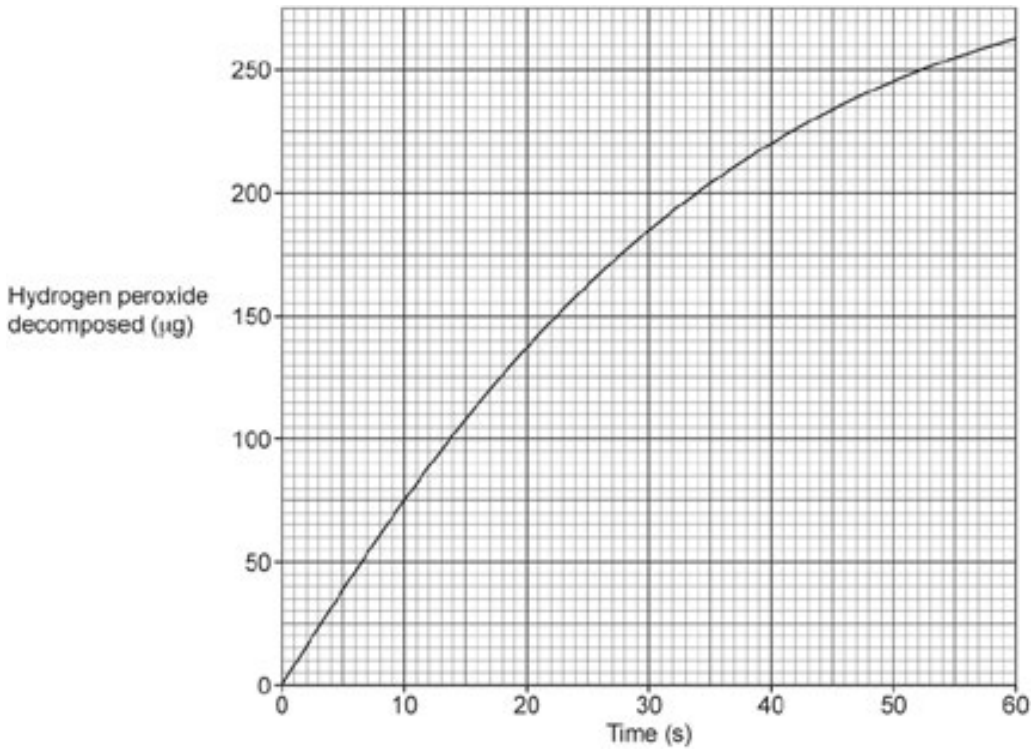
1(a). Hydrogen peroxide is a highly reactive chemical.

Catalase is an intracellular enzyme that catalyses the breakdown of hydrogen peroxide.

i. Explain why it is important that catalase is able to break down hydrogen peroxide very quickly.

---**[2]**

ii. The graph shows a graph of decomposition of hydrogen peroxide against time for catalase.



Calculate the rate of the enzyme catalysed reaction **at 30 s**.

Rate = ... Units = ...**[3]**

(b). Male infertility is associated with low motility (ability to move) of sperm cells.

i. Superoxide dismutase (SOD) is an enzyme that is often located together with catalase in cells.

Superoxide ions are produced in mitochondria and are highly reactive. Superoxide ions cause damage to many biological molecules, including DNA and lipids.

SOD converts superoxide ions into hydrogen peroxide and oxygen.

Explain why sperm cells might have high concentrations of hydrogen peroxide.

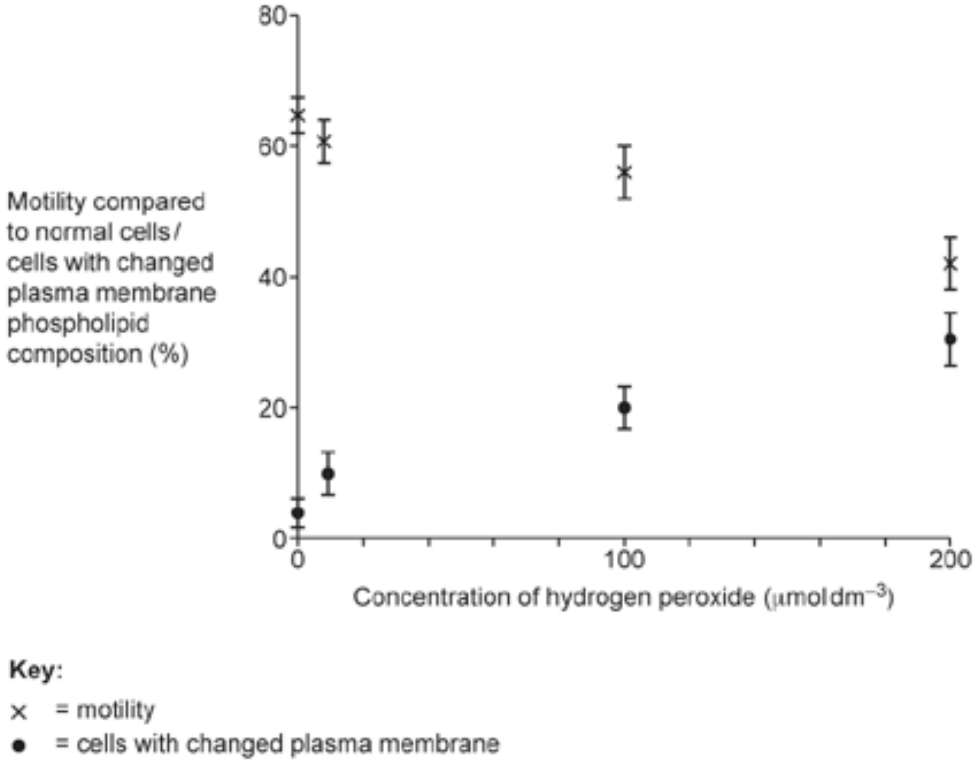
---**[2]**

ii. Scientists investigate the effect of hydrogen peroxide on sperm cells. This is the method that they use:

- incubate sperm cells with different concentrations of hydrogen peroxide for two hours
- measure the motility of the cells compared with normal sperm cells
- measure the percentage of cells that have changes in the composition of phospholipids in the plasma membrane.

They use sperm samples from 10 different men attending a fertility clinic and calculate mean values.

Their results are shown in the figure below



The scientists conclude that hydrogen peroxide causes changes in the plasma membrane of sperm cells that reduces their motility.

Evaluate this conclusion.

_____

_____

_____

_____

_____

_____

_____

_____ **[3]**

iii. Suggest how hydrogen peroxide could affect the plasma membrane.

_____

_____

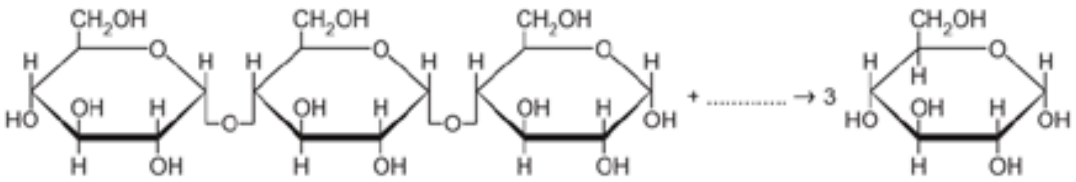
_____

_____

_____ **[2]**

2. Maltotriose is a trisaccharide formed during the breakdown of starch by amylase. It can be broken down further to produce glucose.

i. Complete the equation for the conversion of maltotriose to glucose.



[2]

ii. The enzyme maltase converts maltose to glucose during the final stages of starch digestion in the small intestine.

Suggest why maltotriose can also be converted to glucose by maltase.

[1]

3. DNA has a double helix structure made from polynucleotides.

DNA is replicated during interphase of the eukaryotic cell cycle.

i. The enzyme helicase is active during DNA replication.

Describe the action of helicase.

[2]

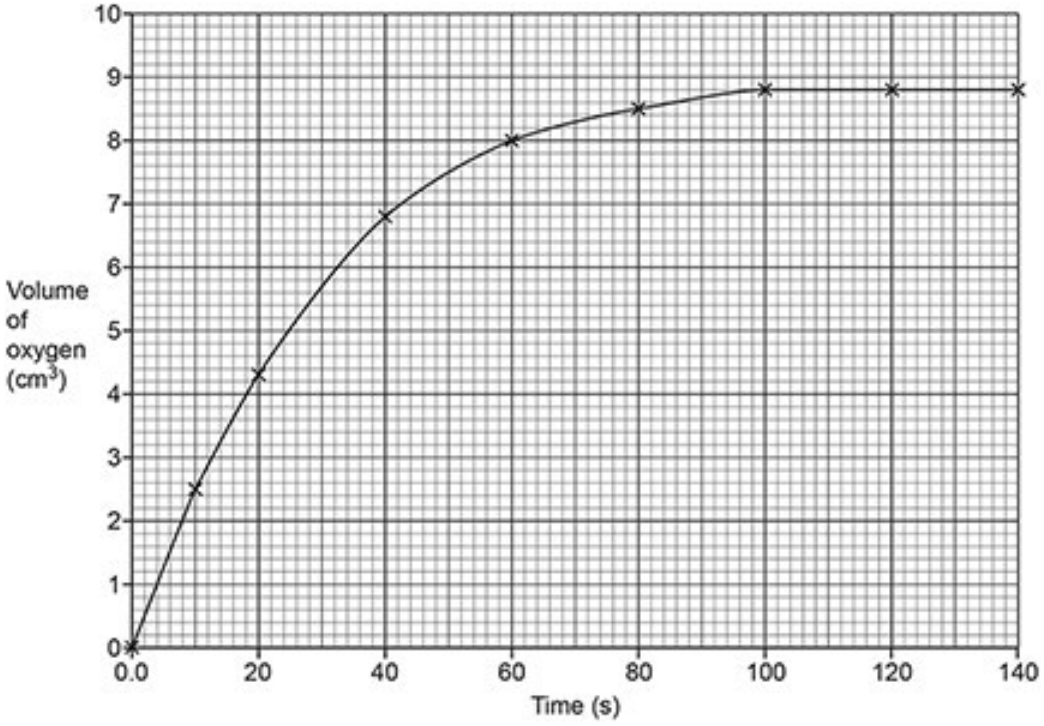
ii. DNA replication conserves genetic information with accuracy.

Explain how errors may occur during DNA replication.

[2]

4(a). A student investigates the rate of catalase activity as it breaks down hydrogen peroxide into oxygen and water.

The volume of oxygen released was recorded over a period of 140 seconds. The results are shown in the graph.



Use the graph to calculate the rate of reaction at **50** seconds.

Give your answer to **2** significant figures.

Rate = ... $cm^3\ s^{-1}$ **[2]**

(b). Hydroxylamine inhibits catalase.

Describe how the student could show that hydroxylamine is a competitive inhibitor.

[2]

5(a). Fungal pathogens such as black sigatoka infect plants.

Many plants produce the enzyme chitinase as a defence against fungal pathogens. Chitinase catalyses the breakdown of chitin in the cell walls of fungi.

Scientists have discovered that when chitin binds to chitinase:

- two amino acids in chitinase move closer together to form a hydrophobic region around the chitin substrate
- other amino acid interactions cause the active site of the enzyme to partially cover the chitin substrate.

i. Name the hypothesis of enzyme action that is supported by the mechanism observed in chitinase.

_____[1]

ii. Explain how the mechanism of enzyme action observed in chitinase increases the rate of chitin breakdown.

_____

_____

_____

_____

_____[2]

(b). A student investigates how the concentration of chitinase in plant tissue changes at different stages of fungal infection.

The student prepares a plant extract solution to be able to record the concentration of chitinase present.

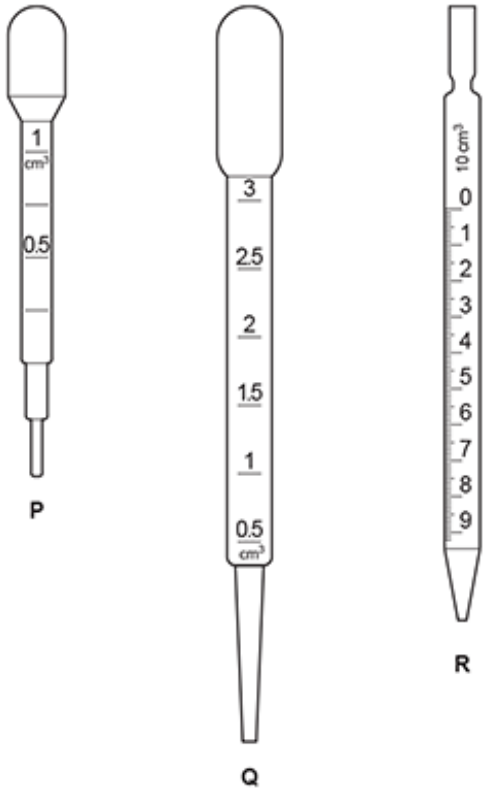
i. The student uses a volumetric flask to measure 250 cm^3 of the solution.

The volumetric flask has an absolute uncertainty of ±0.12 cm^3.

Calculate the percentage error associated with the student's measurement.

Percentage error = ...%**[2]**

ii. Using a pipette, the student transfers several 5 cm^3 samples of the plant extract solution during their investigation.
The diagram shows three different pipettes, **P**, **Q** and **R**.



Explain which pipette, **P**, **Q** or **R**, would reduce the uncertainty when transferring the plant extract solution.

[2]

6. Enzymes that catalyse the removal of CH_3 groups from cytosine bases in DNA are called TET enzymes. The rate of transcription increases when CH_3 groups are removed from DNA.

During embryo development, TET enzymes remove CH_3 from a large number of genes. This TET activity is essential for the development of embryos.

i. Suggest how the activity of TET enzymes affects metabolism at both the cellular and whole organism level.

[2]

ii. Vitamin C binds to TET enzymes and increases their catalytic activity.

State the role of vitamin C when it binds to a TET enzyme.

[1]

iii. Intracellular and extracellular reactions are catalysed by enzymes.

The table lists three enzymes, including TET.

Complete the table to indicate whether the enzyme catalyses an intracellular reaction or an extracellular reaction.

Tick (✓) **one** box in each row.

Enzyme	Type of reaction catalysed	
	Intracellular	**Extracellular**
TET		
Catalase		
Trypsin		

[1]

7. A student investigates the effect of pH on the activity of the enzyme catalase.

Oxygen is one of the products of the reaction catalysed by catalase. The student measures the volume of oxygen produced over a 10-minute period. The student uses these data to calculate the rate of oxygen production.

Which row in the table shows the different types of variables in the student's investigation?

	Control variable	Dependent variable	Independent variable
A	pH	Temperature	Volume of oxygen produced in 10 minutes
B	Volume of oxygen produced in 10 minutes	Catalase concentration	pH
C	Temperature	pH	Volume of oxygen produced in 10 minutes
D	Catalase concentration	Volume of oxygen produced in 10 minutes	pH

Your answer ☐ **[1]**

8. A student investigates the effect of pH on the activity of the enzyme catalase.

Oxygen is one of the products of the reaction catalysed by catalase. The student measures the volume of oxygen produced over a 10-minute period. The student uses these data to calculate the rate of oxygen production.

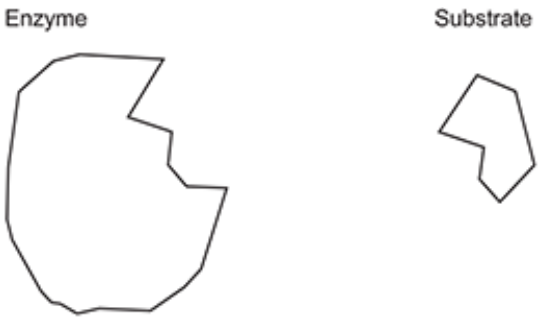
The student determines catalase activity by calculating the rate of oxygen production.

Which units of measurement are appropriate to show the rate of oxygen production?

A cm^{-3}
B $cm^3\ s^{-1}$
C $h\ dm^{-3}$
D $mol\ dm^{-3}$

Your answer ☐ **[1]**

9. The image below shows an enzyme and its substrate.



Which option represents a coenzyme for this enzyme?

A

B

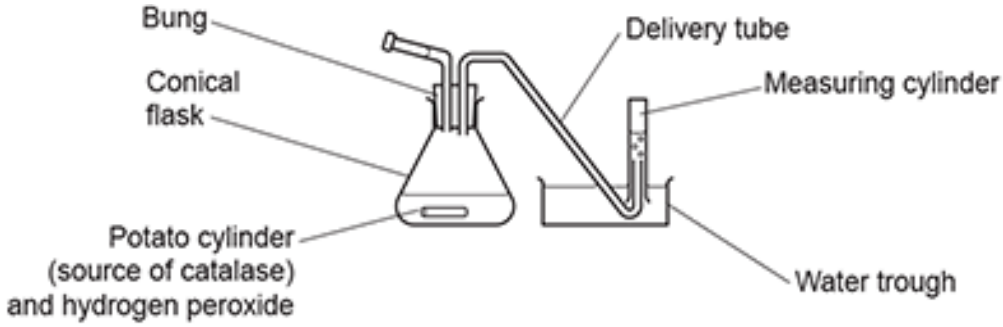
C

D

Your answer ☐ **[1]**

10(a). Catalase is found in many tissues. It is an enzyme that breaks down hydrogen peroxide into oxygen and water.

Some students do an experiment to investigate the effect of hydrogen peroxide concentration on the rate of this reaction using the apparatus shown in the figure below.



This is the method the students use.

1. Use a stock solution of 250 cm^3 of 20 a.u. hydrogen peroxide, to make solutions of 8 a.u. and 2 a.u.
2. Cut 15 cylinders of potato of equal diameter, using a cork borer, and use a ruler to ensure that each one is 5 cm long.
3. Set up the apparatus as shown in the figure.
4. Record the starting position of the water in the measuring cylinder.
5. Place one cylinder of potato into the conical flask.

6. Pour 50 cm^3 of 2 a.u. hydrogen peroxide into the flask, immediately secure the bung and start the stopwatch.
7. Record the volume of gas given off every 30 s for 3 min.
8. Repeat steps 3 to 7 twice.
9. Repeat steps 3 to 8 using 8 a.u. and 20 a.u. hydrogen peroxide.

i. State the independent variable in this investigation.

[1]

ii. Describe how a student could produce an 8 a.u. solution from a 20 a.u. stock solution.

[2]

iii. Liver tissue contains a higher concentration of catalase than potato.
Suggest **two** reasons why the students chose potato rather than liver as a source of catalase.

1

2

[2]

iv. The potato cylinders were cut to equal lengths.

Suggest a further precaution the students should have taken when preparing them, to ensure the investigation was valid.

[1]

(b). Some of the students' results are shown in the tables below.

Results for 2 a.u. hydrogen peroxide

Time (s)	Volume of oxygen produced (cm^3)				
	1	2	3	Mean	Standard deviation
30	5	6	5	5.3	0.6
60	9	10	9	9.3	0.6
90	13	14	13	13.3	0.6
120	16	17	18	17.0	1.0
150	19	20	21	20.0	1.0
180	21	22	23	22.0	1.0

Results for 8 a.u. hydrogen peroxide

Time (s)	Volume of oxygen produced (cm^3)				
	1	2	3	Mean	Standard deviation
30	22	23	23	22.7	0.6
60	37	39	38	38.0	1.0
90	49	49	47	48.3	1.2
120	57	58	55	56.7	1.5
150	61	63	59	61.0	2.0
180	64	67	62	64.3	2.5

Results for 20 a.u. hydrogen peroxide

Time (s)	Volume of oxygen produced (cm^3)				
	1	2	3	Mean	Standard deviation
30	57	55	58	56.7	1.5
60	78	74	78	76.7	
90	89	73	88	83.3	9.0
120	95	79	93	89.0	8.7
150	97	81	95	91.0	8.7
180	97	83	96	92.0	7.8

i. Calculate the standard deviation for the 60 s result at 20 a.u. hydrogen peroxide.

Use the formula: $s = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$

Standard deviation = ... **[2]**

ii. Use the standard deviations to discuss the repeatability of the students' results.

[2]

iii. The students calculated the initial rate of reaction over the first 30 s.

Calculate the rate of reaction over the first 30 s for the result at 2 a.u. hydrogen peroxide.

Rate = ...

Unit = ...

[2]

iv. When analysing the results, the students assumed that the volume of oxygen collected was the same as the volume of oxygen produced from breakdown of hydrogen peroxide.

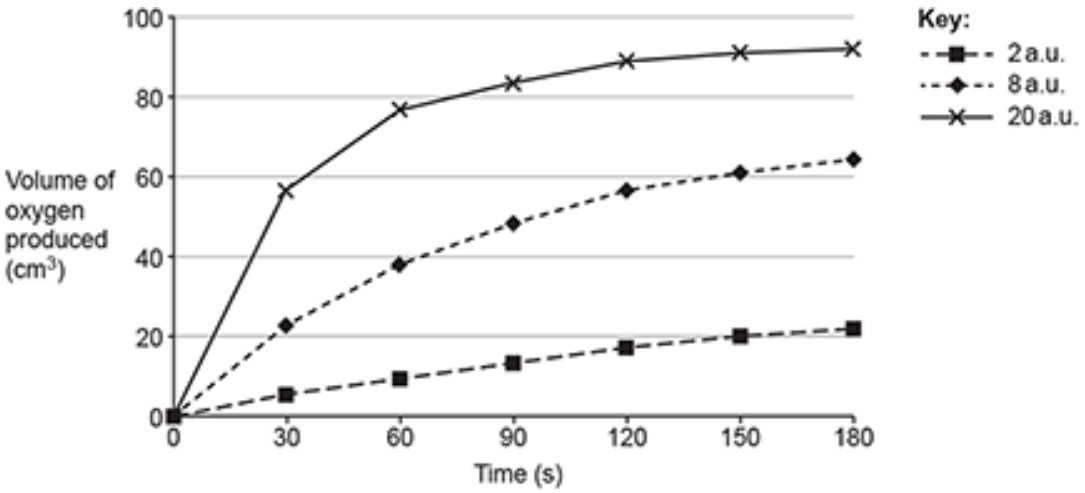
Suggest **two** reasons why the value the students recorded for volume of oxygen collected might not accurately reflect the volume of oxygen produced.

1

2

[2]

(c). The figure below shows a graph of the students' results.



Explain the results for 20 a.u. hydrogen peroxide.

[3]

11. Vitamins are molecules that are consumed in the diet of animals and have essential roles in the body.

Vitamin C affects the activity of enzymes in different ways.

i. Vitamin C acts as a coenzyme for several enzymes in the synthesis of collagen.

Outline the role of coenzymes in biological reactions.

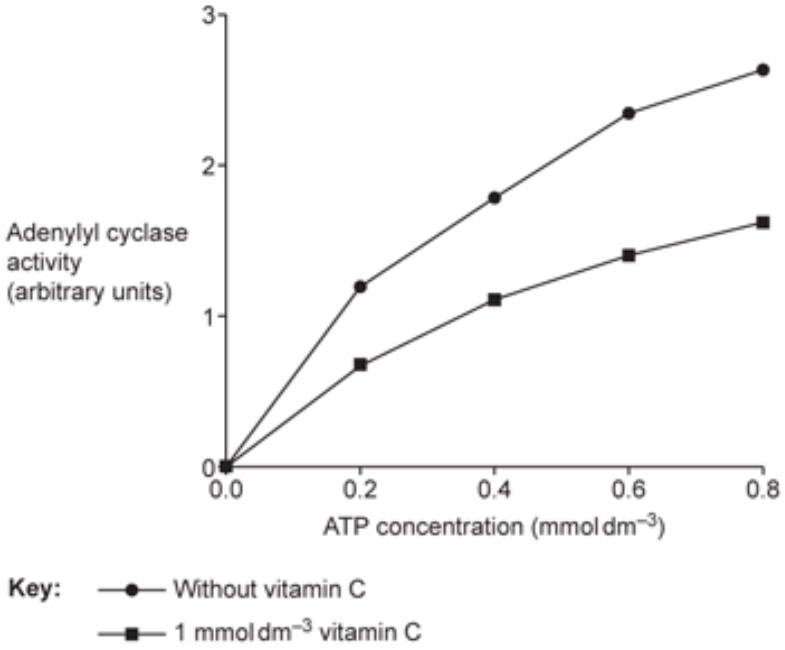
[2]

ii. A scientist investigates the effect of vitamin C on the activity of the enzyme adenylyl cyclase.

Adenylyl cyclase catalyses the conversion of ATP to cAMP.

The scientist measures the activity of adenylyl cyclase without vitamin C and with 1 mmol dm^{-3} of vitamin C.

The scientist's results are shown in the figure below.



Explain what can be concluded from the results in the figure showing the scientist's results about the effect of vitamin C on the activity of adenylyl cyclase.

[2]

12. Increasing the pH of an enzyme solution from 7.4 to 8.0 causes the rate of the reaction to fall by 90%. When the pH of the solution returns to 7.4 the rate of reaction returns to its original value.

Which of the statements about this enzyme-controlled reaction explains these observations?

A Increasing the pH from 7.4 to 8.0 breaks hydrogen bonds but returning the pH to 7.4 allows them to re-form.

B Increasing the pH from 7.4 to 8.0 changes the shape of the active site and so the substrate binds more tightly.

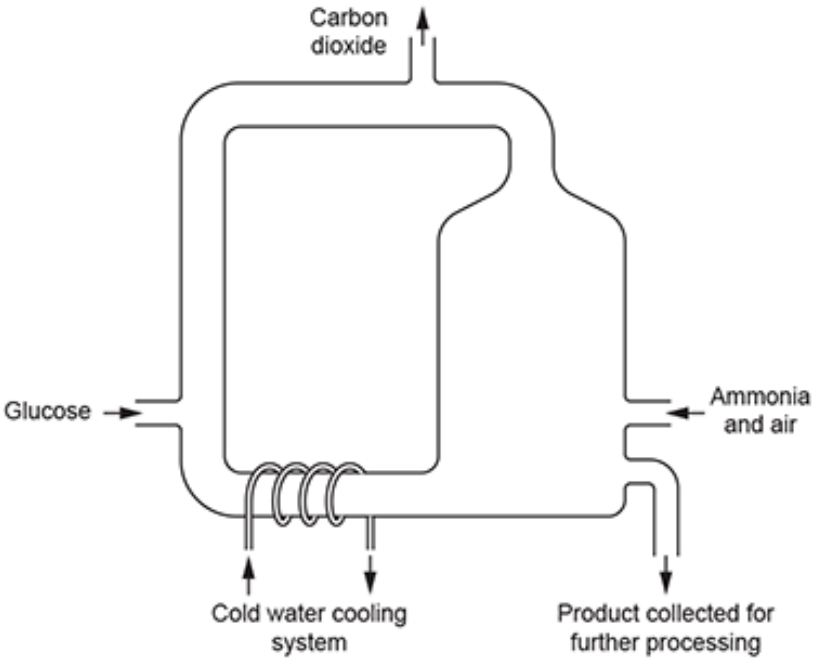
C Increasing the pH from 7.4 to 8.0 denatures the enzyme.

D Reducing the pH below 7.4 will reduce the rate of reaction.

Your answer ☐ **[1]**

13(a). The microorganism that is used to produce mycoprotein is a fungus.

The diagram is of a fermenter used for mycoprotein production.



i. Use the diagram to name the type of fermentation process used for mycoprotein production.

Justify your answer.

Name _____

Justification _____

_____

[1]

ii. Suggest and explain why a cooling system is necessary.

[2]

iii. The air inlet provides the fungus with oxygen for respiration, and ammonia.

Suggest and explain why the fungus is provided with ammonia.

[2]

(b). Microorganisms can be used to produce a variety of food products.

Yoghurt is a food produced from milk using microorganisms.

Yoghurt production involves two bacteria: *Lactobacillus delbrueckii* and *Streptococcus thermophilus*.

i. The bacteria convert the lactose present in milk into lactic acid.

Lactic acid is an important contributor to the flavour of yoghurt. Lactic acid also helps to give yoghurt a longer shelf life than milk.

Suggest how lactic acid helps to extend the shelf life of yoghurt.

[2]

ii. Both bacteria also break down some of the protein casein, which is present in milk.
Name the product of protein breakdown and describe the type of reaction that takes place.

Product _____

Reaction _____

[2]

14. Body plan is important in multicellular organisms.

Complete the following sentences about control of body plan using the most appropriate terms.

Body plan is under genetic and ..... control. Internal and external..... can influence the expression of genes that regulate the cell cycle. Such genes can promote or inhibit programmed cell death, known as ..... . During programmed cell death ..... digest the cell contents and the products are removed by ..... so that they do not damage the surrounding tissues.

[5]

15. Many processes in the body are controlled by enzymes.

Which of the options is an extracellular process controlled by enzymes?

A Conversion of fibrinogen to fibrin during blood clotting
B Digestion of a pathogen inside a lysosome
C DNA replication
D Movement of vesicles from the Golgi apparatus to the cell membrane

Your answer ☐ **[1]**

16. The scientists studied the effect of living at different temperatures on respiration in young fish at different stages of growth.

High oxygen consumption in fish is associated with a fast growth rate.

Their results are shown in **Fig. 20.2**.

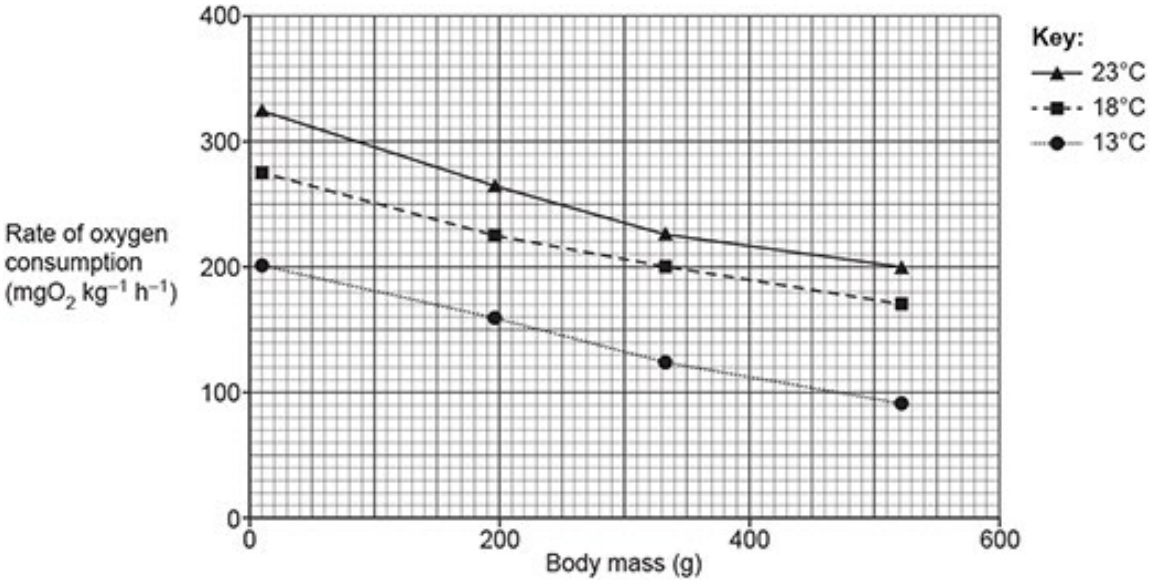


Fig. 20.2

i. Calculate the Q_{10} for respiration in the largest fish.

Give your answer to **3** significant figures.

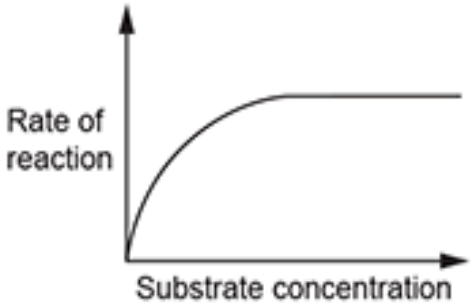
Q_{10} = ... **[2]**

ii. The scientists concluded that the best temperature for farming of *O. insignis* was 18 °C.

Evaluate their conclusion.

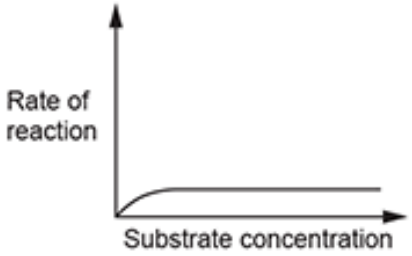
[4]

17. The graph below shows the effect of changing substrate concentration on the rate of an enzymecontrolled reaction.

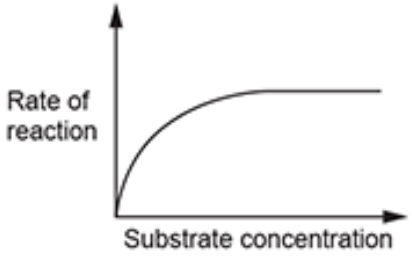


Which graph shows how increasing the concentration of enzyme would affect the rate of this reaction?

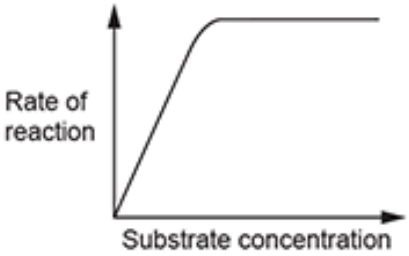
A



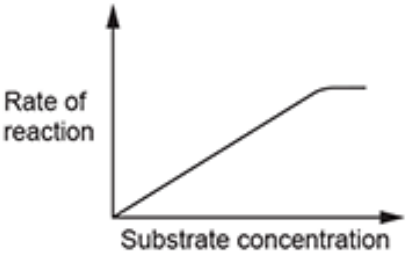
B



C



D



Your answer ☐ **[1]**

18. Which statement about the effect of temperature on enzyme-controlled reactions is **not** correct?

A At temperatures above 40 °C the rate of all enzyme-controlled reactions decreases.
B Increasing the temperature above the optimum changes the tertiary structure of the active site.
C Increasing the temperature increases the kinetic energy of the enzyme and substrate.
D Increasing the temperature increases the probability of enzyme-substrate collisions.

Your answer ☐ **[1]**

19(a). Human insulin is a globular protein with a quaternary structure. One insulin molecule has 51 amino acids.

Fig. 21.1 shows the sequence of amino acids in one molecule of human insulin.

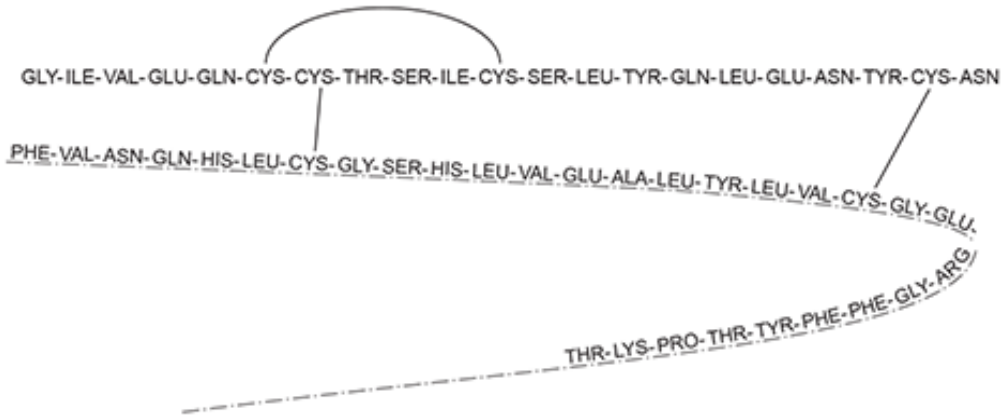


Fig. 21.1

Explain how **Fig. 21.1** shows that insulin has a quaternary structure.

---**[2]**

(b). Insulin is a hormone that regulates blood glucose concentration. People with type 1 diabetes need to inject insulin, to reduce their blood glucose concentration, as they are unable to produce their own insulin.

Diabetics need to inject insulin before every meal as insulin has a short half-life. Enzymes in the liver cells break down insulin, which removes it from the blood.

Insulin glargine is a modified version of human insulin that lasts much longer in the blood.

Fig. 21.3 shows the sequence of amino acids in one molecule of human glargine with the modifications in **bold**.

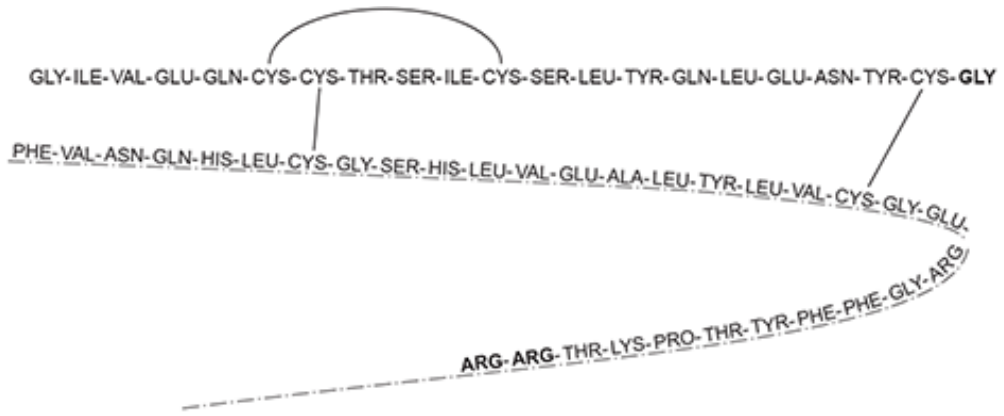


Fig. 21.3

i. Suggest why insulin glargine is long-lasting.

---**[1]**

ii. The table shows some of the DNA triplet codes for amino acids.

1st base of DNA triplet	2nd base of DNA triplet								3rd base of DNA triplet
	T		C		A		G		
A	ATT	(ILE) Isoleucine	ACT	(THR) Threonine	AAT	(ASN) Asparagine	AGT	(SER) Serine	T
	ATC		ACC		AAC		AGC		C
	ATA		ACA		AAA	(LYS) Lysine	AGA	(ARG) Arginine	A
	ATG	(MET) Methionine	ACG		AAG		AGG		G
G	GTT	(VAL) Valine	GCT	(ALA) Alanine	GAT	(ASP) Aspartic acid	GGT	(GLY) Glycine	T
	GTC		GCC		GAC		GGC		C
	GTA		GCA		GAA	(GLU) Glutamic acid	GGA		A
	GTG		GCG		GAG		GGG		G

In order to produce insulin glargine, the human insulin gene is modified by genetic engineering. This is a process which can change the genetic code of the gene. The genetic code of DNA triplet 21 is changed so that the amino acid it codes for is glycine instead of asparagine.

With reference to the table, predict how the genetic code of DNA triplet 21 is changed so that it codes for the amino acid glycine instead of the amino acid asparagine.

---**[2]**

iii. The modified polypeptides that form insulin glargine are made inside cells.

The process of making the modified polypeptides that form insulin glargine involves several steps. The process starts with the modified gene for insulin glargine.

Outline the steps involved in the process of making the modified polypeptides that form insulin glargine, starting with the gene for insulin glargine until when the modified polypeptides are made.

---**[4]**

20. The temperature coefficient (Q_{10}) for catalase is recorded in a data book as 1.15.

A student carries out an experiment to test if this Q_{10} value is correct and collects data with a high level of precision and accuracy.

Which row shows the correct definition of both precision and accuracy for their data?

	Precision	**Accuracy**
A	results have a small standard deviation	mean result is close to 1.15
B	results have a small standard deviation	repeated readings close together
C	results recorded to a high number of decimal places	mean result is close to 1.15
D	results recorded to a high number of decimal places	repeated readings close together

Your answer ☐ **[1]**

21. The reaction between carbon dioxide and water forms carbonic acid. This reaction is catalysed by the enzyme carbonic anhydrase. To catalyse this reaction, carbonic anhydrase needs a cofactor that attaches to its active site as a prosthetic group.

What is the correct cofactor for carbonic anhydrase?

A Ca^{2+}
B Cl^{-}
C H^{+}
D Zn^{2+}

Your answer ☐ **[1]**

END OF QUESTION PAPER