IB · DP · Biology

2 hours 15 questions

Structured Questions: Paper 2

8.1 Metabolism

8.1.1 Metabolic Pathways / 8.1.2 Inhibition / 8.1.3 Bioinformatics & Metabolism / 8.1.4 Skills: Rates of Reaction & Types of Inhibition

Easy (5 questions)	/46
Medium (5 questions)	/46
Hard (5 questions)	/52
Total Marks	**/144**

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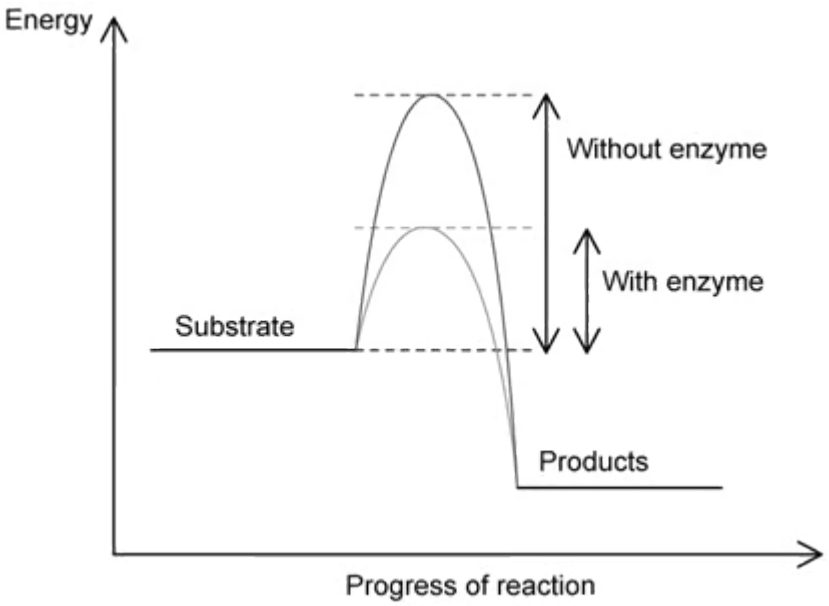
Easy Questions

1 (a) The graph below shows how enzymes affect biological reactions.



Use the graph and your own knowledge of enzyme function to explain how enzymes function as biological catalysts.

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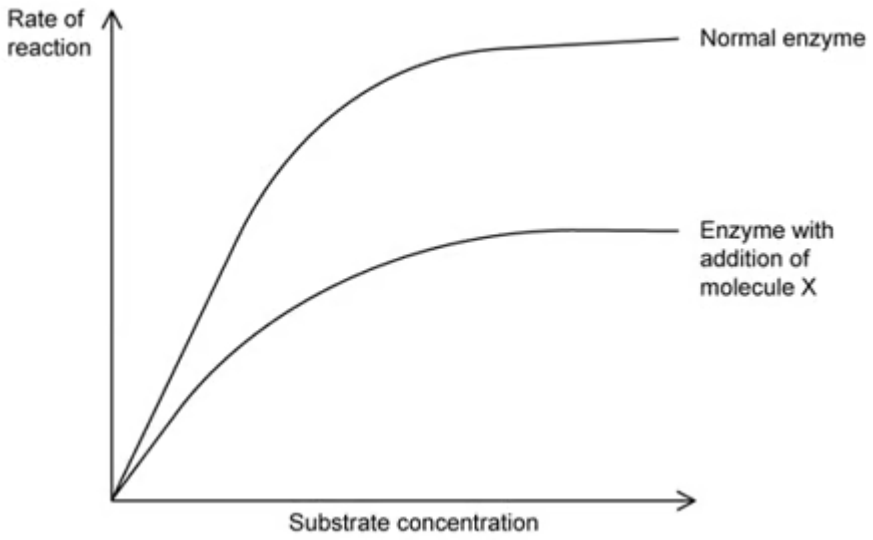
(1 mark)

(b) The graph shows how the addition of a molecule named here as molecule **X** affects the rate of an enzyme-controlled reaction.



Describe how the addition of molecule **X** affects the rate of reaction in the graph.

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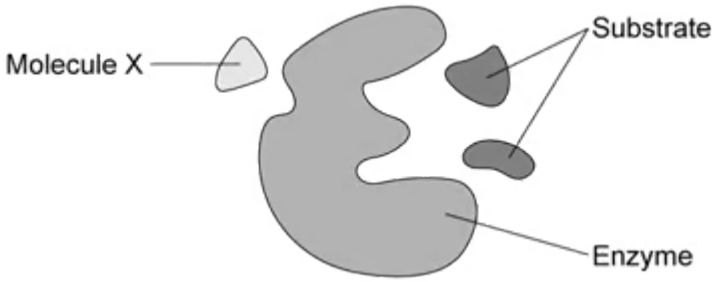
(2 marks)

(c) The image below shows how molecule **X** interacts with the enzyme.



Use the image to explain the results shown in the graph in part **(b).**

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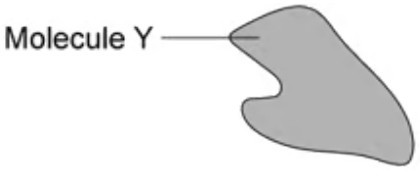
(2 marks)

(d) The image below shows another molecule, molecule **Y**.



Suggest how molecule **Y** might interact with the enzyme shown in part (c).

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(1 mark)

(e) Sketch a line on the graph from part (b) to show how molecule Y might affect the rate of reaction.

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(2 marks)

2 (a) Define the term 'bioinformatics'.

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(1 mark)

(b) The parasite *Plasmodium* causes the disease malaria when injected into the human bloodstream.

Using bioinformatics, scientists can analyse the proteome of the *Plasmodium* parasite to better understand its metabolic pathways including the enzymes which catalyse them.

Define what is meant by the term proteome.

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(1 mark)

(c) So far over 300,000 chemicals have been screened to identify 19 new chemicals that can be used to treat malaria.

Calculate the percentage chance of finding a chemical that can be used to treat malaria.

Give your answer in standard form.

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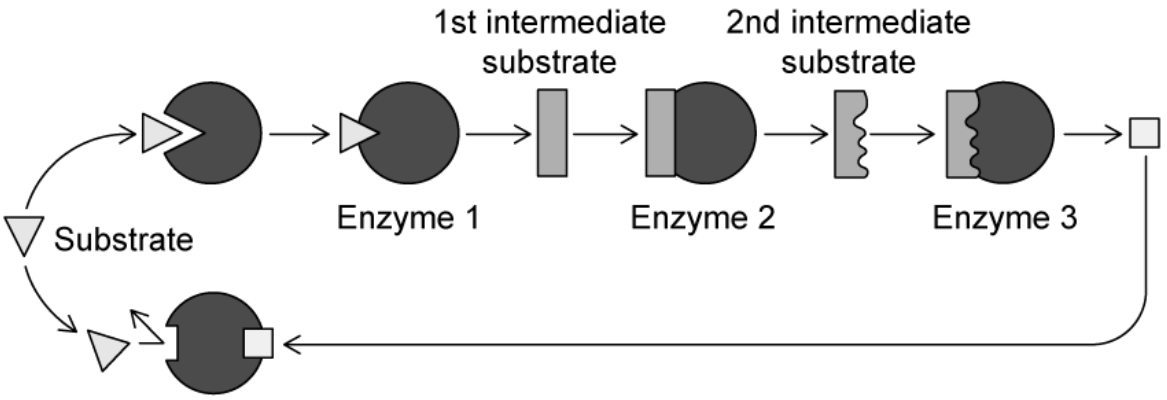
(3 marks)

3 (a) State, with a reason, the type of enzyme inhibition shown in the image below.



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(2 marks)

(b) Explain what is meant by allosteric inhibition.

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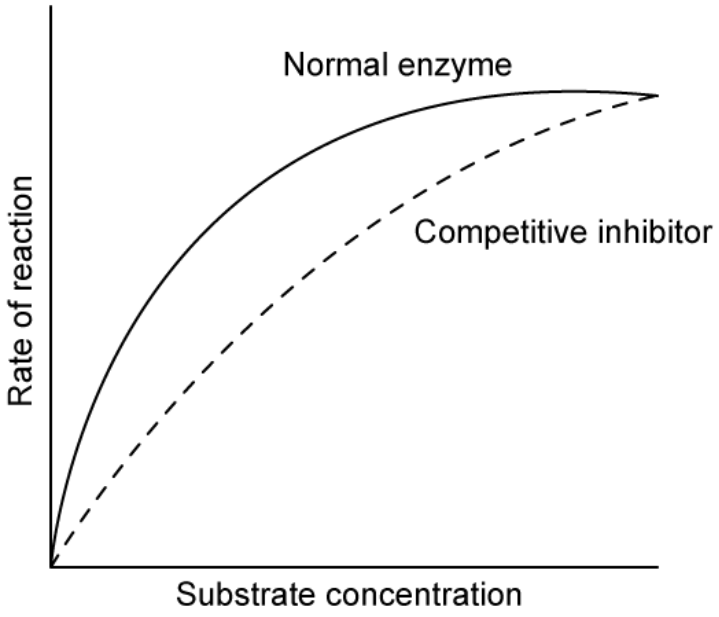
(3 marks)

The graph below shows the relationship between substrate concentration and rate of reaction for a normal enzyme and a competitive inhibitor.

(c)



Explain the effect competitive inhibition has on the rate of reaction.

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(3 marks)

(d) State an example of a competitive and non-competitive inhibitor.

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(2 marks)

4 (a) Metabolic pathways exist in all living organisms.

Explain what is meant by a metabolic pathway.

(3 marks)

(b) Describe the differences between anabolism, catabolism and metabolism.

(3 marks)

(c) Metabolic paths require enzymes. Hexose kinase is the initial enzyme needed during glycolysis, it catalyses the phosphorylation of glucose by ATP. This reaction would occur without the presence of hexose kinase.

Explain the role hexose kinase has in this reaction.

(2 marks)

5 (a) *One mark is available for clarity of communication throughout this question.*

This question is about metabolic pathways.

(i) Describe the meaning of the term metabolic pathway.

[3]

(ii) Outline how end-product inhibition can act to limit a metabolic pathway.

[4]

(7 marks)

(b) State some of the ways scientists can use bioinformatics to help with their research.

(4 marks)

(c) Compare and contrast the allosteric and active sites of an enzyme.

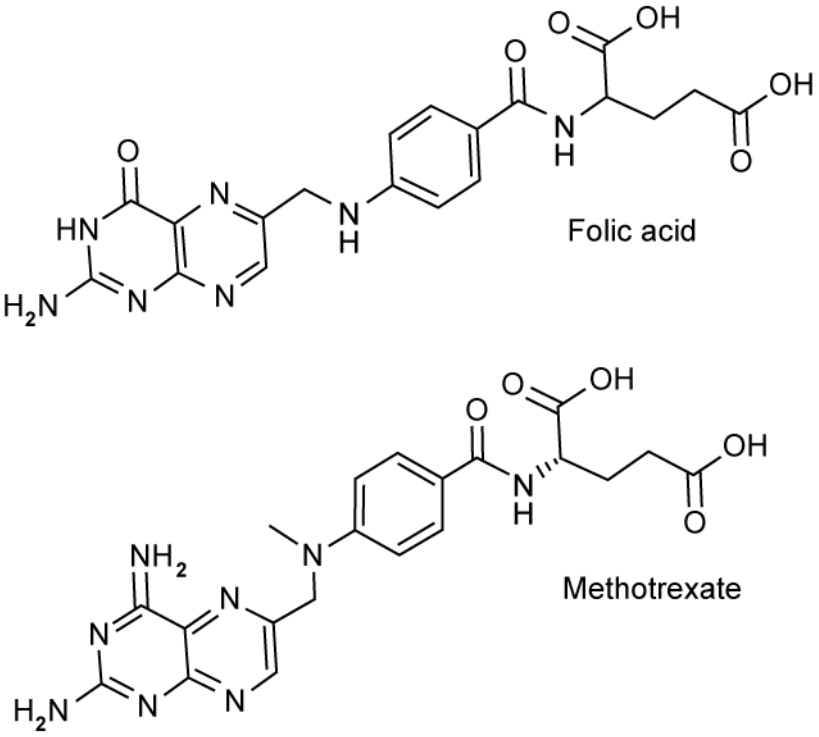
(4 marks)

Medium Questions

1 (a) Folate is a chemical used by cancer cells to make DNA during cell division. Folate is produced through the conversion of folic acid catalysed by the enzyme dihydrofolate reductase.

Methotrexate is a medicinal drug given to people with cancer, and other autoimmune diseases, as it acts as an inhibitor for the enzyme dihydrofolate reductase.

The image below shows the chemical structure for the enzyme's normal substrate, folic acid, as well as the structure of its inhibitor, methotrexate.



Using the images, suggest the method of inhibition used by methotrexate. Explain your answer.

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(2 marks)

(b) Folate is not just used by cancer cells during replication, but by any cells of the human body that replicate quickly.

Methotrexate is commonly used as part of chemotherapy treatment for cancer sufferers.

Using this information, suggest why people that undergo chemotherapy lose their hair.

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(3 marks)

(c) There are many enzymes that are unique to cancer cells. Designing drugs to specifically target those enzymes could remove many difficult side-effects for the patients.

Reference to databases of information detailing the action and chemical structure of different chemicals could aid scientists in identifying a suitable chemical to tackle cancer cells without the same impact on other body cells seen in the use of methotrexate.

State the name given to this method of chemical identification and suggest how it might it be used to identify suitable cancer drugs.

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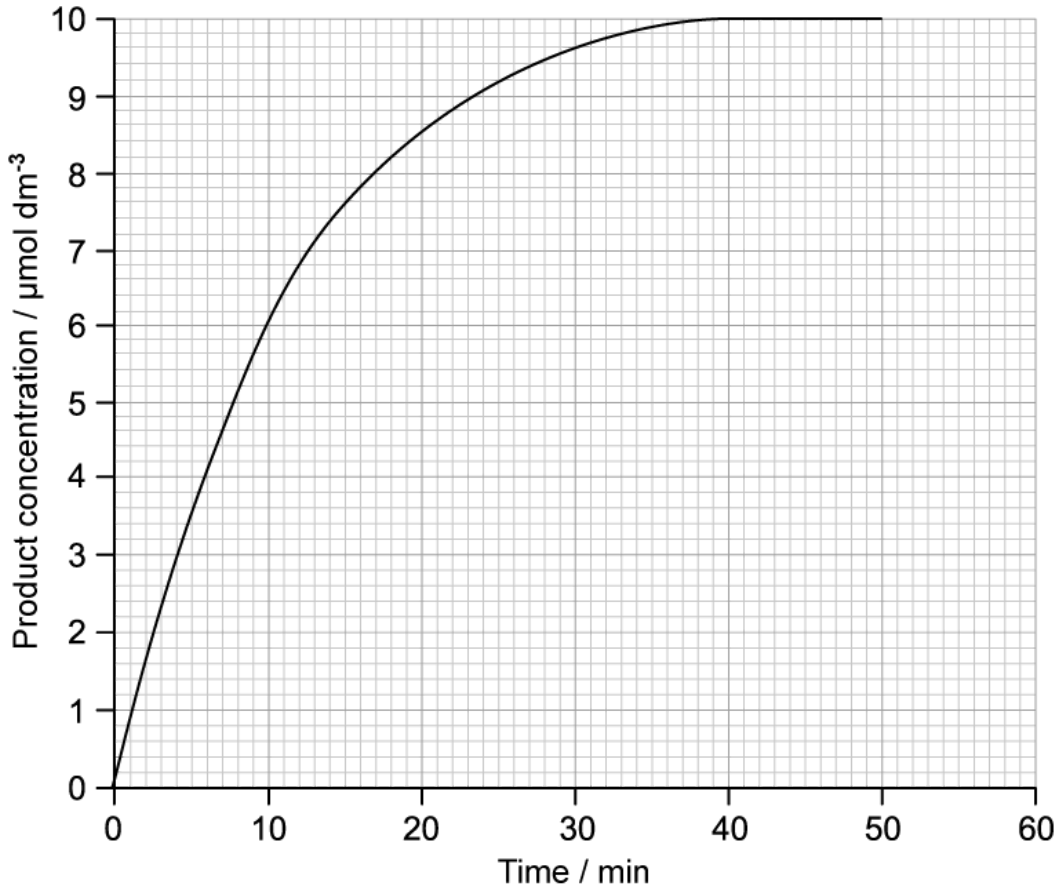
(2 marks)

2 (a) Trypsin is an enzyme produced by the pancreas that hydrolyses proteins in the small intestine.

The activity of trypsin was investigated by placing a small amount of the enzyme with a known concentration of protein.

The graph below shows the progress of this reaction when it is carried out at 25 °C.



Calculate the initial rate of the reaction in the graph. Show your working.

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(2 marks)

(b) The procedure was repeated at the same temperature in the presence of a competitive inhibitor of trypsin.

Predict the results that will be obtained using the competitive inhibitor.

(2 marks)

(c) Describe how your prediction for part b) would be different if a non-competitive inhibitor was used rather than a competitive inhibitor.

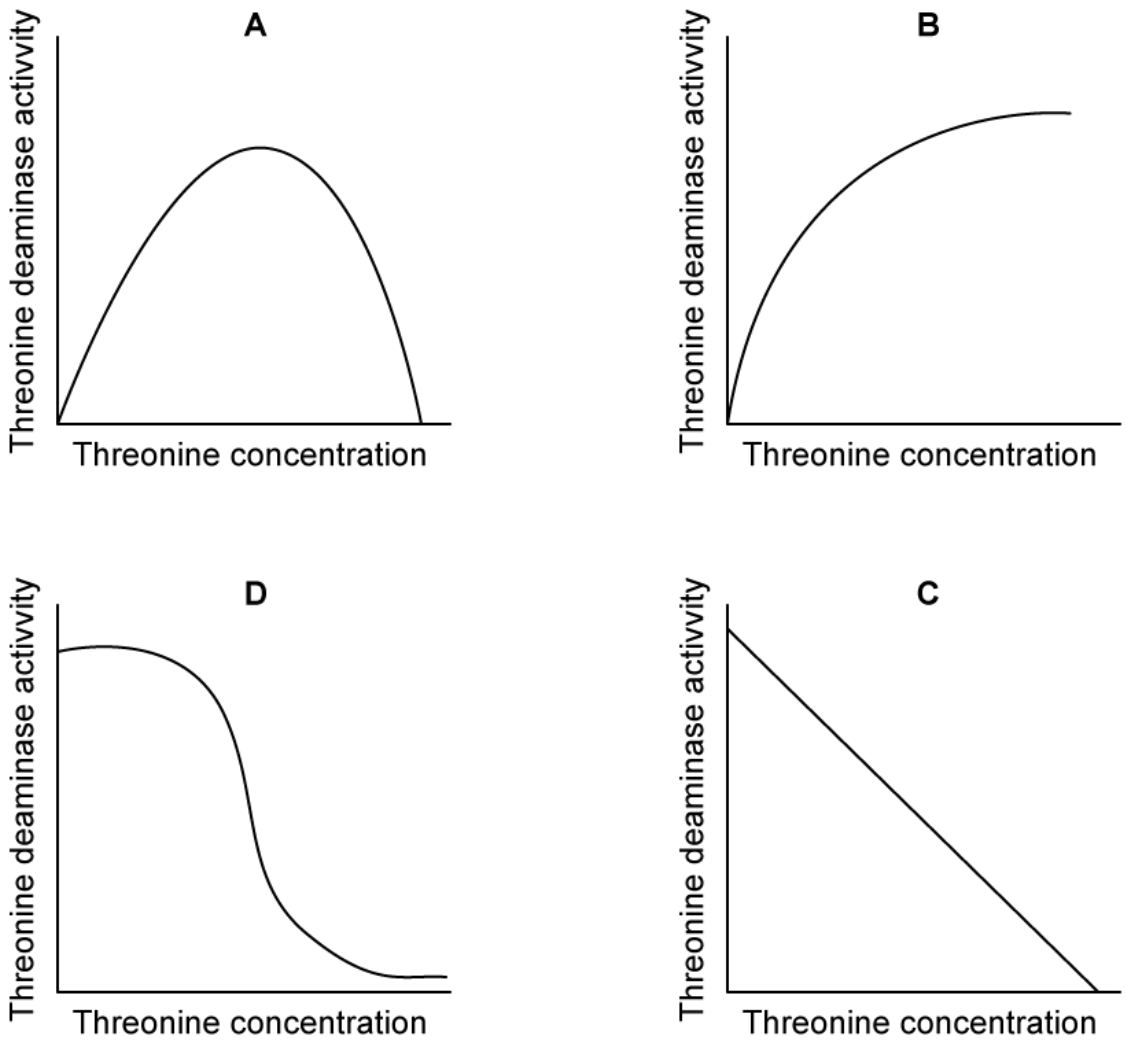
(2 marks)

(d) The investigation was extended to compare the initial reaction rates of trypsin obtained from different species of animal.

Suggest **two** advantages of calculating the **initial** reaction rates of enzyme catalysed reactions here rather than the reaction rates at another point during the experiment.

(2 marks)

3 (a) Threonine deaminase catalyses the conversion of threonine into an intermediate substrate, before producing the end product of isoleucine.



State which graph represents the relationship between threonine concentration and threonine deaminase concentration.

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(1 mark)

(b) Explain the effect a build up of isoleucine concentration would have on the activity of threonine deaminase.

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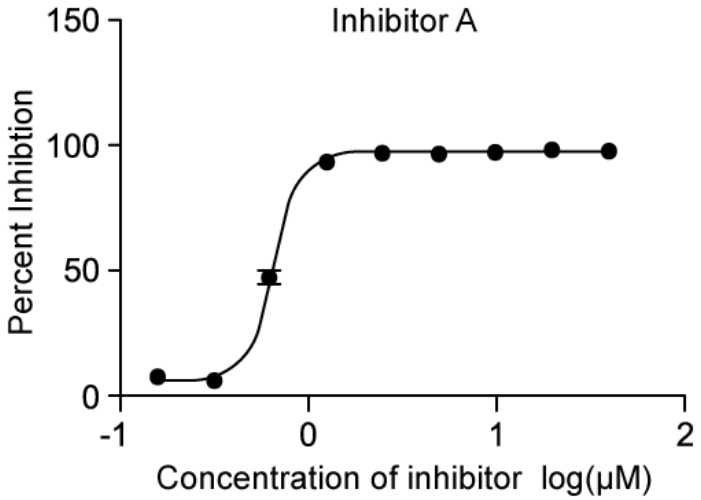
(3 marks)

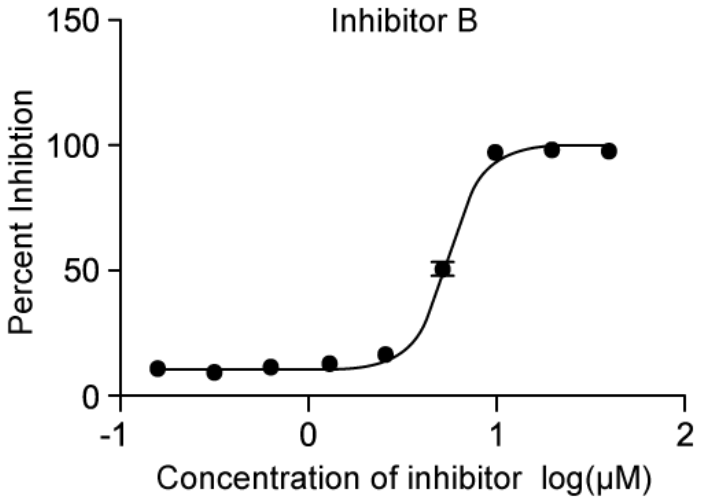
(c) Explain how end product inhibition is an example of negative feedback.

(3 marks)

4 (a) *Plasmodium falciparum* is a protozoan parasite of humans that causes malaria. Scientists have sequenced the proteome of this parasite and have determined a number of enzymes involved in its metabolic pathways. One such enzyme is hexokinase which is involved in the phosphorylation of glucose within the parasite.

The scientists tested two potential enzyme inhibitors, Inhibitor A and Inhibitor B, on the activity of hexokinase. The results are shown in the graphs below.





Compare and contrast the effect of the two inhibitors on the percentage inhibition.

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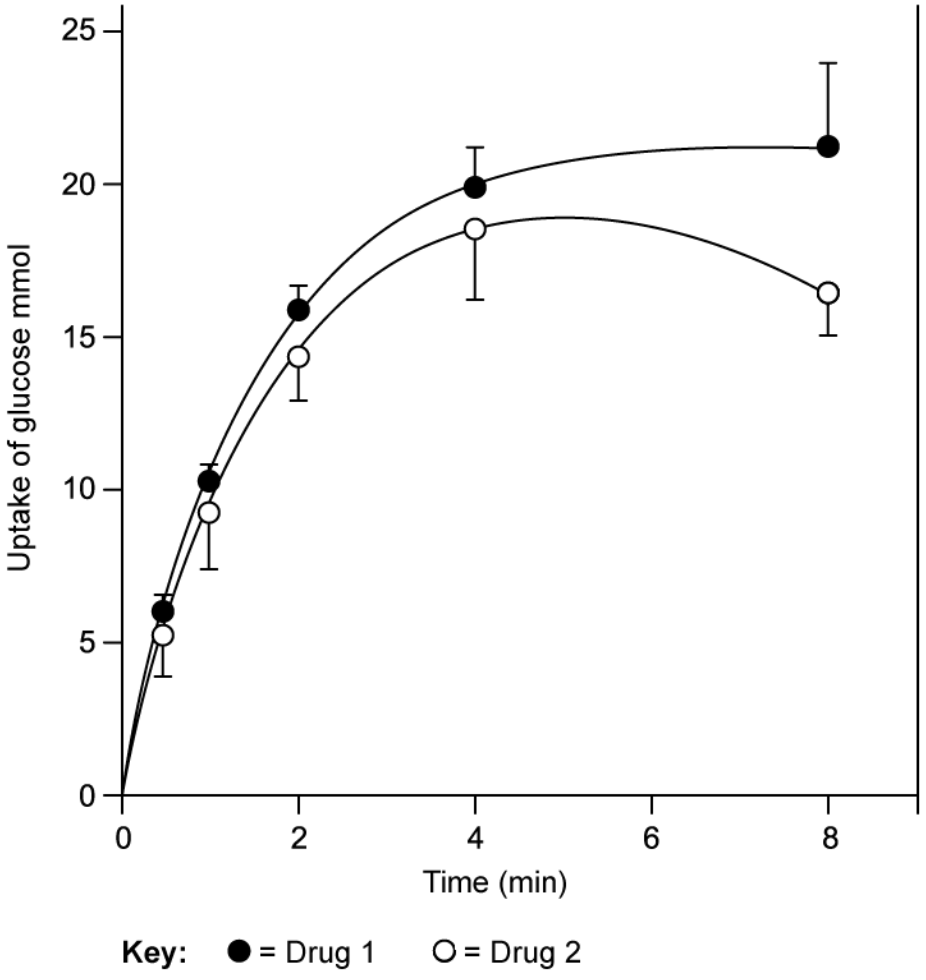
(2 marks)

(b) Deduce, with reasons, whether the inhibitors act as competitive or non-competitive inhibitors.

(2 marks)

(c) The *Plasmodium falciparum* parasite depends on glycolysis for its survival, particularly the uptake of glucose from its host cells which is mediated by hexokinase.

The scientists investigated the action of hexokinase within *Plasmodium falciparum*. They tagged hexokinase with two different potential drugs that inhibit its action. Their results are shown in the graph below.



Describe how to calculate the rate of reaction from the graph.

(2 marks)

(d) The scientists concluded that drug 1 was less effective than drug 2.

Evaluate this conclusion.

(3 marks)

5 (a) *One mark is available for clarity of communication throughout this question.*

Explain the effect of inhibitors on the activity of enzymes.

(8 marks)

(b) Outline how bioinformatics has been used to identify anti-malarial drugs.

(4 marks)

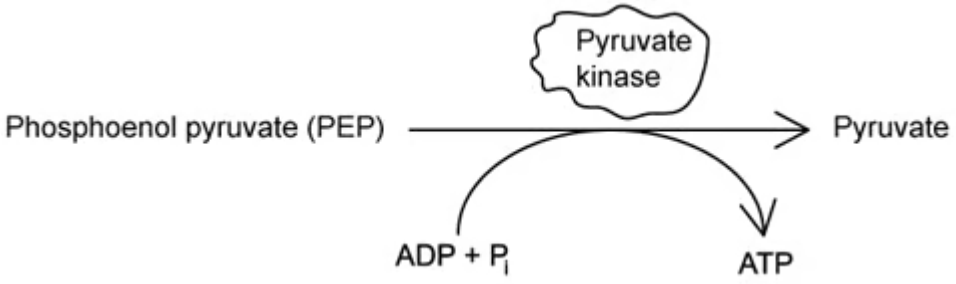
(c) Distinguish between an enzyme catalysed reaction and a non enzymatic reaction.

(3 marks)

Hard Questions

1 (a) Many products of multi-step cellular reactions act as inhibitors of the enzymes that catalyse the preceding steps in a metabolic pathway.

For example, ATP acts as a non-competitive inhibitor of the enzyme pyruvate kinase, which catalyses the final step of glycolysis.



Suggest how the inhibition of pyruvate kinase by ATP allows cells to prevent overproduction and wasting of cellular energy.

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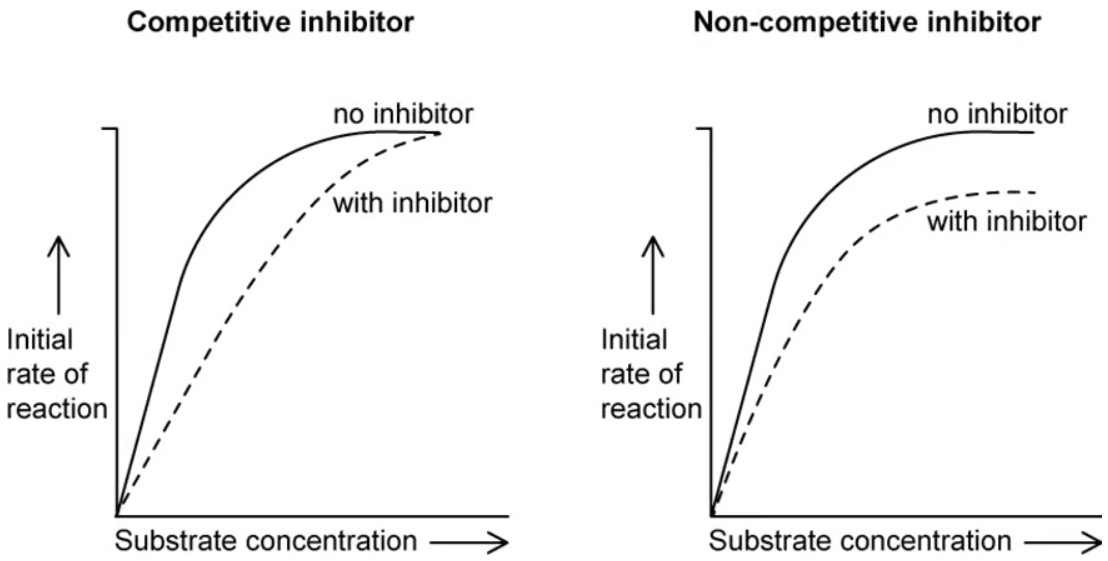
(3 marks)

(b) The graphs below shows the effects of increasing substrate concentration on enzyme activity in the presence and absence of a competitive and a non-competitive inhibitor.



Sketch a line on both graphs to indicate the effect of increasing inhibitor concentration in each case. Explain the position and shape of each line.

(4 marks)

(c) Compare and contrast the features of a substrate and a competitive inhibitor.

(4 marks)

2 (a) Copper (II) ions act as non-competitive inhibitors of the enzyme catalase.

Describe how copper (II) ions work to inhibit the activity of catalase.

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(2 marks)

(b) Catalase is found in all living things that are exposed to oxygen. It protects cells from damage by breaking down the toxic chemical hydrogen peroxide into water and oxygen.

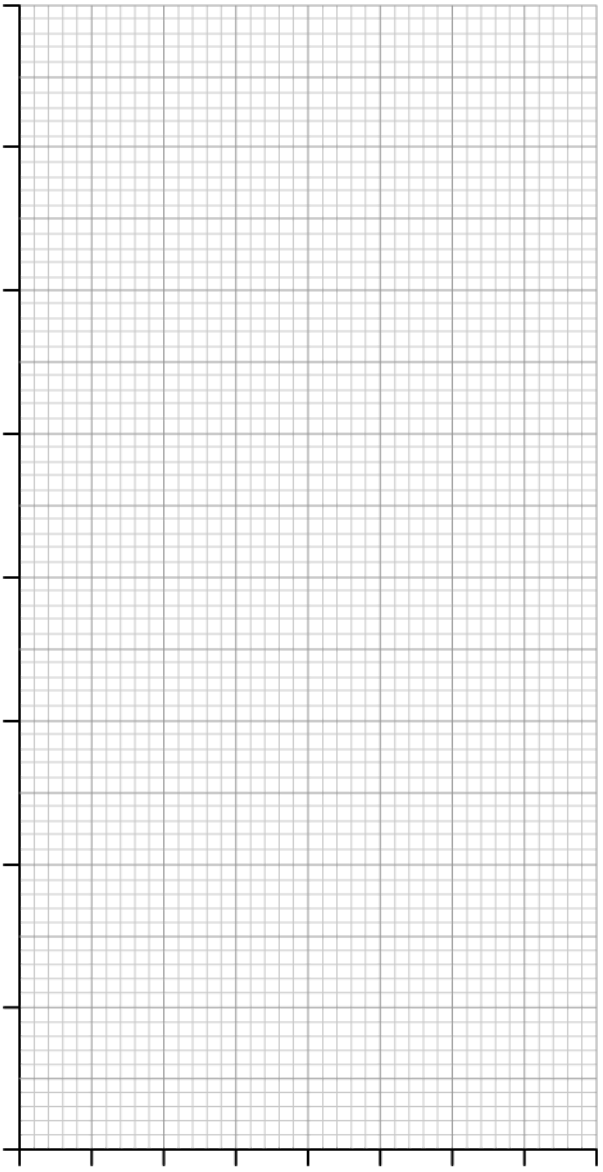
Numbers of fish living in copper contaminated water have shown a decline in numbers. Scientists can study the action of catalase in fish in order to understand the full impact of copper contamination on the fish.

A group of students carried out an experiment to explore the effects of copper sulfate on the action of catalase. They measured the activity of catalase exposed to different concentrations of copper sulfate.

The results of their experiment are shown in the table below.

Concentration of copper sulfate (moles dm^{-3})	Volume of oxygen gas produced (cm^3)
0.00	15.70
0.05	11.32
0.10	8.12
0.15	6.25
0.20	4.98

In the space provided below, draw a graph of the results in the table.



(4 marks)

(c) What can the students conclude from their results?

(2 marks)

(d) Three rivers in the Scottish Highlands were polluted with copper, which affected the aquatic wildlife. Scientists were provided with one dead brown trout, *Salmo trutta*, from each of the rivers.

Scientists were unable to take a direct measurement of the copper ion concentration in the river.

Using the information provided in part **(b)**, suggest the dependent, independent and control variables of an experiment using the fish tissue to compare the copper ion pollution in the three rivers.

(3 marks)

3 (a) It is predicted that there could be as many as 80 000 plant species in the Amazon rainforest, however, many of these have never been studied or even formally identified.

Once a new plant species have been discovered, molecular analysis can be carried out on its chemical composition, including the identification of any chemicals unique to that species. The details of this analysis will be stored in a database.

What are some of the benefits of storing information about these chemicals in a database?

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(2 marks)

(b) When trying to conserve a forested area that has been earmarked for development or logging, scientists often need to put a monetary value on the area being conserved in order to compare this to the potential value of removing the forest.

Putting a value on the unique chemicals found in the plant species in the area can be hugely helpful in this process, but it is often a slow process to collect this information.

How can bioinformatics help to improve conservation in these areas?

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(2 marks)

When studying plant species in areas of high biodiversity, or in any extreme environment, it is often useful to look at the metabolic pathways linked to the adaptations of the plants.

To investigate the metabolic pathways scientists can determine the proteome of the plant, or just focus on the proteome of specific specialised cells.

Suggest why just studying the proteome alone might not be enough to fully understand the metabolic pathways in the plant.

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(c) .....

(2 marks)

4 (a) Antifreeze is a chemical often used in vehicles, such as cars, to act as an engine coolant.

A small number of people have accidentally consumed antifreeze and become poisoned as a result. Once a person consumes antifreeze it is important that they receive treatment straight away, otherwise, there is a risk of death. This is because if the methanol goes to the liver it can be broken down by the enzyme alcohol dehydrogenase into toxic products such as methanoic acid and formaldehyde. If the methanol can't bind to the enzyme it will just be excreted via the kidneys and the person can be saved.

One method of treating methanol poisoning, in the rare instances where no other treatment is available, is to use large quantities of the alcohol ethanol.

Suggest how ethanol might be able to save someone from methanol poisoning.

(3 marks)

(b) Although it may be an effective antidote, suggest why it is not recommended that people with methanol poisoning consume ethanol other than in extreme circumstances where no other treatment is available.

(1 mark)

(c) One medicinal chemical that can be used to treat antifreeze poisoning is called fomepizole, which is a competitive inhibitor of the enzyme alcohol dehydrogenase.

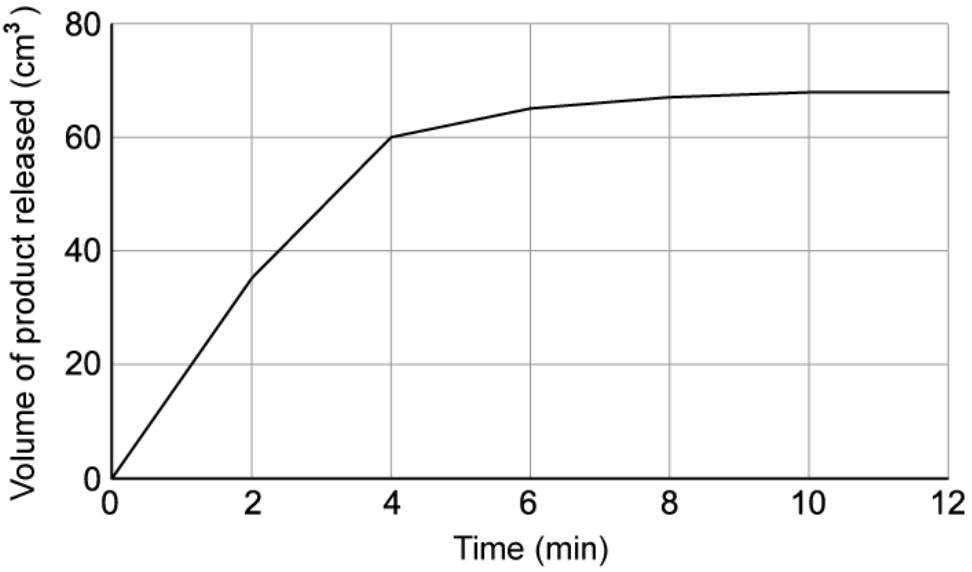
Fomepizole is 160,000 times more likely to bind to alcohol dehydrogenase than methanol.

Using your knowledge of enzyme structure, suggest how this might be possible.

(2 marks)

(d) Scientists were trying to investigate the rate of reaction of alcohol dehydrogenase by measuring the quantity of product, methanoic acid, produced over time, with a fixed quantity of methanol added at the start.

The graph below shows their results.



Use the graph below to calculate the rate of reaction of alcohol dehydrogenase after 3 minutes.

(3 marks)

5 (a) *One mark is available for clarity of communication throughout this question.*

Phosphofructokinase (PFK) is an enzyme that catalyses an important step in the glycolysis process of respiration. PFK is inhibited by ATP.

PFK is known as the "pacemaker" enzyme for respiration.

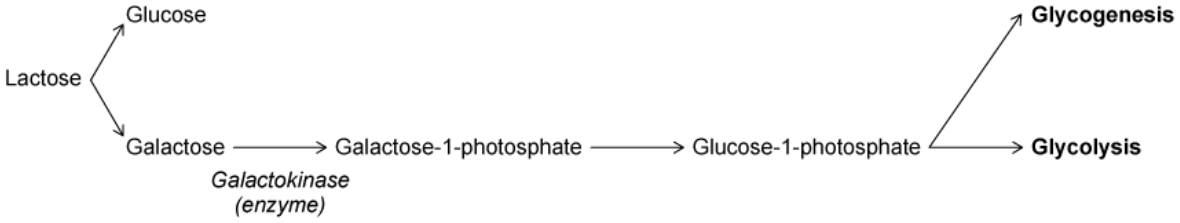
Suggest what is meant by the term "pacemaker" in this context.

(3 marks)

(b) Describe and explain the similarities and differences between competitive and non-competitive enzyme inhibition.

(5 marks)

(c) The image below shows the pathway the human body uses to metabolise lactose.



There is a genetic condition that exists called galactosemia, which causes large quantities of galactose to build up in the body, particularly in the liver tissues.

If left untreated, it can be very harmful to sufferers, in the worst cases, it can lead to death.

Galactosemia is rare and only occurs in around 1 per 60,000 births for people of European ancestry, often skipping a generation before re-emerging.

Using the information from the question and your own knowledge, suggest the cause of galactosemia, some symptoms, a type of treatment for the condition.

(7 marks)