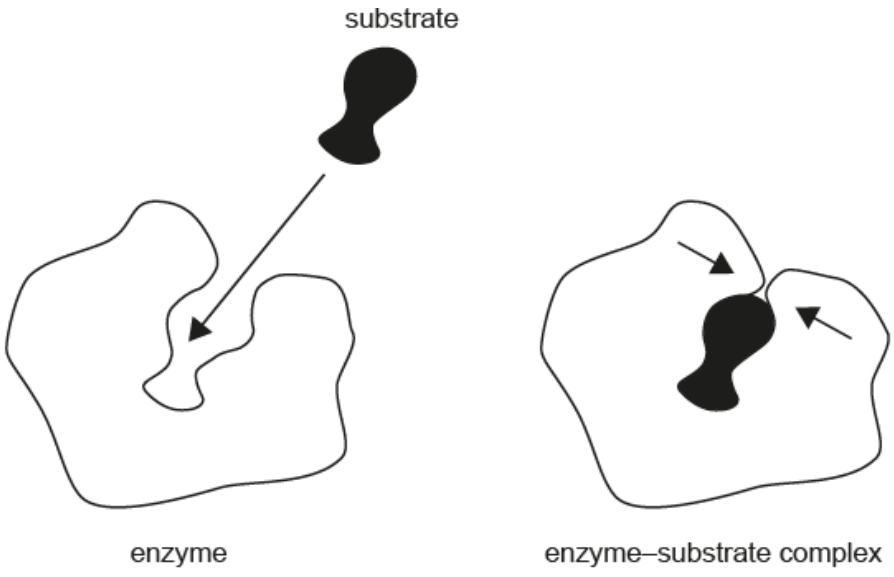
cholesterol synthesis in the body?



[1]

9. [Maximum mark: 1]

The diagram shows the formation of an enzyme–substrate complex.



[Source: Olson, K., 2012. *Induced Fit Enzyme Catalyst.* [image online] Available at: https://commons.wikimedia.org/wiki/File:InducedFit_Enzyme_Catalyst.png. Public domain. Source adapted.]

What describes the process shown in the diagram?

A. The lock and key hypothesis, as the substrate is complementary to the enzyme.

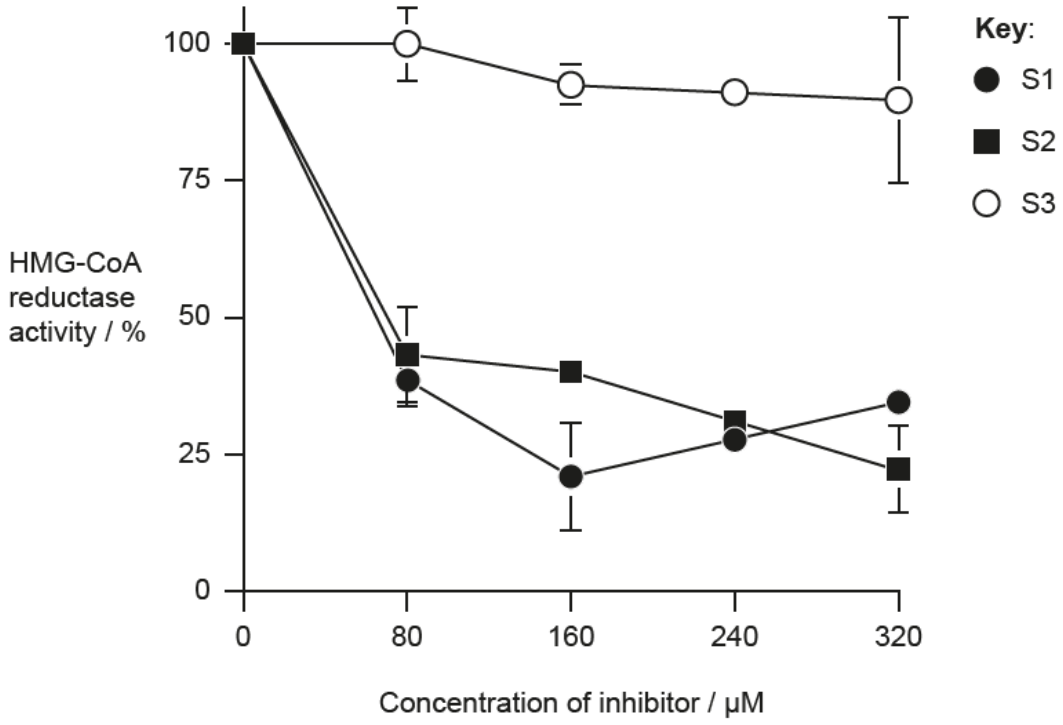
B. The substrate permanently alters the shape of the enzyme's active site.

C. The substrate and the active site have the same shape.

D. The active site changes shape to accommodate the substrate in the induced-fit model. [1]

10. [Maximum mark: 9]

The inhibitory effect of three different statins (S1, S2 and S3) on the activity of HMG-CoA reductase, an enzyme involved in cholesterol metabolism in the liver, was investigated.



[Source: Rao, S., Porter, D., Chen, X., Herliczek, T., Lowe, M. and Keyomarsi, K., © 1999, The National Academy of Sciences. Lovastatin-mediated G1 arrest is through inhibition of the proteasome, independent of hydroxymethyl glutaryl-CoA reductase. *Proc Natl Acad Sci USA* 96, pp. 7797–7802. https://doi.org/10.1073/pnas.96.14.7797. Source adapted.]

(a.i) Identify an independent variable in this investigation. [1]

(a.ii) State **one** variable that needs to be controlled. [1]

(b) Compare and contrast the effect of increasing concentrations of S1 and S2 on the mean activity of HMG-CoA reductase. [3]

(c) Outline how the rate of reaction of HMG-CoA reductase can be calculated. [1]

(d) Statins limit the synthesis of cholesterol by acting as competitive inhibitors. Distinguish between competitive and non-competitive inhibition. [1]

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(e) Describe the role of enzymes in **one named** process that prevents infections in the human body. [2]

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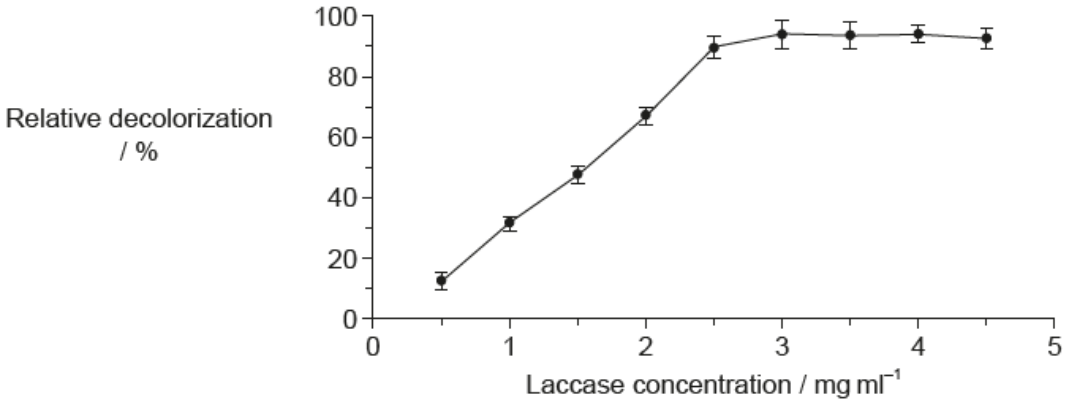
11. [Maximum mark: 8]

Laccase is an enzyme that has the ability to decompose synthetic dyes used in the production of clothing and thus could potentially help reduce synthetic dye pollution.

An experiment was performed in which laccase was immobilized in alginate beads to determine the effectiveness of laccase immobilization in decolorizing the dye crystal violet. The graph shows the effect of laccase concentration on relative decolorization activity of the immobilized laccase. Error bars represent ± SD.



[Source: Mogharabi, M., Nassiri, N., Bozorgi-Koushalshahi, M., Nafissi-Varcheh, N., Bagherzadeh, G. and Faramarzi, M., 2012. Immobilization of Laccase in Alginate-Gelatin Mixed Gel and Decolorization of Synthetic Dyes. *Bioinorganic Chemistry and Applications* vol 2012. https://doi.org/10.1155/2012/823830. Source adapted. Licensed under CC BY 3.0 Attribution Unported Deed (https://creativecommons.org/licenses/by/3.0/deed.en).]

(a) Predict the relative decolorization of crystal violet at an laccase concentration of 5 mg ml^{-1}.

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[1]

(b) Deduce the significance of overlapping error bars in the data for laccase concentrations from 3 mg ml^{-1} to 4 mg ml^{-1}. [1]

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(c) Discuss the variables that need to be controlled in this investigation. [2]

(d) Suggest how the percentage of decolorization could be obtained experimentally. [3]

(e) Distinguish between processes involved in cyclical and linear metabolic pathways. [1]

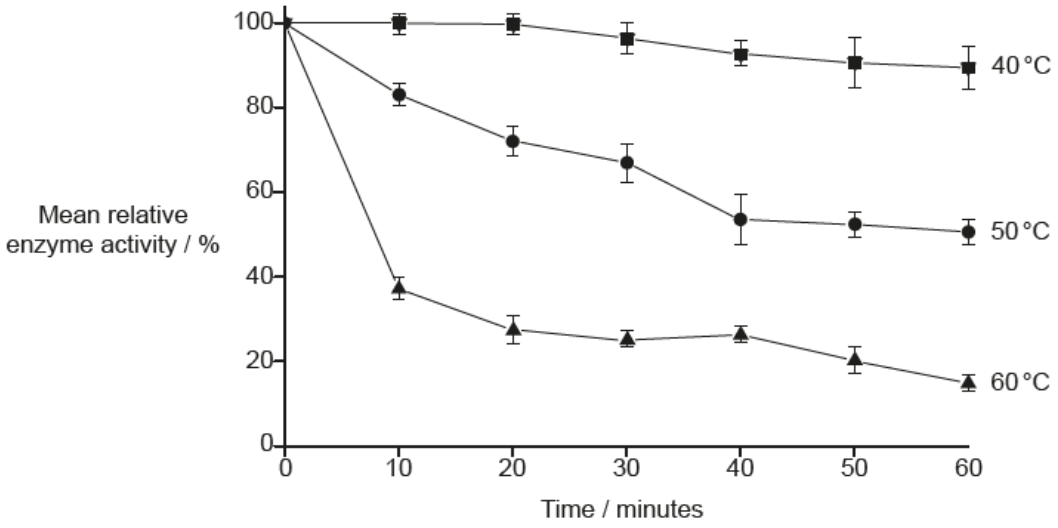
12. [Maximum mark: 7]

A scientist investigated the effect of storage temperature on the activity of an enzyme.

The scientist incubated three lipase solutions for one hour at three different storage
temperatures (40 °C, 50 °C or 60 °C).

At every 10-minute interval, a sample of lipase solution was taken and immediately used to
catalyse the digestion of a small volume of oil. The values were then compared to the results
obtained at the optimum temperature for lipase (37 °C). Relative enzyme activity values
were determined.

The graph shows the mean results of the investigation.



[Source: Zheng, C., 2021. Study on enzymatic activity and lipase catalysis by lipase high-yield strain. Conf. Ser.:
Earth Environ. Sci. 632 032016. https://doi.org/10.1088/1755-1315/632/3/032016. Source adapted.]

(a) Identify the independent variable in this investigation. [1]

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(b) Identify **one** factor that needs to be controlled in this investigation.

[1]

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(c) Explain the relationship shown between storage temperature and relative enzyme activity. [2]

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(d) Describe how the reliability of the results obtained in this investigation is indicated on the graph. [1]

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(e) When oils are digested, fatty acids are produced. These reduce the pH of the reaction mixture. Explain how the rate of reaction could be measured in this investigation. [2]

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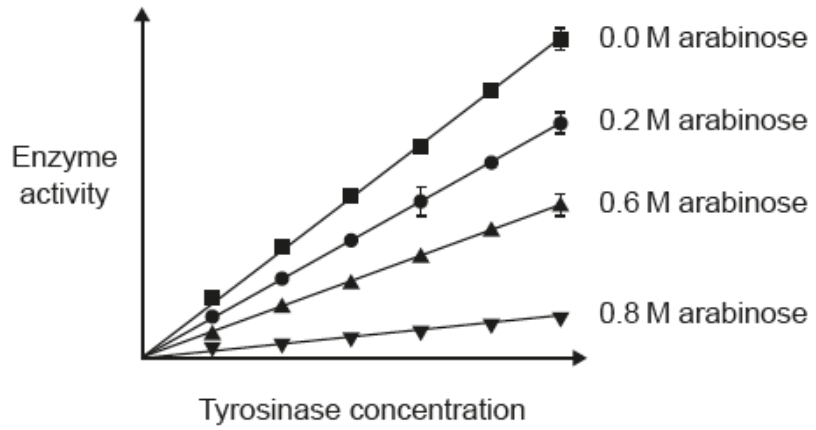
13. [Maximum mark: 1]

The graph shows the activity of the enzyme tyrosinase at different concentrations of tyrosinase and arabinose.



[Source: Liu, H.-J., Ji, S., Fan, Y.-Q., Yan, L., Yang, J.-M., Zhou, H.-M., Lee, J. and Wang, Y.-L., 2012. *Enzyme Research* [online] Available at: https://www.hindawi.com/journals/er/2012/731427/ [Accessed 2 January 2024]. Reference redacted. Source adapted.]

Which hypothesis is consistent with the data in the graph?

A. Arabinose is the substrate for tyrosinase.

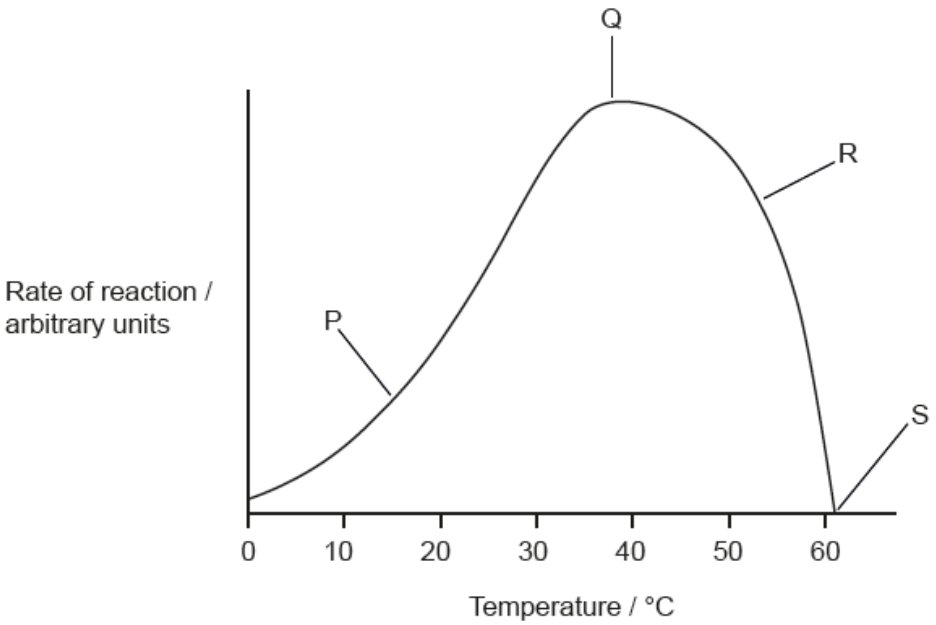
B. Arabinose and tyrosine are the substrates for tyrosinase.

C. Arabinose prevents binding of the substrate to the active site of tyrosinase.

D. Arabinose concentration is negatively correlated with tyrosinase concentration. [1]

14. [Maximum mark: 1]

The graph shows the effect of temperature on the rate of a chemical reaction catalysed by enzymes.



What is a valid statement about a labelled point in the graph?

A. At P, substrate concentration is limiting the rate of reaction.

B. At Q, substrate and enzyme molecules achieve their highest kinetic energy.

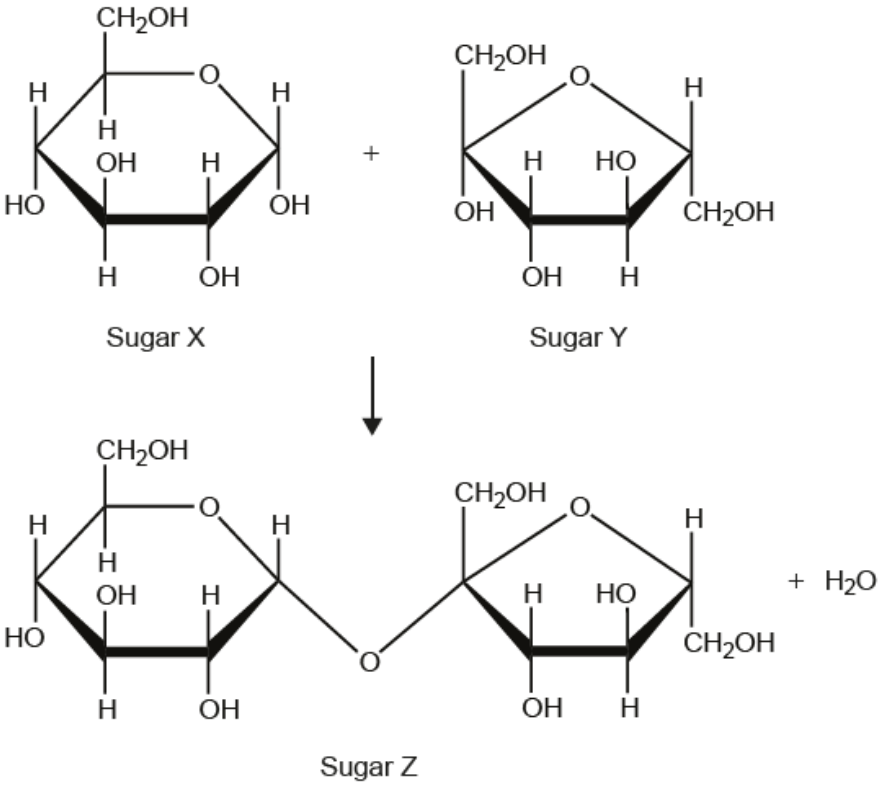
C. At R, some active sites have changed shape.

D. At S, all substrate molecules have formed product.

[1]

15. [Maximum mark: 1]

The equation shows a reaction that leaf cells perform.



What are features of this reaction?

A. Sugar X is alpha-D-glucose, Sugar Z is maltose, and the reaction is catabolic. [1]

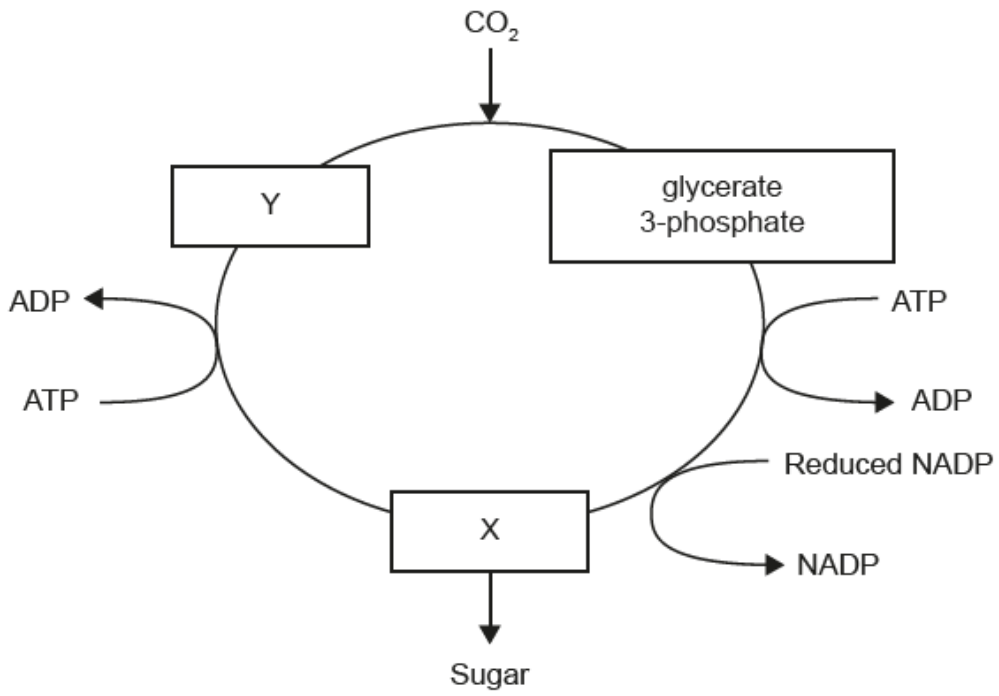
B. Sugar Y is beta-D-glucose, Sugar Z is sucrose, and the reaction is anabolic.

C. A disaccharide is produced by a condensation reaction.

D. Two monosaccharides are combined in a hydrolysis reaction.

16. [Maximum mark: 6]

The diagram shows the Calvin cycle.



(a) Identify the molecules X and Y.

X: .....
Y: .....

[2]

(b) A product of the Calvin cycle is transported in the phloem.

(b.i) State the name of the molecule that is transported. [1]

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(b.ii) Explain how this molecule is transported from leaves to roots. [3]

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17. [Maximum mark: 15]

Chemicals are involved at all levels of biology: cell functions, structure of organisms, interactions with the environment.

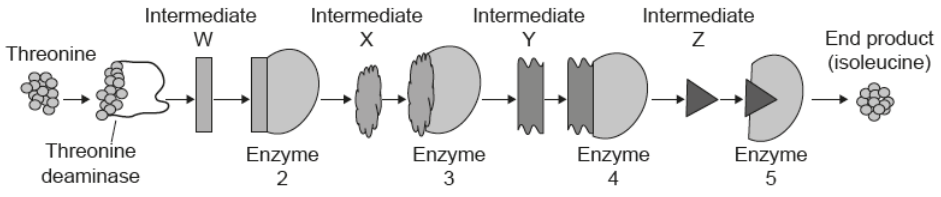
(a) Distinguish between competitive and non-competitive enzyme inhibition. [4]

(b) Outline the process of micropropagation in plants and its benefits. [4]

(c) Rising levels of carbon dioxide pose threats to marine life. Explain the causes of increased carbon dioxide and its effects in oceans. [7]

18. [Maximum mark: 1]

The production of isoleucine from threonine is summarized in the diagram. This process involves several steps and is regulated by feedback inhibition.



[Source: Isogai, S., et al., 2022. High-Level Production of Isoleucine and Fusel Alcohol by Expression of the Feedback Inhibition. *Applied and environmental microbiology* 88(5), e0213021. [e-journal] Available at: https://journals.asm.org/doi/10.1128/aem.02130-21 [Accessed 12 April 2023]. Source adapted.]

What occurs during isoleucine production?

A. Isoleucine inhibits the conversion of intermediate W to intermediate X.

B. Isoleucine inhibits the conversion of intermediate Y to intermediate Z.

C. Threonine inhibits threonine deaminase activity.

D. Isoleucine inhibits threonine deaminase activity. [1]

19. [Maximum mark: 1]

What feature is common to both the Krebs cycle and the Calvin cycle?

A. They are forms of catabolism.

B. They are forms of anabolism.

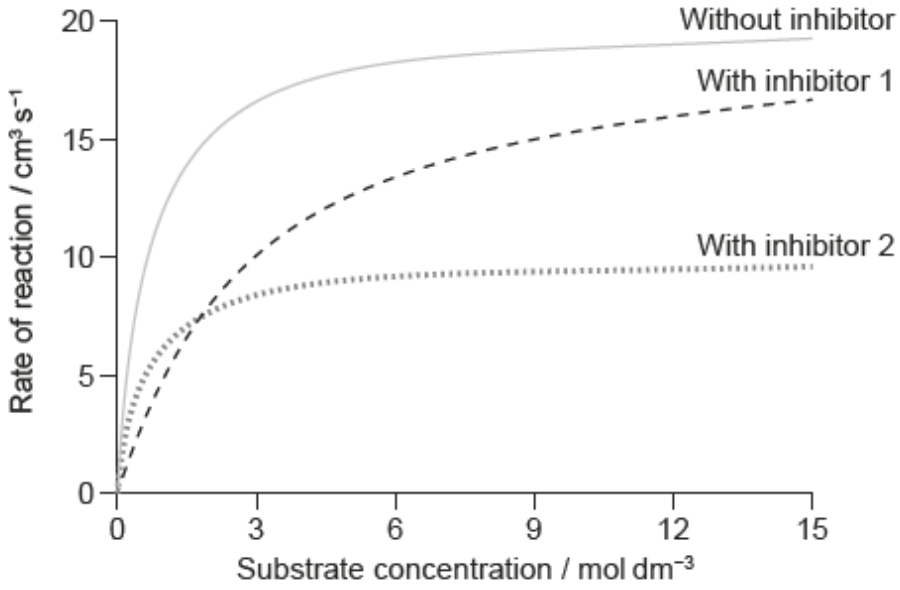
C. They involve reduction reactions.

D. They produce large amounts of ATP. [1]

20. [Maximum mark: 1]

A group of students investigated the effect of increasing substrate concentration on the rate of an enzyme-catalysed reaction in the presence of two inhibitory substances. The results are shown in the

graph.



What can be deduced from these results?

A. At all substrate concentrations, both inhibitors compete for the enzyme's active site.

B. Both inhibitors are specific for this enzyme-catalysed reaction.

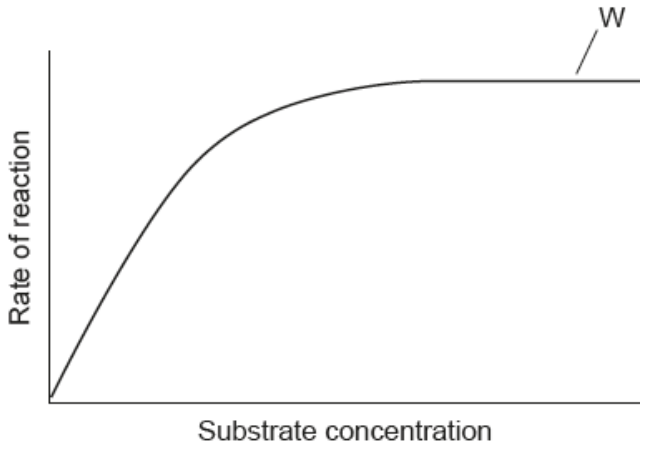
C. At very low substrate concentrations, inhibitor 2 shows a higher inhibitory effect.

[1]

D. Inhibitor 1 and substrate have similar shapes.

21. [Maximum mark: 1]

The graph shows the effect of substrate concentration on the rate of an enzyme-controlled reaction.



What explains the shape of the curve at W?

A. The amount of substrate is limiting.

B. The end point of the reaction has been reached. [1]

C. All active sites are occupied by substrate molecules.

D. Collisions between molecules have reached the fastest speed.

22. [Maximum mark: 15]
Carbon dioxide and oxygen are essential gases in many biological processes.

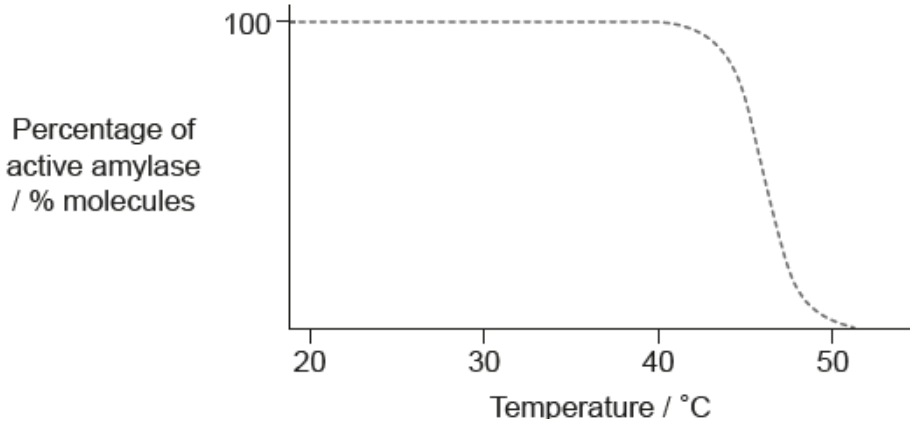
(a) Outline anaerobic cell respiration. [4]

(b) Describe conditions necessary in the lungs for efficient gas exchange in humans. [3]

(c) With reference to Calvin's experiment, explain the fixation of carbon dioxide in photosynthesis. [8]

23. [Maximum mark: 4]

In an experiment, starch was hydrolysed with human amylase. The graph shows the percentage of active amylase molecules as the temperature was raised from 20 to 50 °C.



(a.i) Label with an A the point on the graph where the rate of hydrolysis would be highest. [1]

(a.ii) Outline the reason for the decrease in the percentage of active amylase after 40 °C. [1]

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(b) Explain how the small intestine is adapted to absorb the products of starch digestion. [2]

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24. [Maximum mark: 1]

What is a feature of enzyme inhibition?

A. In the pathway that converts threonine to isoleucine, end-product inhibition occurs when isoleucine binds to threonine.

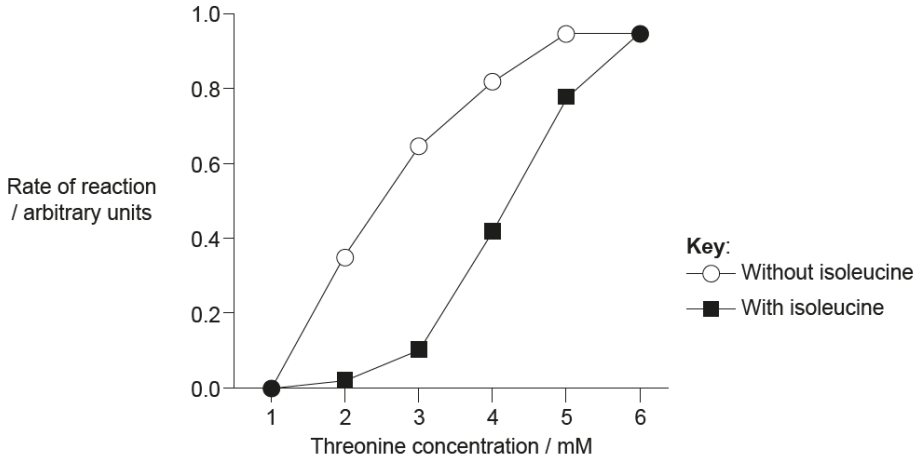
B. Increasing the amount of substrate will increase the amount of product when a reaction is inhibited by non-competitive inhibitors.

C. Competitive inhibitors prevent catalysis by binding to an allosteric site.

D. Non-competitive inhibitors are a different shape from the substrate. [1]

25. [Maximum mark: 1]

Through a series of enzymatic reactions, the amino acid threonine is converted to isoleucine. The graph shows the rate of reaction of threonine deaminase according to the concentration of its substrate threonine, with and without the presence of isoleucine.



[Source: Calhoun, D.H., Rimernian, R.A. and Hatfield, G.W., 1973. Threonine Deaminase from Escherichia coli. I. Purification and Properties. *The Journal Of Biological Chemistry*, 248(10), pp. 3511–3516. Open Access.]

What can be seen from these results?

A. Threonine deaminase only works in the presence of isoleucine.

B. Isoleucine inhibits threonine deaminase at low concentrations of threonine.

C. Production of isoleucine is inhibited at high concentration of threonine.

D. End-product inhibition controls the production of threonine deaminase. [1]

26. [Maximum mark: 5]
The image represents the structure of the enzyme Rubisco from common pea (*Pisum sativum*).

(a) State **one** function of Rubisco. [1]

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(b) State a role of the active site of an enzyme. [1]

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(c) State the genus of the plant where this Rubisco is found. [1]

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(d) Outline **one** factor that could affect the activity of Rubisco. [2]

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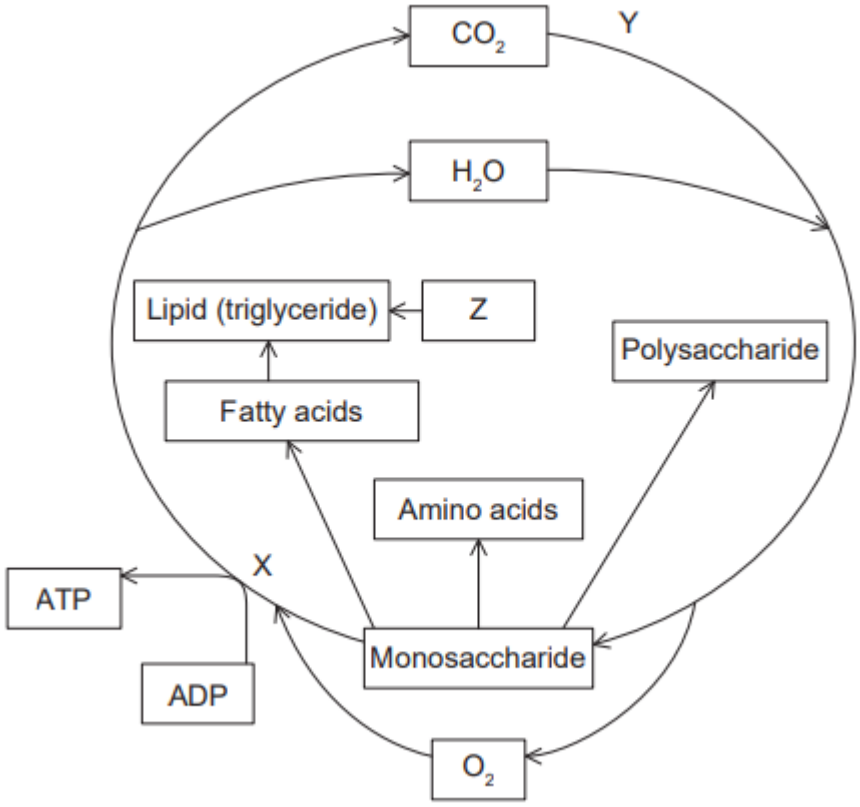
27. [Maximum mark: 7]

The diagram shows some of the metabolic processes taking place in a plant cell.



(a.i) Identify the process Y and state the name of the organelle where it takes place in a plant cell.

Process Y:

Name of the organelle: [1]

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(a.ii) Identify the molecule Z. [1]

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(b) State the type of reaction which converts excess monosaccharides to polysaccharides. [1]

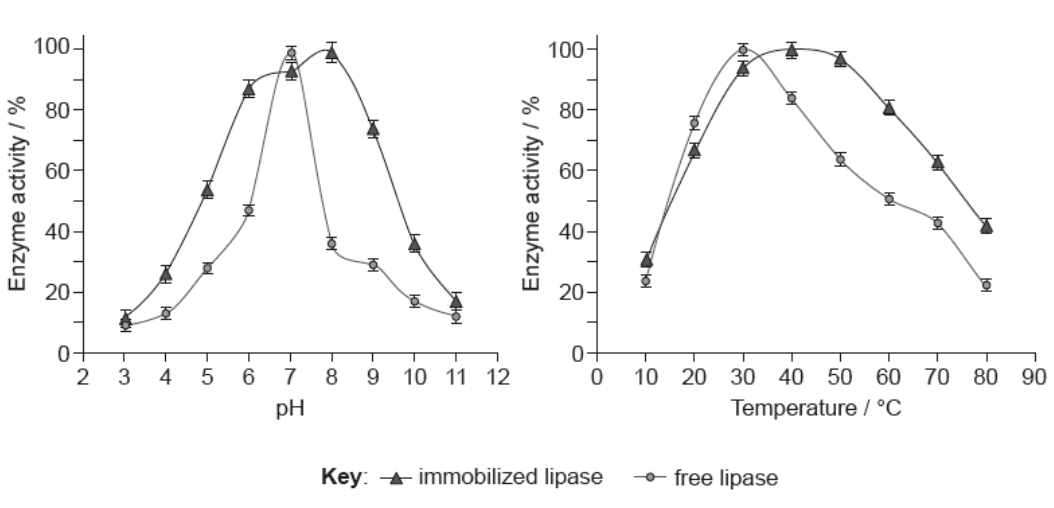
(c) The process X uses oxygen and produces ATP. Identify the process X. [1]

(d) Outline the uses of ATP in plant cells. [2]

(e) With reference to the diagram, identify **one** example of catabolism. [1]

28. [Maximum mark: 4]

Lipase was extracted from the fungus *Aspergillus niger* and used to hydrolyse one of its substrates. This was repeated for an immobilized form of lipase. The graph shows how the enzyme activity varied at different pH and temperature levels.



[Source: adapted from Zdarta, J.; Klapiszewski, Ł.; Wysokowski, M.; Norman, M.; Kołodziejczak-Radzimska, A.; Moszyński, D.; Ehrlich, H.; Maciejewski, H.; Stelling, A.L.; Jesionowski, T. Chitin-Lignin Material as a Novel Matrix for Enzyme Immobilization. Mar. *Drugs* 2015, **13**, 2424–2446.]

(a) State the effect immobilization of lipase has on its optimum temperature. [1]

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(b) The graph of the effect of pH on immobilized lipase activity does not allow for the determination of optimum pH precisely. Explain how a more exact value for the optimum pH could be determined. [2]

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(c) Based on these experimental results, suggest **one** advantage of immobilizing lipase. [1]

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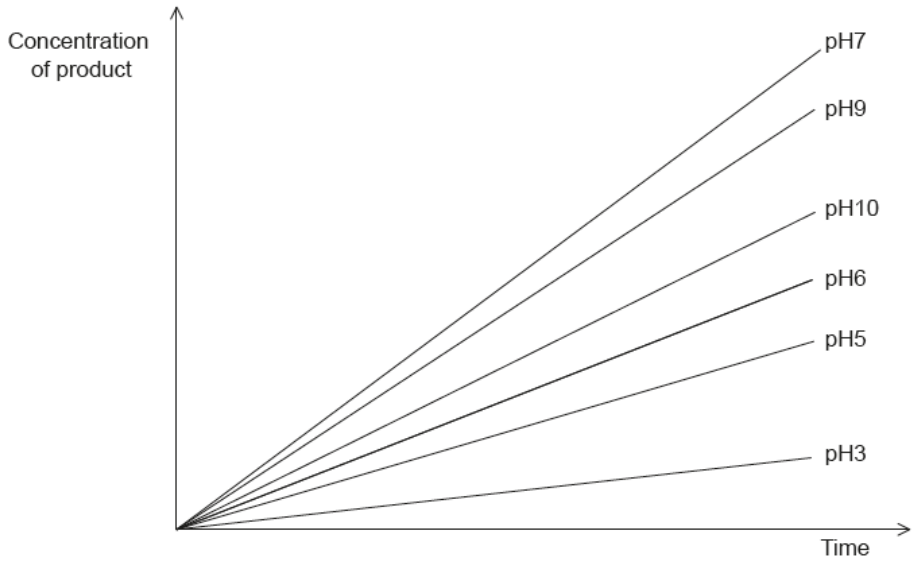
29. [Maximum mark: 1]

The graph shows the results of an investigation into the activity of turnip peroxidase. The accumulation of the product of the reaction catalysed by the enzyme is shown at different pH values.



[Source: © International Baccalaureate Organization 2019]

Based on the data in the graph, what is most probably the optimum pH for turnip peroxidase?

A. Between 3 and 5

B. Between 10 and 11

C. Between 7 and 8

D. Between 9 and 10 [1]

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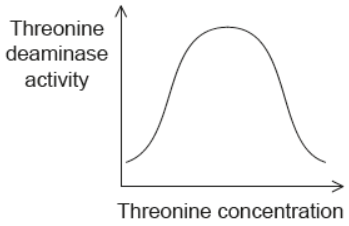
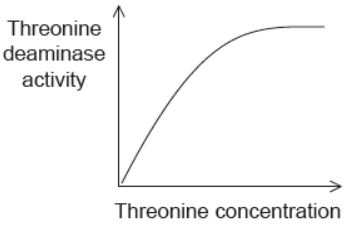
30. [Maximum mark: 1]

The first enzyme in the metabolic pathway that produces isoleucine is threonine deaminase. Which graph illustrates the relationship between threonine deaminase activity and threonine concentration?

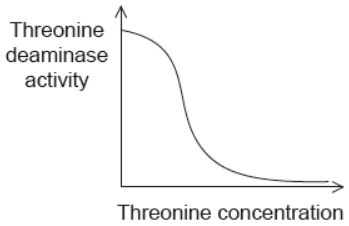
A.



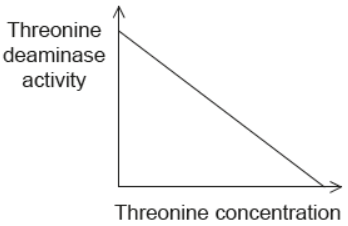
B.



C.



D.



[Source: © International Baccalaureate Organization 2019] [1]

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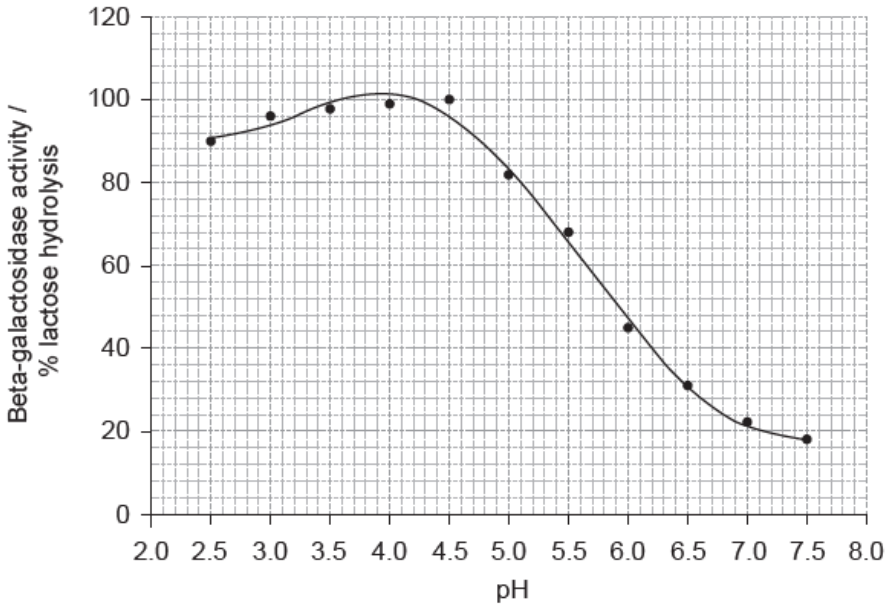
31. [Maximum mark: 3]

The enzyme beta-galactosidase hydrolyses lactose to release glucose and fructose. A study was carried out to determine how acidity affects the activity of a beta-galactosidase enzyme, extracted from the fungus *Penicillium simplicissimum*.



[Source: Cruz R, *et al*. Properties of a new fungal β-galactosidase with potential application in the dairy industry.
Revista de Microbiologia **30**: 265–271, 1999]

(a) State another independent variable that would affect the activity of this enzyme. [1]

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(b) Outline the measurements which would need to be taken to determine the activity of the beta-galactosidase at different pH values. [2]