

# Chapter 3

## How are biochemical pathways regulated?

### Keywords and terms

*Regulation of biochemical pathways in photosynthesis and cellular respiration*

activation energy	active site	adenosine diphosphate
adenosine triphosphate	anabolic	catabolic
catalyst	coenzyme	cofactor
endergonic	enzyme	exergonic
induced-fit model	irreversible inhibition	lock-and-key model
metabolism	NADH	NADPH
product	reactant	substrate

*Photosynthesis as an example of a biochemical pathway*

Calvin cycle	grana	photosynthesis
stroma	light dependent stage	light independent stage
Rubisco	C <sub>3</sub> plant	C <sub>4</sub> plant
CAM plant		

*Cellular respiration as an example of a biochemical pathway*

aerobic respiration	anaerobic fermentation	cellular respiration
cristae	electron transport chain	glycolysis
pyruvate	Krebs cycle	mitochondrion

*Biotechnology applications of biochemical pathways*

biomass	biofuel
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### Content review questions

#### Regulation of biochemical pathways in photosynthesis and cellular respiration

- 1 Is energy used by living organisms?
- 2 Why do cells need energy?
- 3 What is the difference between anabolic and catabolic reactions?
- 4 What is the difference between exergonic and endergonic reactions? Give an example of each type.
- 5 Define the term 'enzyme'.
- 6 What is the 'lock-and-key' model and how does it differ from the induced fit?
- 7 Use the terms 'substrate', 'enzyme' and 'product' to explain the role of enzymes in living organisms.
- 8 Do enzymes increase the amount of product produced in a reaction?
- 9 With respect to reactions involving enzymes, what is meant by the rate of reaction?
- 10 What is an enzyme's active site and how is it formed?

- 11 Enzymes can be denatured. How is this done and what are the consequences?
- 12 Explain the difference between competitive and non-competitive enzyme inhibitors.
- 13 What are coenzymes and what do they do?
- 14 Complete the following table.

Loaded coenzyme	Unloaded form	Function	Involved in photosynthesis/ cellular respiration
ATP			
NADH			
NADPH			

- 15 What is ATP (adenosine triphosphate)? Explain its role in cells.

#### Photosynthesis

- 16 Enzyme function is affected by

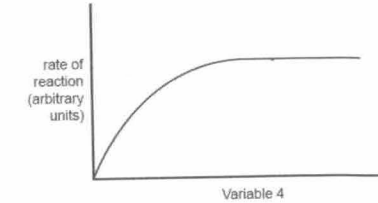
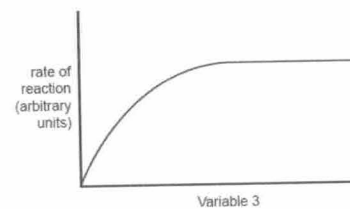
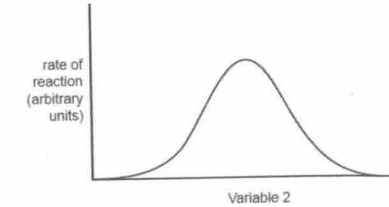
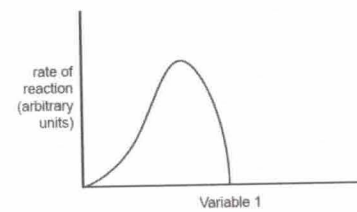
A: temperature

B: pH

C: substrate concentration

D: enzyme concentration

Match the above factors to the graphs below and explain the shape of the curve.



Variable	Factor	Explanation
1		
2		
3		
4		

43 Explain the following graphs by completing the table.

Factor affecting photosynthesis	Explanation
<p>rate of cellular respiration (arbitrary units)</p> <p>Glucose availability</p>	
<p>rate of cellular respiration (arbitrary units)</p> <p>Temperature</p>	
<p>rate of cellular respiration (arbitrary units)</p> <p>Oxygen concentration</p>	

#### Biotechnical applications of biochemical pathways

- 44 Describe how the CRISPR-Cas9 technologies may be used to improve photosynthesis efficiency and crop yields.
- 45 What is meant by the terms 'biomass' and 'biofuel'?
- 46 Explain how biomass can be used to make biofuel.

#### Multiple-choice questions

47 [VCAA 2015 SA Q6]

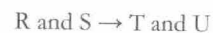
An experiment was conducted to investigate enzyme activity. A small quantity of amylase solution was added to a solution of starch dissolved in water at 35 °C. It was observed that maltose was produced.

Which one of the following is the substrate in this reaction?

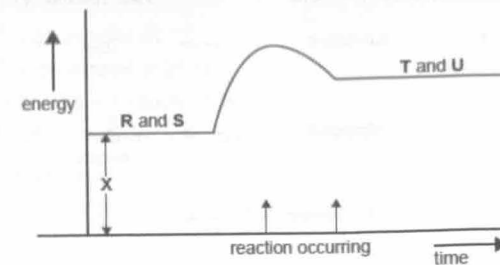
- A water
- B starch
- C maltose
- D amylase

48 [VCAA 2013 E1 SA Q8]

Consider the following reaction in which substrate molecule R and substrate molecule S are converted into product molecule T and product molecule U.



The following graph shows the energy available in the molecules against time.

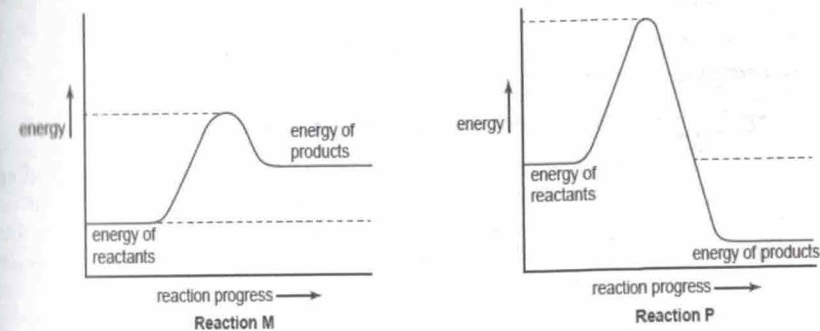


Based on the information in the graph, a correct conclusion would be that

- A this is an anabolic reaction.
- B the reaction would release energy.
- C value of the activation energy for the reaction is shown by X.
- D product molecules T and U have less energy than substrate molecules R and S.

49 [VCAA 2011 E1 SA Q23]

The following graphs depict two different reactions.

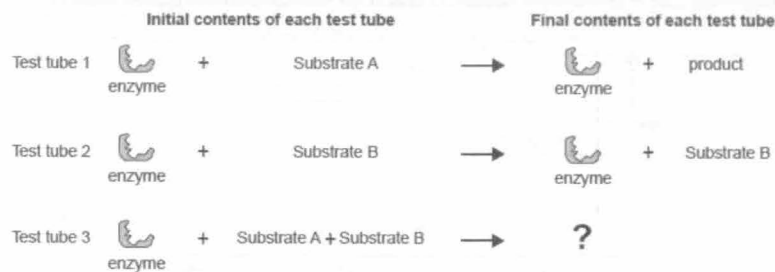


From the two graphs, it is reasonable to conclude that

- A in reaction P, the energy level of the products is greater than that of the reactants.
- B activation energy of reaction M is greater than that of reaction P.
- C both graphs M and P represent endothermic reactions.
- D energy is released in reaction P only.

50 [VCAA 2020 SA Q4]

A group of Biology students set up an experiment with three test tubes. Each test tube contained the same enzyme and was kept under the same experimental conditions. All concentrations and volumes of substrate and enzyme placed in the test tubes were kept the same. The diagram on the next page shows the initial contents of each test tube and the final contents of test tubes 1 and 2.



Source: adapted from Chemistry LibreTexts, <<https://chem.libretexts.org>>

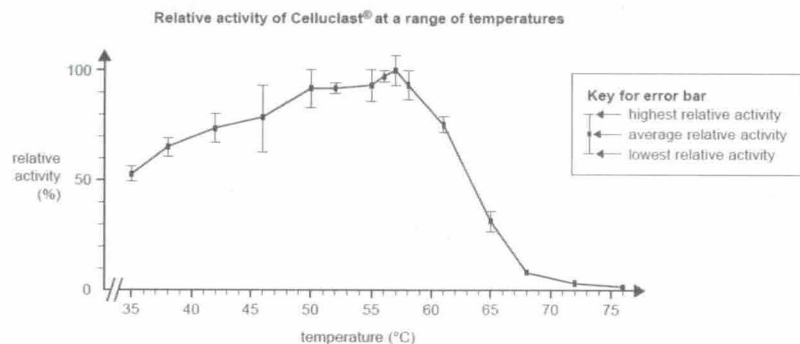
An enzyme-substrate complex was formed in each of the three test tubes. When compared to the final contents of Test tube 1, the concentration of product contained in the final contents of

Test tube 3 will

- A be the same because both Substrate A and Substrate B are able to bind to the enzyme at the same time.
- B increase because Substrate A is a substrate that can bind to the enzyme's active site.
- C decrease due to competitive reversible inhibition by Substrate B.
- D be zero due to the presence of an irreversible inhibitor.

Use the following information to answer Questions 51 and 52.

Celluclast<sup>®</sup> is an enzyme. The activity of Celluclast<sup>®</sup> at a range of temperatures and at a pH of 5 was measured. The experiment was repeated five times. The relative activity (%) of Celluclast<sup>®</sup> was calculated and plotted on a graph, as shown on the following page. The range of the calculated measurements at each temperature is shown as an error bar on the graph that follows.



Source: J Herlet et al., 'A new method to evaluate temperature vs pH activity profiles for biotechnological relevant enzymes', *Biotechnology for Biofuels*, 10, 234 (2017), <<https://doi.org/10.1186/s13068-017-0923-9>>

### 51 [VCAA 2020 SA Q13]

It is reasonable to conclude that

- A Celluclast<sup>®</sup> is inactive at 61 °C.
- B Celluclast<sup>®</sup> is denatured at 35 °C.
- C the optimum pH for Celluclast<sup>®</sup> is pH 5.
- D the optimum temperature for Celluclast<sup>®</sup> is around 57 °C.

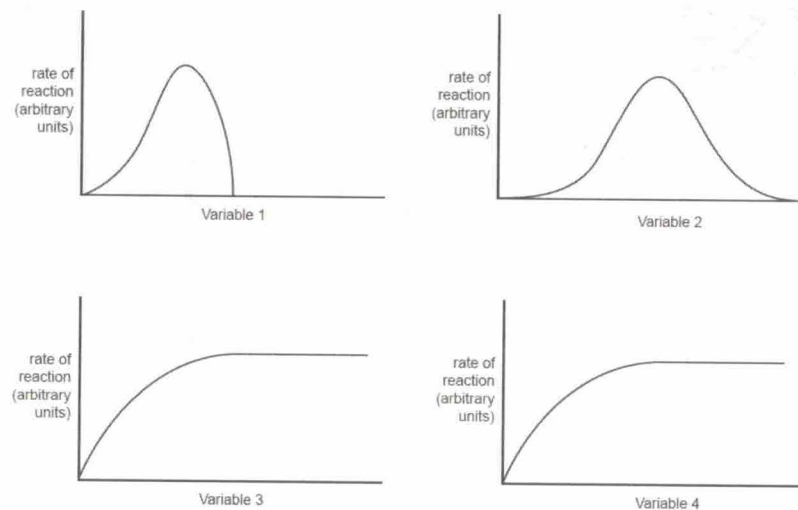
### 52 [VCAA 2020 SA Q14]

The error bars on the graph indicate that the measurements taken at

- A 38 °C were more valid than at 35 °C.
- B 52 °C were more precise than at 46 °C.
- C 46 °C were more accurate than at 55 °C.
- D 58 °C had more random errors than at 42 °C.

### 53 [VCAA 2018 SA Q7]

Four students performed a series of experiments to investigate the effect of four different variables on the rate of an enzyme-catalysed reaction. In each experiment the students changed one of the following variables: substrate concentration, pH, temperature and enzyme concentration. After recording their data, the students displayed their results in a series of graphs, as shown below. Each graph is a line of best fit for their data.



The students did not label the horizontal axis on any of their graphs. The next day, the students could not agree on which variable should be labelled on the horizontal axis of each graph. The students made the following suggestions as to what each variable could be.



Student	Variable 1	Variable 2	Variable 3	Variable 4
Marcus	substrate concentration	temperature	pH	enzyme concentration
Billy	temperature	substrate concentration	enzyme concentration	pH
Voula	enzyme concentration	temperature	substrate concentration	pH
Sheena	temperature	pH	enzyme concentration	substrate concentration

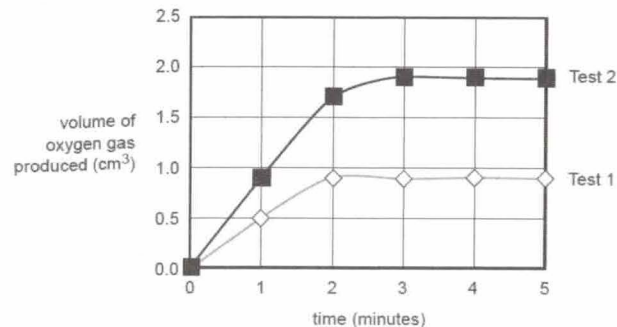
Which student correctly identified all four variables on the horizontal axes?

- A Marcus
- B Billy
- C Voula
- D Sheena

Use the following information to answer Questions 54–56.

Hydrogen peroxide is a toxic by-product of many biochemical reactions. Cells break down hydrogen peroxide into water and oxygen gas with the help of the intracellular enzyme catalase. The optimum pH of catalase is 7.

A Biology student measured the activity of catalase by recording the volume of oxygen gas produced from the decomposition of hydrogen peroxide when a catalase suspension was added to it. The catalase suspension was made from ground, raw potato mixed with distilled water. The student performed two tests and graphed the results.



Test 1 used 5 mL of 3% hydrogen peroxide solution and 0.5 mL of catalase suspension, and was conducted at 20 °C in a buffer solution of pH 7.

Test 2 was carried out under identical conditions to Test 1, except for one factor that the student changed.

54 [VCAA 2017 SA Q6]

An explanation for the results of Test 2 would be that the student

- A increased the concentration of catalase by adding less water to the ground potato.
- B increased the temperature by placing the test tube in a water bath set at 30 °C.
- C used a hydrogen peroxide solution with a higher concentration.
- D added a catalase suspension made from a cooked potato chip.

55 [VCAA 2017 SA Q7]

The student then performed more tests by varying the pH of the buffer solution.

It is expected that

- A at pH 6 the reaction will cease.
- B at pH 9 the reaction will be faster.
- C at pH 2 and pH 10 very little oxygen will be produced.
- D a greater volume of oxygen will be produced each time the pH is increased.

56 [VCAA 2017 SA Q8]

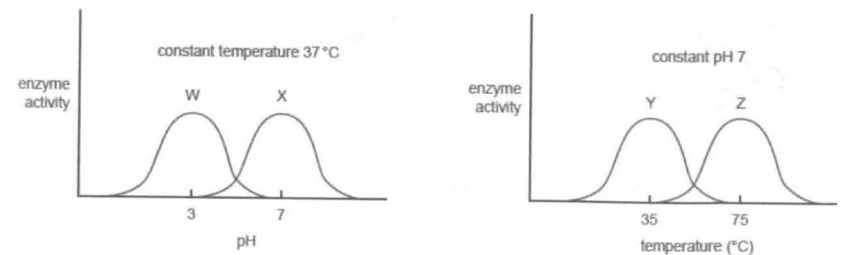
During the experiment, the student measured the varying pH levels using a digital pH meter. The student calibrated the meter using a pH 7 buffer solution.

The reason the student calibrated the pH meter was to

- A ensure a random error would not influence the results.
- B eliminate the effect of all uncontrolled variables.
- C enable the use of the instrument with precision.
- D allow the pH to be measured accurately.

57 [VCAA 2014 SA Q13]

The following graphs show the way four enzymes, W, X, Y and Z, change their activity in different pH and temperature situations.



Which one of the following statements about the activity of the four enzymes is true?

- A At pH 7, enzyme Y is denatured at temperatures below 20 °C.
- B Enzyme Z could be an intracellular human enzyme.
- C At pH 3 and a temperature of 37 °C, the active site of enzyme W binds well with its substrate.
- D At pH 3 and a temperature of 37 °C, enzyme X functions at its optimum.

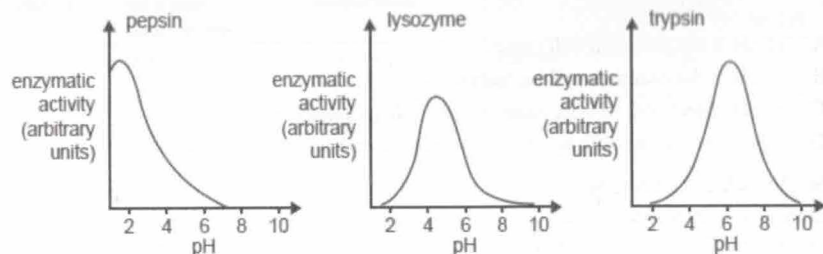
58 [VCAA 2012 E1 SA Q2]

The activity of an enzyme is

- A decreased by the presence of an inhibitor.
- B unaffected by the pH of the cytosol of a cell.
- C reduced at very low temperatures due to denaturation.
- D increased as the temperature rises above the enzyme's optimum temperature.

59 [VCAA 2011 E1 SA Q16]

Examine the following graphs.



From these graphs it is reasonable to infer that at a pH of 4

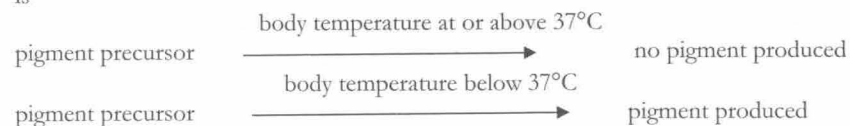
- A trypsin would be inactive.
- B all the pepsin would be denatured.
- C all three enzymes would lack a functional active site.
- D lysozyme has the highest activity of the three enzymes.

60 [VCAA 2011 E1 SA Q22]

The following image is of a Siamese cat.



The colour produced in the fur of a Siamese cat is under the control of a tyrosinase enzyme that is sensitive to particular temperatures. A summary of the enzyme action is



The core body temperature of a cat ranges from about 38°C to 39.2°C.

It is likely that in Melbourne

- A Siamese kittens have dark fur over their bodies when they are born.
- B Siamese cats that live outside a house show an increase in pigment during summer.
- C Siamese cats that live inside a house in winter have darker fur than those that live outside.
- D Siamese cats that live outside in winter have darker fur than Siamese cats in tropical regions.

61 [VCAA 2018 SA Q10]

Which pair of molecules contains the greatest amount of stored energy?

- A NADH and ATP
- B NAD<sup>+</sup> and ATP
- C NAD<sup>+</sup> and ADP
- D NADH and ADP

62 [VCAA 2017 SA Q16]

A molecule that takes part in many biochemical reactions is NADP<sup>+</sup>.

It is correct to state that

- A NADP<sup>+</sup> becomes NADH when it is loaded.
- B NADP<sup>+</sup> has a higher energy level when it is unloaded.
- C energy is released when NADP<sup>+</sup> is converted to NADPH.
- D NADP<sup>+</sup> carries additional energy when protons and electrons are added to it.

63 [VCAA 2016 SA Q9]

ATP is important in living cells as it

- A is required for osmosis.
- B provides a supply of usable energy for the cell.
- C provides one of the building blocks for lipid synthesis.
- D is an important structural component of the plasma membrane.

64 [VCAA 2015 SA Q7]

The production of adenosine triphosphate (ATP) is represented by the following equation.



The production of ATP

- A is a catabolic reaction.
- B requires an overall input of energy.
- C only occurs in the absence of oxygen.
- D occurs only in the mitochondria of a cell.

65 [VCAA 2016 SA Q16]

Which one of the following is a catabolic process?

- A the conversion of glycogen to glucose.
- B the production of carbohydrates during photosynthesis.
- C the synthesis of a polypeptide hormone from amino acids.
- D the formation of a triglyceride from glycerol and fatty acids.

66 [VCAA 2020 SA Q9]

The dependent variable in this experiment is the

- A amount of sodium hydrogen carbonate added to the beaker.
- B number of bubbles produced in one minute.
- C time taken to count the bubbles produced.
- D distance of the lamp from the beaker.

67 [VCAA 2020 SA Q10]

The bubbles produced in this experiment are likely to contain

- A oxygen.
- B glucose.
- C water vapour.
- D carbon dioxide.

68 [VCAA 2020 SA Q11]

Repeating the experiment three times and finding an average result at each distance increases the

- A reliability of the data.
- B accuracy of the data.
- C precision of the data.
- D validity of the data.

69 [VCAA 2020 SA Q12]

During photosynthesis

- A ATP and NADH created in the light-independent stage are transported to the chloroplasts' thylakoid membranes.
- B ADP and NADH are used in the electron transport chain after being created in the light-dependent stage.
- C ATP and NADPH are created in the grana of the chloroplasts and are used in the light-independent stage.
- D ADP and NADPH are created during the Krebs cycle and carried to the stroma of the chloroplasts.

70 [VCAA 2020 SA Q33]

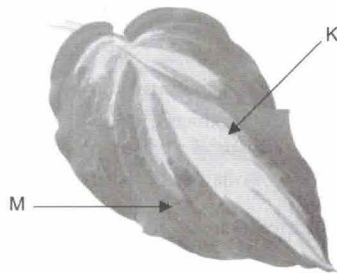
A student completed an experiment to investigate how light is reflected from different leaves. The results were recorded qualitatively.

Which one of the following could be a correct statement about the qualitative data obtained by the student?

- A An average result for the data could be obtained.
- B The same number would be recorded for each result.
- C The data was obtained by measuring the wavelength of light.
- D The data could be the names of the different colours of the reflected light.

71 [VCAA 2017 SA Q15]

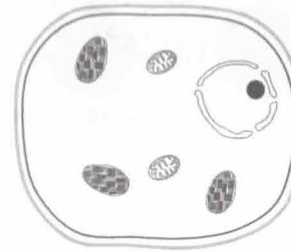
A variegated leaf from a plant is shown below.



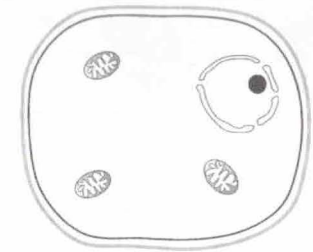
Due to copyright restrictions, this image has been replaced with an equivalent likeness. To view the original image, please visit the VCAA website.

Cells from sections M and K were examined and simple sketches were produced.

A typical cell from section M



A typical cell from section K



From this information, it can be concluded that

- A cells in section K would be unable to carry out aerobic respiration.
- B light-independent reactions of photosynthesis can occur in cells from section K.
- C there is chlorophyll present in cells from section K but not in cells from section M.
- D glucose would be manufactured from carbon dioxide and water in cells from section M but not in cells from section K.

72 [VCAA 2014 SA Q7]

During photosynthesis in chloroplasts, energy is used to split water, forming oxygen and hydrogen ions. The splitting of water occurs

- A in the stroma during the light-independent reaction.
- B in the grana during the light-dependent reaction.
- C on the membrane of the thylakoids during the light-independent reaction.
- D on the surface of the outer chloroplast membrane during the light-dependent reaction.

73 [VCAA 2016 SA Q10]

Plants grown in light were supplied with water containing radioactive oxygen atoms. After four hours, an analysis of the chemicals in and around the plants was undertaken.

Which one of the following would contain the radioactive oxygen atoms after four hours?

- A protein
- B glucose
- C oxygen gas
- D carbon dioxide gas

74 [VCAA 2016 SA Q11]

Which one of the following statements about photosynthesis in chloroplasts is correct?

- A The grana are the site of the light-independent stage.
- B Chlorophyll found in the stroma traps light for use during the light-dependent stage.
- C The light-dependent stage produces ATP for use during the light-independent stage.
- D The light-independent stage captures carbon dioxide for use during the light-dependent stage to produce glucose.



75 [VCAA 2014 SA Q8]

An increase in the atmospheric CO<sub>2</sub> level increases the rate of photosynthesis. The rate of photosynthesis increases because

- A the rate of the light-independent reactions on the thylakoid membranes of the chloroplasts increases.
- B water loss from the leaf decreases, resulting in the availability of water for photosynthesis increasing.
- C the increased CO<sub>2</sub> level lowers the pH inside the chloroplasts and increases the rate of enzyme-catalysed reactions.
- D the rate of the light-independent reactions in the stroma increases with the increase in CO<sub>2</sub> level.

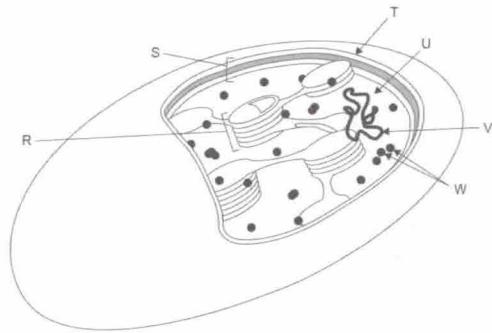
76 [Adapted VCAA 2012 E1 SA Q22]

Carbon dioxide is an input in

- A synthesis of polypeptide molecules.
- B breakdown of glucose during glycolysis.
- C the light-independent reactions of photosynthesis.
- D the electron transport chain in cellular respiration.

Use the following information to answer Question 77.

The diagram that follows shows the structures of a chloroplast, labelled R–W.



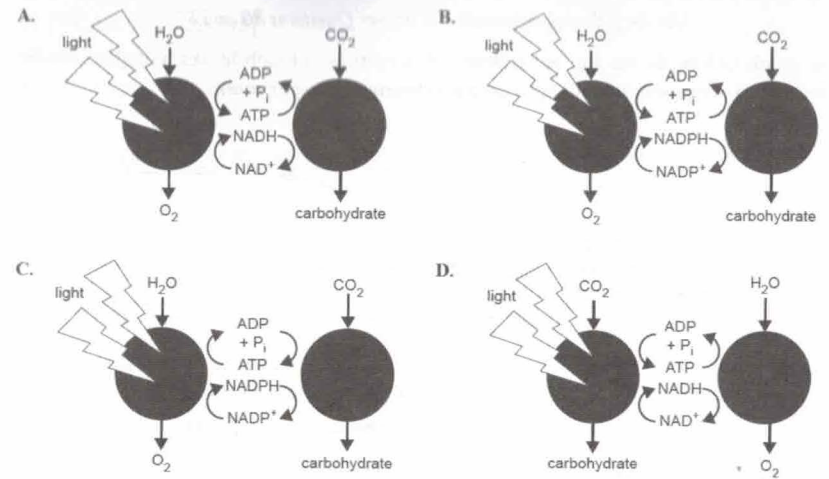
77 [VCAA 2018 SA Q14]

The light-independent reaction of photosynthesis occurs at

- A T.
- B U.
- C V.
- D W.

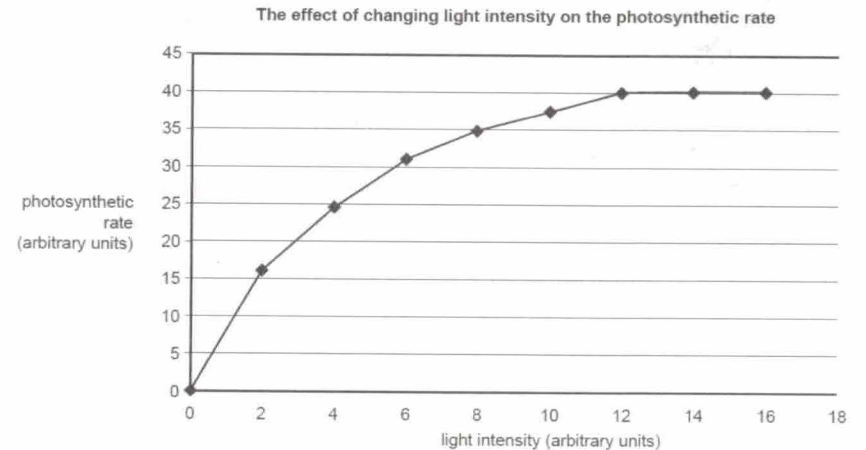
78 [VCAA 2018 SA Q15]

Which one of the diagrams on the following page correctly represents the inputs and outputs of photosynthesis?



79 [VCAA 2019 SA Q15]

An experiment was carried out at a constant temperature and with a constant carbon dioxide concentration in order to determine the effect of changing light intensity on the photosynthetic rate. A graph of the results is shown on the next page.

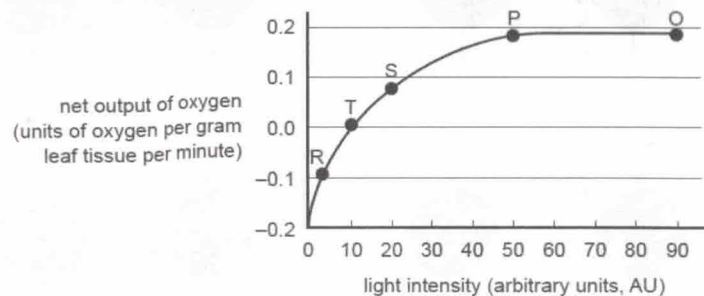


Based on your knowledge and the information in the graph, which one of the following conclusions can be reached?

- A Photosynthesis ceases to occur at a light intensity of 14 arbitrary units.
- B Plants do not undergo photosynthesis at a light intensity of 1 arbitrary unit.
- C Light intensity is a limiting factor when the photosynthetic rate is less than 40 arbitrary units.
- D Increasing the amount of carbon dioxide at a light intensity of 16 arbitrary units would lead to a decrease in the photosynthetic rate.

Use the following information to answer Questions 80 and 81.

The graph below shows the net output of oxygen in spinach leaves as light intensity is increased. Temperature is kept constant during the experiment.



80 [VCAA 2017 SA Q13]

Which one of the following conclusions can be made based on the graph?

- A At point T photosynthesis is no longer occurring.
- B The optimal level of light intensity for photosynthesis is 40 AU.
- C At point S the amount of oxygen output is a third of that at point P.
- D Below 10 AU of light intensity the aerobic respiration rate is greater than the photosynthesis rate.

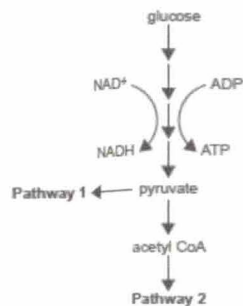
81 [VCAA 2017 SA Q14]

The rate of oxygen output remains constant between points P and O because

- A heat has denatured the enzymes involved in the photosynthesis reactions.
- B the concentration of available carbon dioxide limits the rate of photosynthesis.
- C the light intensity has damaged the chlorophyll molecules present in the spinach chloroplasts.
- D high levels of oxygen produced at point P have accumulated around the spinach leaves, resulting in no more oxygen being produced.

Use the following information to answer Questions 82 and 83.

Shown below is a simplified diagram summarising a series of biochemical processes in a plant cell.



Source: adapted from MG Stovell et al., 'Assessing metabolism and injury in acute human traumatic brain injury with magnetic resonance spectroscopy: Current and future applications', *Frontiers in Neurology*, 12 September 2017, <<https://doi.org/10.3389/fneur.2017.00426>>

82 [VCAA 2020 SA Q5]

Which one of the following is a correct statement?

- A Pathway 2 releases oxygen as a by-product.
- B Pathway 1 requires carbon dioxide as an input.
- C ATP is produced in Pathway 1 and is used by the cell as an energy source.
- D NADH created in Pathway 2 carries electrons into the electron transport chain.

83 [VCAA 2020 SA Q6]

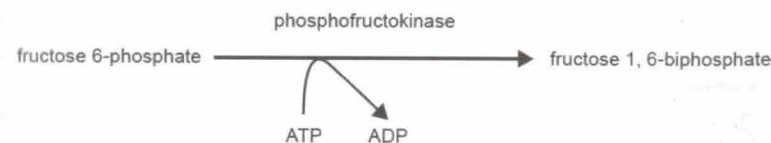
The final products of Pathway 1 are produced in the

- A cristae.
- B cytosol.
- C mitochondrial matrix.
- D chloroplast membranes.

84 [VCAA 2017 SA Q5]

The biochemical pathway of glycolysis involves nine intermediate reaction steps.

One of these steps is represented in the diagram below.



It is correct to state that, in this reaction, phosphofructokinase

- A acts as a coenzyme.
- B increases the rate of reaction.
- C is the substrate for the reaction.
- D releases energy in the form of ADP.

85 [VCAA 2019 SA Q14]

In glycolysis, the ATP yield per molecule of glucose is

- A 4 ATP produced and 2 ATP used for a net gain of 2 ATP.
- B 2 ATP produced and 4 ATP used for a net loss of 2 ATP.
- C 36 to 38 ATP produced for a net gain of 2 ATP.
- D 36 to 38 ATP used for a net loss of 2 ATP.

Use the following information to answer Questions 86–88.

An experiment was carried out by students to test the effect of temperature on the growth of bacteria. Bacterial cells were spread onto plates of nutrient agar that were then kept at three different temperatures:  $-10^{\circ}\text{C}$ ,  $15^{\circ}\text{C}$  and  $25^{\circ}\text{C}$ .

All other variables were kept constant. The experiment was carried out over four days. The nutrient agar was observed every day at the same time and the percentage of nutrient agar covered by bacteria was recorded. At the conclusion of the experiment, the results were recorded in a table, which is shown on the next page.



Time (Days)	Percentage of nutrient agar covered by bacteria at three different temperatures		
	-10°C	15°C	25°C
0	0	0	0
1	0	5	10
2	0	10	20
3	0	15	40
4	0	20	60

**86 [VCAA 2019 SA Q7]**

Which one of the following hypotheses is supported by the results?

- A If the bacteria grow for four days, then the nutrient agar will be completely covered in bacteria.
- B If the bacteria are kept in the dark, then the bacteria will grow more slowly.
- C If the bacteria grow faster, then the temperature of the location will increase.
- D If the temperature increases, then the bacteria will grow more quickly.

**87 [VCAA 2019 SA Q8]**

In this experiment, the dependent variable is

- A time.
- B temperature.
- C the number of bacterial cells.
- D the percentage of nutrient agar covered by bacteria.

**88 [VCAA 2019 SA Q9]**

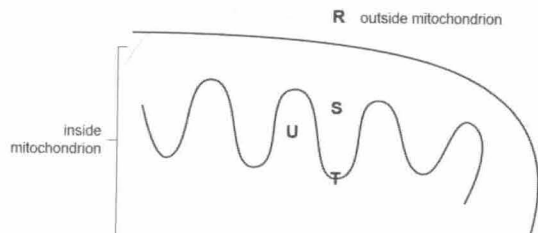
The students wanted to check the reliability of their data.

The students should

- A repeat the experiment several times to find out if they would obtain the same data.
- B organise their data into a different format to help identify a trend.
- C change the independent variable in the experiment.
- D rewrite the method for completing the experiment.

**89 [VCAA 2018 SA Q8]**

The diagram that follows shows a section through a part of a mitochondrion.



The sites of the pathways in aerobic respiration are

- A R – glycolysis, S – Krebs cycle, T – electron transport chain.
- B U – glycolysis, T – Krebs cycle, R – electron transport chain.
- C R – glycolysis, U – Krebs cycle, T – electron transport chain.
- D T – glycolysis, R – Krebs cycle, S – electron transport chain.

**90 [VCAA 2018 SA Q9]**

Which of the following gives the inputs and outputs of the electron transport chain in an animal cell?

	Inputs	Outputs
A	NADH, ADP, oxygen, P <sub>i</sub>	ATP, NAD <sup>+</sup> , water
B	NADH, ADP, water, P <sub>i</sub>	ATP, NAD <sup>+</sup> , oxygen
C	NAD <sup>+</sup> , ADP, oxygen, P <sub>i</sub>	NADH, ATP, water
D	NADH, ADP, water, P <sub>i</sub>	NADP <sup>+</sup> , ATP, oxygen

**91 [VCAA 2017 SA Q11]**

An animal cell culture was exposed to radioactively labelled oxygen. The cells were then monitored for three minutes. After this time, the radioactively labelled oxygen atoms would be present in which cellular chemical?

- A adenosine triphosphate
- B carbon dioxide
- C glucose
- D water

Use the following information to answer Questions 92 and 93.

Rotenone is a chemical compound that is used as an insecticide and a piscicide (a substance that kills fish). The rotenone molecule disrupts the electron transport chain in animal cells by interfering with one of the essential reactions within the electron transport chain.

**92 [VCAA 2015 SA Q9]**

Which one of the following statements best explains the effect of rotenone in causing death in insects and fish?

- A The rate of glycolysis would increase.
- B ATP would accumulate in the mitochondria.
- C Aerobic respiration in the mitochondria would be disrupted.
- D The cell membrane would no longer be permeable to oxygen.

**93 [VCAA 2015 SA Q10]**

In the past, people sometimes put extracts containing rotenone into a river to poison the fish, allowing the fish to be more easily caught. When rotenone-poisoned fish are eaten by people, no poisonous effect is observed.

Which one of the following statements best explains this observation?

- A Rotenone is not absorbed through the cell membranes of people who have eaten poisoned fish.
- B Rotenone is not absorbed by fish tissue and remains dissolved in water.
- C Human cell metabolism does not involve the electron transport chain.
- D Rotenone only affects organisms that respire anaerobically.

94 [VCAA 2015 SA Q12]

A student was investigating four cell types from different organisms. She recorded the results of her microscopic examination of the cells in the table below.

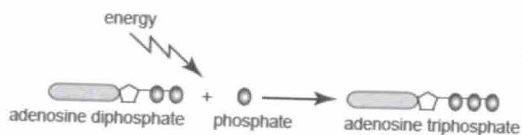
	Cell W	Cell X	Cell Y	Cell Z
Mitochondria	few	many	absent	few
Chloroplasts	present	absent	absent	present
Nucleus	present	present	absent	present

Which one of the following is the correct conclusion that can be drawn from this data?

- A Cell W could be a muscle cell from an insect.
- B Cell Y could be a living leaf cell from a corn plant.
- C Cell X could be a heart-muscle cell from a mammal.
- D Cell Z could be an underground root cell from a pea plant.

Use the following information to answer Questions 95 and 96.

Adenosine diphosphate (ADP) is an organic molecule found in large quantities in most cells. ADP is converted to adenosine triphosphate (ATP) by phosphorylation, as shown in the following diagram.



95 [VCAA 2012 E1 SA Q21]

The original source of energy for this reaction is

- A ADP.
- B glucose.
- C sunlight.
- D phosphate.

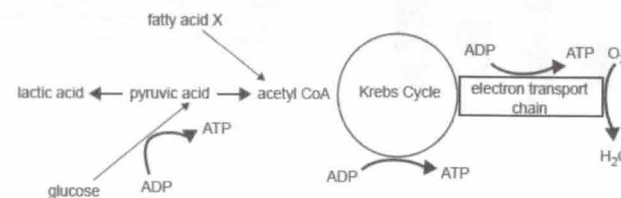
96 [VCAA 2012 E1 SA Q22]

The process that produces the largest number of ATP molecules is

- A synthesis of polypeptide molecules.
- B breakdown of glucose during glycolysis.
- C the light-independent reactions of photosynthesis.
- D the electron transport chain in cellular respiration.

97 [VCAA 2014 SA Q12]

If there is insufficient glucose for cellular respiration, fatty acids can be changed to acetyl CoA. Each fatty acid X molecule produces eight molecules of acetyl CoA. The diagram below summarises the pathways for the breakdown of fatty acid X and glucose. The number of molecules produced in each step is not shown.



Referring to the information above and your knowledge of cellular respiration, which one of the following conclusions can be made?

- A Most of the ATP is made in the Krebs Cycle.
- B Pyruvic acid is converted to acetyl CoA under anaerobic conditions.
- C No ATP can be formed from the breakdown of glucose under anaerobic conditions.
- D One fatty acid X molecule produces more ATP in aerobic conditions than one glucose molecule does.

98 [VCAA 2019 SA Q12]

During which process would the production of lactic acid be observed?

- A aerobic cellular respiration
- B fermentation in animals
- C fermentation in yeasts
- D photosynthesis

99 [VCAA 2020 SA Q40]

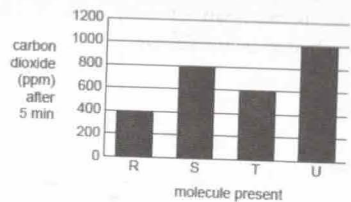
A student investigated the effect of the presence of four different molecules, R, S, T and U, on the rate of cellular respiration in human liver cells. The production of carbon dioxide by the cells was recorded over a five-minute interval. The final concentration of carbon dioxide was recorded. The data collected is shown below.

Molecule present	Concentration of carbon dioxide (ppm) after five minutes
R	400
S	800
T	600
U	1000

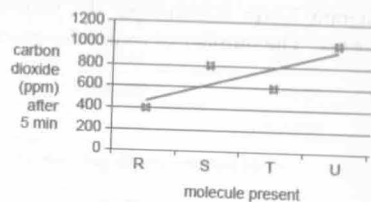
The student presented the results as a graph.

Which one of the following graphs is the best representation of the results?

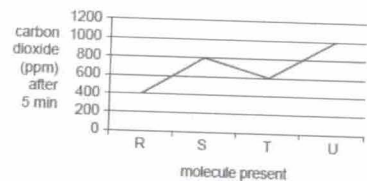
**A.** Effect of four different molecules on rate of cellular respiration in human liver cells



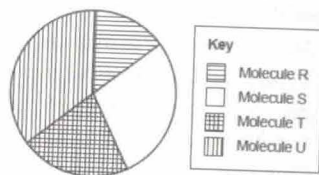
**B.** Effect of four different molecules on rate of cellular respiration in human liver cells



**C.** Effect of four different molecules on rate of cellular respiration in human liver cells



**D.** Effect of four different molecules on rate of cellular respiration in human liver cells



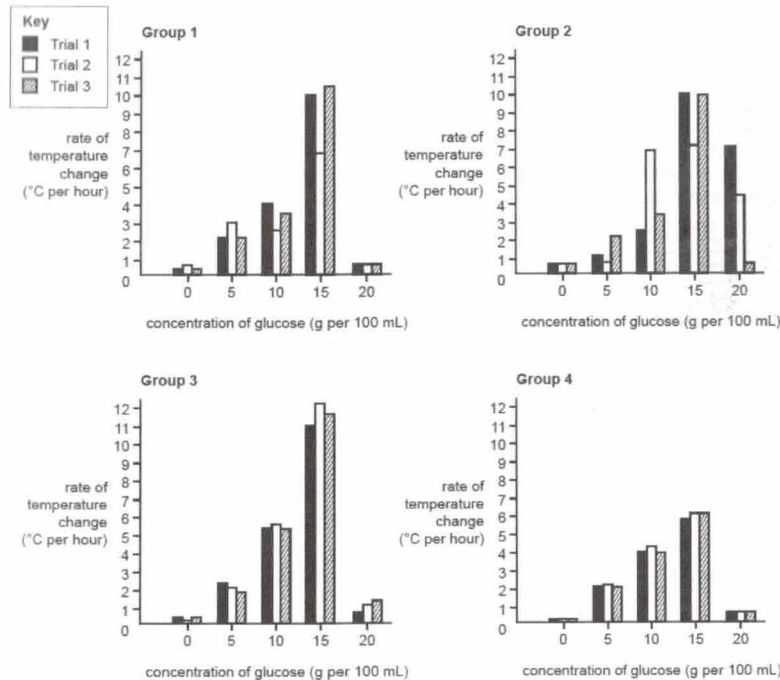
**101 [VCAA 2018 SA Q11]**

Which one of the following statements is correct?

- A Group 1's measurements are the most accurate but the least precise.
- B Group 2's measurements are accurate but not precise.
- C Group 3's measurements are precise but not accurate.
- D Group 4's measurements are both accurate and precise.

**102 [VCAA 2018 SA Q12]**

Each group conducted the experiment three times (Trial 1, Trial 2, Trial 3). Five different concentrations of glucose were used in each trial. Each group plotted its results on a graph, as shown on the next page. The black bar represents Trial 1, the white bar represents Trial 2 and the striped bar represents Trial 3.



Which one of the following statements about the experiment's results can be concluded from the graphs?

- A Group 1's results are more valid than the other groups', but less reliable.
- B Group 2's results are less reliable, but more precise and accurate.
- C Group 3's results are the most accurate and reliable.
- D Group 4's results are more reliable than the other groups'.

**100 [VCAA 2019 SA Q13]**

The rate of aerobic cellular respiration in a human cell may increase if the

- A temperature of the cell is lowered from 37 °C to 35 °C.
- B oxygen concentration available to the mitochondria increases.
- C carbon dioxide concentration in the cytosol of the cell increases.
- D rate of facilitated diffusion of glucose into the cytosol of the cell decreases.

Use the following information to answer Questions 101 and 102.

Four groups of students carried out an experiment in which the effect of glucose concentration on the fermentation rate of yeast was measured. The fermentation rate was determined by the rate of temperature change of the fermenting mixture.

Before beginning the experiment, each group practised measuring the temperature of water and checked the group's thermometer against an electronic thermometer that gave a true measure of temperature.

The following results were obtained during the practice.

Group	Each group's thermometer readings (°C)			Electronic thermometer reading (°C)
	1st measurement	2nd measurement	3rd measurement	
1	18.0	17.0	17.5	20.1
2	18.0	18.0	18.5	20.5
3	21.0	21.0	20.5	19.9
4	18.0	19.0	21.0	20.2



## Short-answer questions

### 103 [VCAA 2019 SB Q11]

Three students wanted to investigate the activity of the enzyme lipase for a practical investigation. Student 1 made the following notes before designing her experiment.

Lipase catalyses the breakdown of fats into glycerol and fatty acids.  
Fatty acids can neutralise an alkaline solution.  
Sodium carbonate is an alkaline solution.

Student 1 set up four test tubes each containing 5 mL of a fatty solution and 10 mL of sodium carbonate solution. Each test tube was suspended in a water bath. Each water bath was set at a different temperature. pH probes were placed into each test tube. Each solution had a pH of 8.

After setting up the four test tubes in the water baths, Student 1 waited until the solution in the test tube was the same temperature as the water in the water bath. Student 1 then added 5 mL of lipase solution to each test tube. Student 1 timed how long it took for the pH of the solution to become neutral (pH of 7).

Student 1 repeated the experiment so that she had three measurements for each temperature. She obtained the data shown in Table 1.

**Table 1. Results from Student 1**

Temperature (°C)	Time taken for solution to become neutral (seconds)		
	Measurement 1	Measurement 2	Measurement 3
5	240	238	241
15	229	230	226
25	200	201	202
35	180	181	180

- a Student 1 was concerned about the precision of her measurements. Analyse the data above and state the temperature at which the measurements are the most precise.  
Justify your response. [2 marks]
- b State whether Student 1 obtained qualitative or quantitative data. Outline a difference between the two types of data. [2 marks]
- c Student 2 repeated the experiment designed by Student 1 the next day and obtained the data shown in Table 2.

**Table 2. Results from Student 2**

Temperature (°C)	Time taken for solution to become neutral (seconds)		
	Measurement 1	Measurement 2	Measurement 3
5	241	239	242
15	230	155	230
25	201	202	170
35	181	181	181

Student 2 indicated that he had errors in his measurements.

Identify which of his measurements have errors. Give two examples of sources of error for these measurements. [3 marks]

- d Later that day, the third student performed the experiment. Student 3's data is shown in Table 3.

**Table 3. Results from Student 3**

Temperature (°C)	Time taken for solution to become neutral (seconds)		
	Measurement 1	Measurement 2	Measurement 3
5	141	139	142
15	130	130	130
25	101	102	102
35	81	81	81

After comparing his results with the other students' results, Student 3 realised he had made an error.

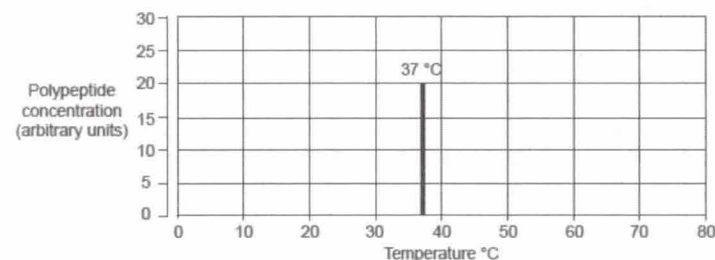
Name the type of error that was made by Student 3 and identify **one** source of error that may account for the results obtained by this student. [2 marks]

- e Identify a limitation of the experiment that was carried out by all three students. What could the students do to address this limitation? [2 marks]

[Total 11 marks]

### 104 [VCAA 2012 E1 SB Q5]

Half an hour after an adult person completed eating a protein-rich meal, a sample was taken of the contents of their stomach. This sample was divided into three equal parts in separate tubes. Each tube was incubated at a different temperature for 10 hours. After that time, each tube's contents was tested to determine its polypeptide concentration. The result for the sample incubated at 37°C is shown on the graph below.



- a On the graph above, draw the results you would expect for the samples incubated at 10°C and 80°C. [2 marks]
- b Explain your predicted results for the polypeptide concentrations at temperatures of 10°C and 80°C. [2 marks]

[Total 4 marks]

Six students performed a trial experiment on enzyme activity. The enzyme they were studying acts on a cloudy suspension, breaking it down into a soluble form. The lesson ended, and students were asked to stop their experiment. They then recorded the time the experiment had run and their observations. These data are collated in the following table.

Student	Volume of enzyme solution (mL)	Temperature (°C)	pH	Volume of cloudy suspension (mL)	Time (minutes)	Observation at end of lesson
1	5	37	2	10	9	Cloudy
2	5	37	2	10	20	Clear
3	5	37	4	10	35	Clear
4	5	37	4	10	20	Cloudy
5	5	37	6	10	8	Cloudy
6	5	37	6	10	40	Cloudy

- a What is the purpose of this experiment? [1 mark]
- b Describe two changes that would improve the validity of the data collected in the experiment. [2 marks]
- c The experiment was repeated with all trials running for 40 minutes. Complete the table to predict the results. [1 mark]

Student	Volume of enzyme solution (mL)	Temperature (°C)	pH	Volume of cloudy suspension (mL)	Time (minutes)	Observation at end of lesson
1	5	37	2	10	40	
2	5	37	2	10	40	
3	5	37	4	10	40	
4	5	37	4	10	40	
5	5	37	6	10	40	
6	5	37	6	10	40	

[Total 4 marks]

### 106 [VCAA 2020 SB Q3]

Greenhouses have been used to generate higher crop yields than open-field agriculture. To encourage plant growth in greenhouses, the conditions required for photosynthesis are controlled. Commercial greenhouses, like the ones shown on the next page, often use a lot of energy for heating, ventilation, lighting and water.



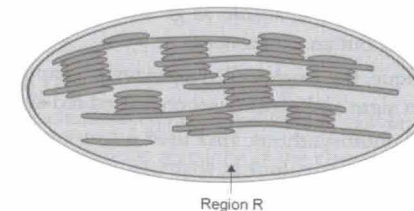
Due to copyright restrictions, this image has been replaced with an equivalent likeness. To view the original image, please visit the VCAA website.

- a Consider the reactions of photosynthesis. Why would it be important to maintain the temperature within narrow limits in a commercial greenhouse? Justify your answer. [2 marks]
- b Scientists are developing a new material to cover greenhouses, which can split incoming light and convert the rays from green wavelengths into red wavelengths. Explain how this new material increases crop yields. [2 marks]
- c In plants and algae, photosynthesis is carried out in chloroplasts. It is thought that chloroplasts originated from bacteria. Describe two features of chloroplasts that support the theory that chloroplasts originated from bacteria. [2 marks]

[Total 6 marks]

### 107 [VCAA 2019 SB Q2]

- a A chloroplast is surrounded by a double membrane.
- i Name **two** molecules, as inputs for photosynthesis, that would need to diffuse from the cytosol of the plant cell across the chloroplast membranes and into the chloroplast. [1 mark]
- ii Under high magnification, the internal structure of a chloroplast is visible. The diagram below shows part of this structure.



Due to copyright restrictions, this image has been replaced with an equivalent likeness. To view the original image, please visit the VCAA website.

- A higher concentration of oxygen is found in Region R when a plant is photosynthesising compared to when it is not photosynthesising.

Account for the differences in oxygen concentrations found in this region.

[2 marks]

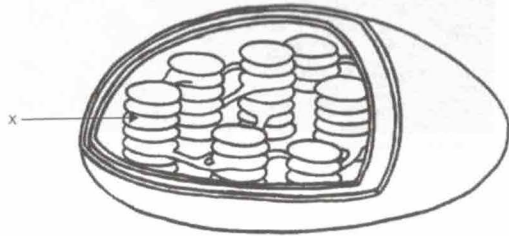


- b Describe the role played by each of the coenzymes NADPH and ATP in photosynthesis. [2 marks]

[Total 5 marks]

108 [VCAA 2015 SB Q3]

Below is a diagram of a chloroplast.



Source: J Soucie; © BIODIDAC

- a Name the structure labelled X. [1 mark]
- b Complete the table below by referring to the diagram above and your knowledge of photosynthesis. [3 marks]

Name of the stage of photosynthesis that occurs at X	_____	
Two input molecules that are required for reactions at X	1 _____	2 _____
Two output molecules that result from reactions at X	1 _____	2 _____

[Total 4 marks]

109 [VCAA 2018 SB Q11]

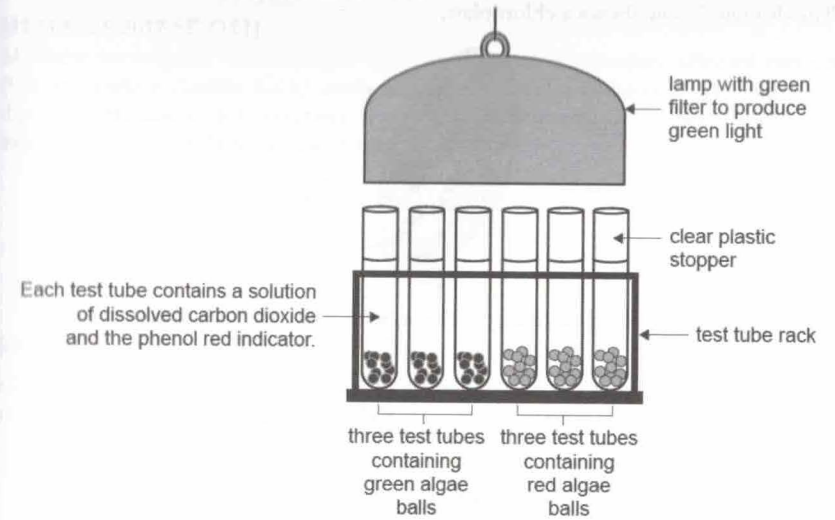
Elsa read that red algae survive at greater water depths than green algae because of a pigment in the red algae called phycoerythrin. This pigment enables the algae to absorb more of the green light available at greater water depths. Elsa decided to investigate this by carrying out an experiment.

Using a standard technique, the single-celled algae were trapped in jelly balls. One set of balls contained green algae and another set contained red algae.

To measure the rate of photosynthesis, Elsa used a stopwatch and the pH indicator phenol red. Phenol red changes colour in solutions with different concentrations of carbon dioxide. In low carbon dioxide concentrations, phenol red is pink and in higher carbon dioxide concentrations it is yellow.

Elsa placed the jelly balls into test tubes and covered them with a solution containing dissolved carbon dioxide. Phenol red indicator was added to each solution.

The diagram on the following page shows the set-up of Elsa's experiment.



- a State the hypothesis that Elsa was testing. [1 mark]
- b List three variables that would need to be controlled to ensure the experiment produced valid results. [3 marks]
- c State the independent variable and the dependent variable in this experiment. [2 marks]
- d What results would disprove the hypothesis of Elsa's experiment? [2 marks]
- e Elsa's laboratory partner suggested that they should also set up an identical experiment but keep the test tubes and their contents in the dark. Explain why this is a good suggestion. [1 mark]
- f Elsa's teacher said that even if the students completed the additional experiment in the dark and even if all of those results supported the hypothesis, there may still be other plausible explanations for their results. Suggest **two** other explanations to which the teacher could be referring. [2 marks]

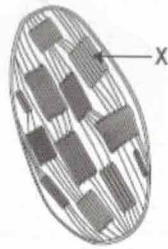
[Total 11 marks]

110 [VCAA 2011 E1 SB Q7]

- a Write the word or chemical equation for aerobic cellular respiration. [1 mark]
- b Cyanide inactivates metabolic reactions at the cristae of mitochondria. Cyanide poisoning often results in death. Explain why. [2 marks]

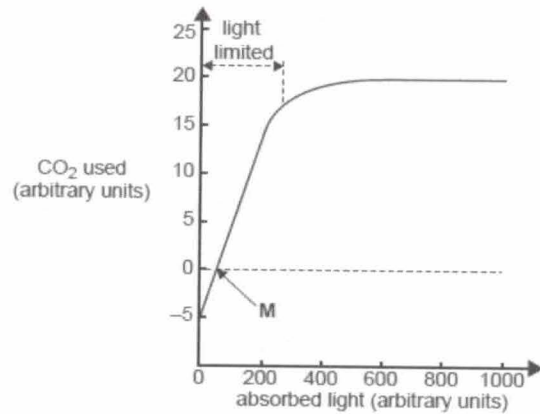


The diagram below shows a chloroplast.



- c Describe the chemical changes that occur at location X when light is present. [2 marks]

The graph below shows the rate of carbon dioxide exchange between a leaf and its external environment as light intensity is altered. All other variables are kept constant throughout the experiment.



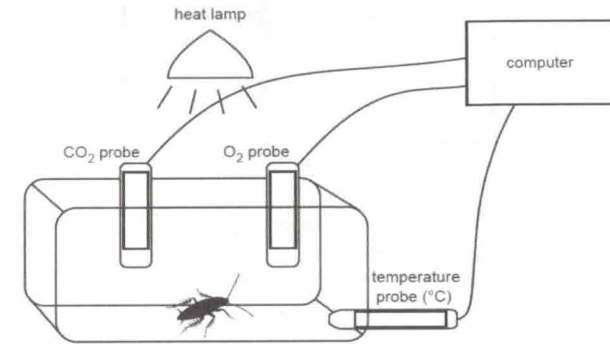
- d i Outline what is occurring at point M in terms of chemical reactions. [1 mark]  
 ii Explain why the graph line becomes nearly horizontal from about 600 units of absorbed light. [1 mark]

RuBisCo is an enzyme found in chloroplasts. Its normal function is to catalyse the reaction in which carbon dioxide is a substrate. In certain plants, when the level of carbon dioxide is low in the leaf, RuBisCo uses oxygen as the substrate and releases hydrogen peroxide and ammonia.

- e Explain why it is beneficial for a plant to have a high level of carbon dioxide in its leaves. [2 marks]  
 [Total 9 marks]

111 [VCAA 2017 SB Q11]

Matthew investigated how changes in environmental temperature affected oxygen ( $O_2$ ) and carbon dioxide ( $CO_2$ ) levels in the air around a cockroach. He used three digital probes linked to a computer, a closed animal chamber and a heat lamp in the experimental set-up shown in the diagram that follows.



- a Name the cellular process being investigated in Matthew's experiment. [1 mark]  
 b Identify the  
 • dependent variables  
 • independent variable. [2 marks]

Before placing the cockroach in the chamber, Matthew decided to measure the temperature, and carbon dioxide and oxygen levels for four minutes. The following results were recorded.

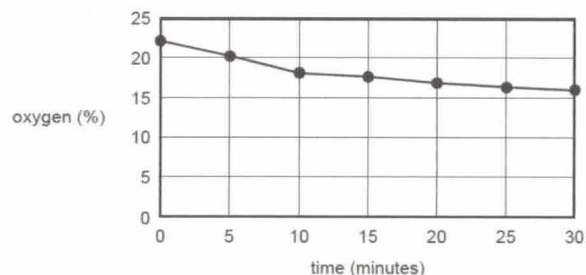
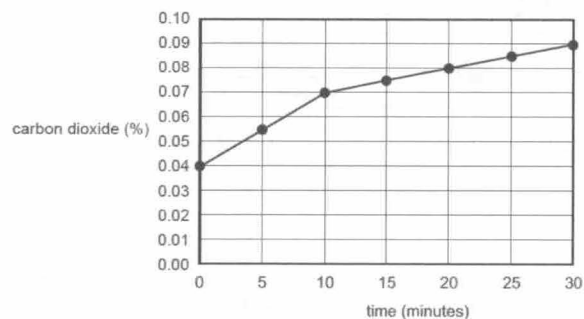
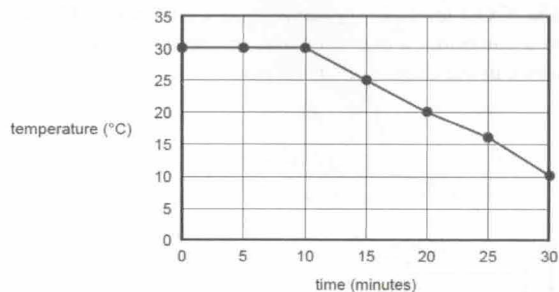
Time (minutes)	$CO_2$ (%)	$O_2$ (%)	Temperature ( $^{\circ}C$ )
0	0.04	22.3	29.5
1	0.04	22.1	29.8
2	0.04	22.0	30.0
3	0.04	22.0	30.0
4	0.04	22.0	30.0

- c Explain why Matthew recorded the data for four minutes and not just one minute. [1 mark]

After the initial four-minute period, Matthew quickly placed the cockroach in the chamber and began recording the data from the digital probes. After 10 minutes, he placed ice packs around the sides of the animal chamber to slowly bring the temperature of the chamber down to  $10^{\circ}C$ . He recorded the data using the digital probes for a further 20 minutes. He repeated the experiment once every day for the next six days with the same cockroach. At all times, he took care to ensure that the cockroach showed no signs of stress.

- d Other than repeating the entire experiment, identify two control measures Matthew should have included in his experimental design. Explain how each of these control measures could affect the results if not kept constant. [4 marks]

Matthew constructed the following graphs from the averaged results of the seven experiments.



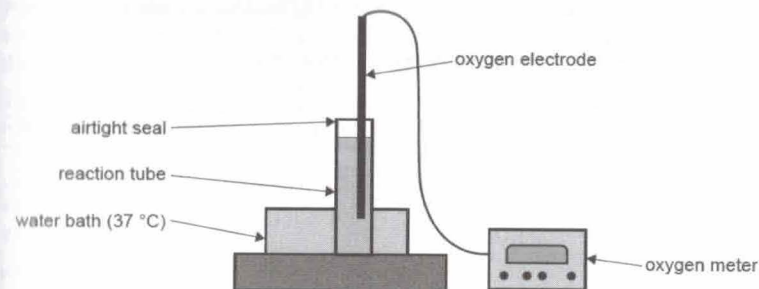
- e i Using the graphical data, describe the changes in the levels of carbon dioxide and oxygen when the temperature in the chamber was kept constant compared to when the temperature was decreasing. [2 marks]
- ii What conclusion do you think Matthew can draw from his investigation? You should refer to each of the following in your response:
- the cellular process named in **part a**.
  - the variables identified in **part b**.
  - the evidence collected during Matthew's experiments.

[4 marks]

[Total 14 marks]

### 112 [VCAA 2016 SB Q4]

The apparatus shown in the diagram below was used in a series of experiments to study aerobic respiration.



In three different experiments, the reaction tube initially contained the following:

- suspension of mitochondria
- cytosol of cells from which the mitochondria had been removed
- suspension of mitochondria and cytosol of cells.

The temperatures and pH of the mixtures within the reaction tubes were carefully controlled so as not to damage the mitochondrial structure or any of the enzymes.

In each experiment, a solution containing glucose was first added to the mixture in the reaction tube and the oxygen concentration was measured for three minutes. Then, a pyruvate solution was added and the oxygen concentration was measured again for three minutes.

Using your knowledge and understanding of aerobic respiration and mitochondria, give your **prediction** of the change in oxygen concentration of the mixture in the reaction tube after the addition of each substance in the different 3 experiments and give a **reason** for your prediction.

**Experiment 1** – Suspension of mitochondria

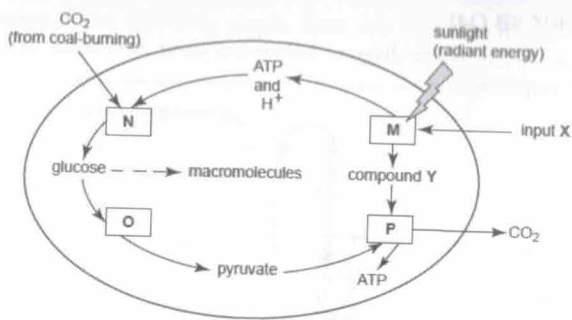
**Experiment 2** – Cytosol of cells from which the mitochondria had been removed

**Experiment 3** – Suspension of mitochondria and cytosol of cells

[Total 6 marks]

### 113 [VCAA 2012 E1 SB Q8]

Climate change has been linked to an excess of carbon dioxide in the atmosphere. The burning of coal is a major contributor to this excess of carbon dioxide. Microalgae such as *Chlorella* can use greater amounts of carbon dioxide than land plants and they do not require prime soil, reliable rainfall and a particular climate. *Chlorella* can be grown cheaply in existing or engineered ponds which are supplied with carbon dioxide from a coal-burning power station nearby. The diagram on the next page represents a summary of the processes (labelled M, N, O, P) occurring in a *Chlorella* cell.



- a Name
- i input X [1 mark]
- ii compound Y [1 mark]
- b With reference to the diagram of processes in a *Chlorella* cell, complete the following table.

Process	Name of process	Site of process
M		Grana of chloroplast
O	Glycolysis	
P	Stages of cellular respiration	

[3 marks]

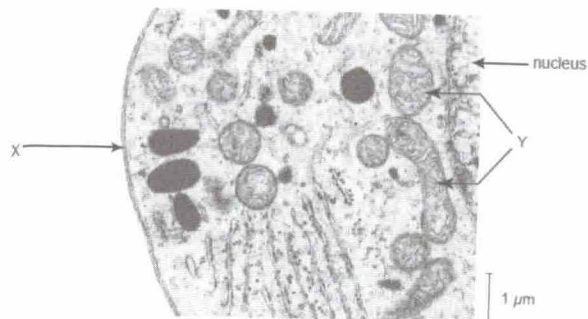
*Chlorella* pond farms could reduce 50% of the carbon dioxide that is produced by coal-burning power stations. Consider the summary of processes occurring in a *Chlorella* cell.

- c Given that carbon dioxide is an output of process P, explain how *Chlorella* farming could prevent 50% of the carbon dioxide emitted by coal-burning power stations from entering the atmosphere. [2 marks]
- d What are two conditions, other than carbon dioxide supply, that an engineer or biologist maintaining a *Chlorella* pond farm would need to control to keep the growing conditions at an optimum level? [1 mark]

[Total 8 marks]

114 [VCAA 2012 E1 SB Q1]

The electron-micrograph below shows a portion of a cell.



- a Name and describe structure X. [2 marks]
- b It has been suggested that as humans age, the structures labelled Y become less efficient. Explain the consequence of this for an elderly person. [2 marks]

[Total 4 marks]

115 [VCAA 2013 SB Q1]

Yeast is a single-celled, microscopic fungus that uses sucrose as a food source. An experiment was carried out to investigate cellular respiration by a particular species of yeast. Yeast cells were placed in a container and a sucrose solution was added. An airtight lid was placed on the container. The percentages of oxygen and ethanol in the container were recorded over a one-hour period.

The experiment was carried out at room temperature. The results are shown in the following table.

	Percentage of oxygen	Percentage of ethanol
at the start of the experiment	21	0
at the end of the experiment	18	4

- a Explain any changes that have been observed in oxygen and ethanol levels within the airtight container. [2 marks]

Levels of carbon dioxide were also monitored during the experiment.

- b Predict whether the carbon dioxide concentration inside the airtight container would increase, stay the same or decrease within the time the experiment was carried out. Explain the reasoning behind your prediction. [2 marks]

Scientists are looking at ways to increase the efficiency of photosynthesis in plants, including the way in which carbon dioxide is captured.

- c i Name the stage of photosynthesis in which carbon dioxide is captured. [1 mark]
- ii The stage of photosynthesis in which carbon dioxide is captured requires other inputs. Name **two** other **inputs**, and describe the **role** played by each in this stage of photosynthesis. [2 marks]

[Total 7 marks]

116 [VCAA 2016 SB Q2]

Plant materials containing cellulose and other polysaccharides are reacted with acids to break them down to produce glucose. This glucose is then used by yeast cells for fermentation.

- a Why is fermentation important for yeast cells? [1 mark]
- b What are the products of fermentation in yeast cells? [1 mark]

A by-product of the acid treatment of plant materials is a group of chemical compounds called furans. It has been observed that as the concentration of furans increases, the rate of fermentation decreases. The enzyme alcohol dehydrogenase is required for the process of fermentation.

- c Design an experiment to test the hypothesis that one of the furans, called furfural, is an inhibitor of the enzyme alcohol dehydrogenase. Assume that the experiment will be repeated many times and that environmental factors are kept constant. [4 marks]
- d Scientists have proposed that furfural is a competitive inhibitor of the enzyme alcohol dehydrogenase.

Explain how furfural could act as a competitive inhibitor of the enzyme alcohol dehydrogenase. [2 marks]

[Total 8 marks]