IB · HL · Biology

4 hours 30 questions

Structured Questions

Photosynthesis

The Process of Photosynthesis / Separating Photosynthetic Pigments: Skills / Absorption Spectra / Absorption & Action Spectra: Skills / Limiting Factors of Photosynthesis: Skills / Carbon Dioxide Enrichment Experiments / Photosystems (HL) / Light Dependent Reactions (HL) / Photophosphorylation (HL) / Light Independent Reactions (HL) / Interdependence of Photosynthetic Reactions (HL)

Easy (10 questions)	/74
Medium (10 questions)	/82
Hard (10 questions)	/108
Total Marks	**/264**

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Easy Questions

1 (a) Chloroplasts contain various photosynthetic pigments.

State the role of a photosynthetic pigment.

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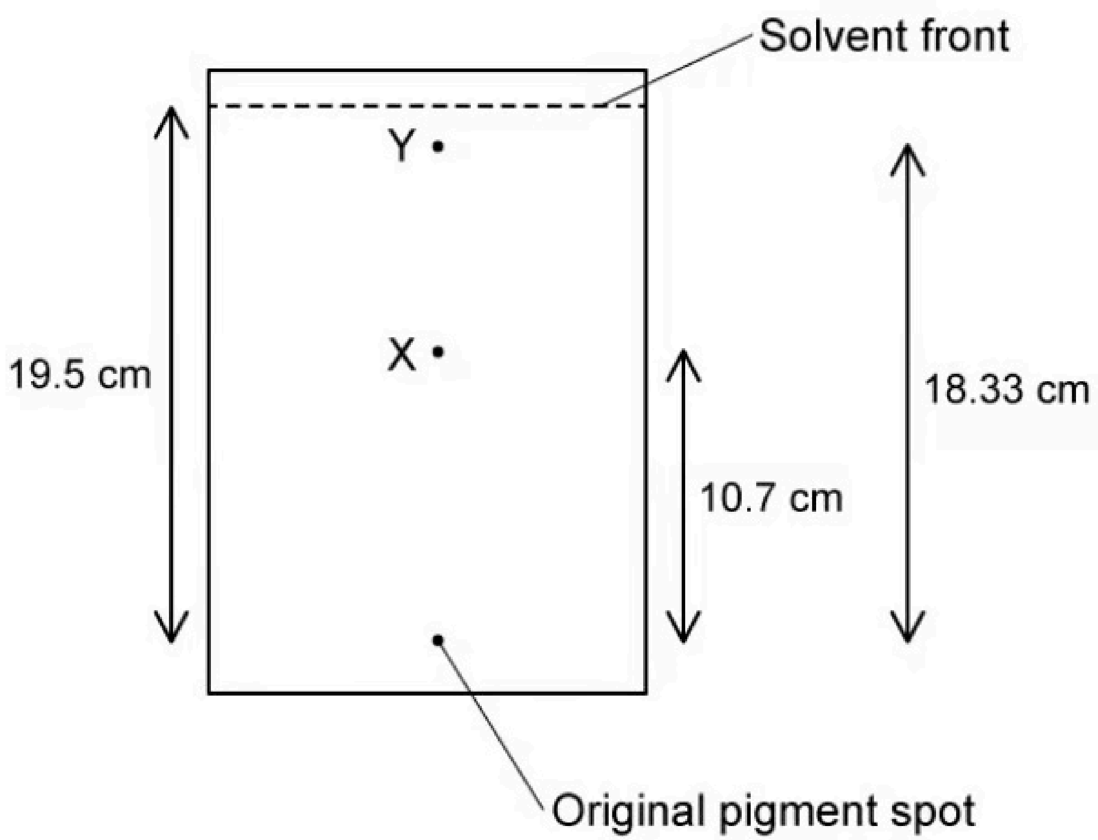
(1 mark)

(b) The pigments in a chloroplast can be separated and identified using a technique called thin layer chromatography. After extracting pigments from a spinach leaf a student carried out thin layer chromatography. Some of their results can be seen below.



Use the equation provided to calculate the R_f values for pigments **X** and **Y**.

$$R_f = \frac{Distance\ moved\ by\ pigment}{Distance\ moved\ by\ solvent}$$

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(2 marks)

(c) The table below contains value ranges for the R_f values of common photosynthetic pigments.

Pigment	**R_f value range**
Carotene	0.89 - 0.95
Neoxanthin	0.05 - 0.11
Chlorophyll a	0.64 - 0.69
Chlorophyll b	0.53 - 0.62
Pheophytin a	0.78 - 0.86

Use your answers to part b) to identify pigments **X** and **Y** from part b).

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(2 marks)

2 (a) State why the majority of plants look green to human eyes.

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(1 mark)

(b) The effect of different colours of light on the growth of *Arabidopsis thaliana* (thale cress) seedlings was studied. Three different colours of light were tested and measurements of seedling height, shoot length, and biomass were taken. The results of the study are shown in the table below.

Colour of light	Wavelength of light / nm	Height of seedlings / cm	Shoot length / cm	Total biomass / g
Blue	450	2.3	2.0	2.4
Orange	600	3.5	2.8	2.8
Red	630	7.4	6.1	3.7

State what can be concluded about the effect of different colours of light on the growth of *Arabidopsis thaliana* from the data shown.

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(2 marks)

(c) Oxygen can be thought of as a waste product of photosynthesis.

Identify the process by which this oxygen is produced.

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(1 mark)

(d) The process in part c) releases oxygen into the atmosphere, increasing atmospheric oxygen concentration.

State **two other** impacts that photosynthesis would have had on the atmosphere of prehistoric earth.

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(2 marks)

3 (a) State what is meant by the term **photosynthesis**.

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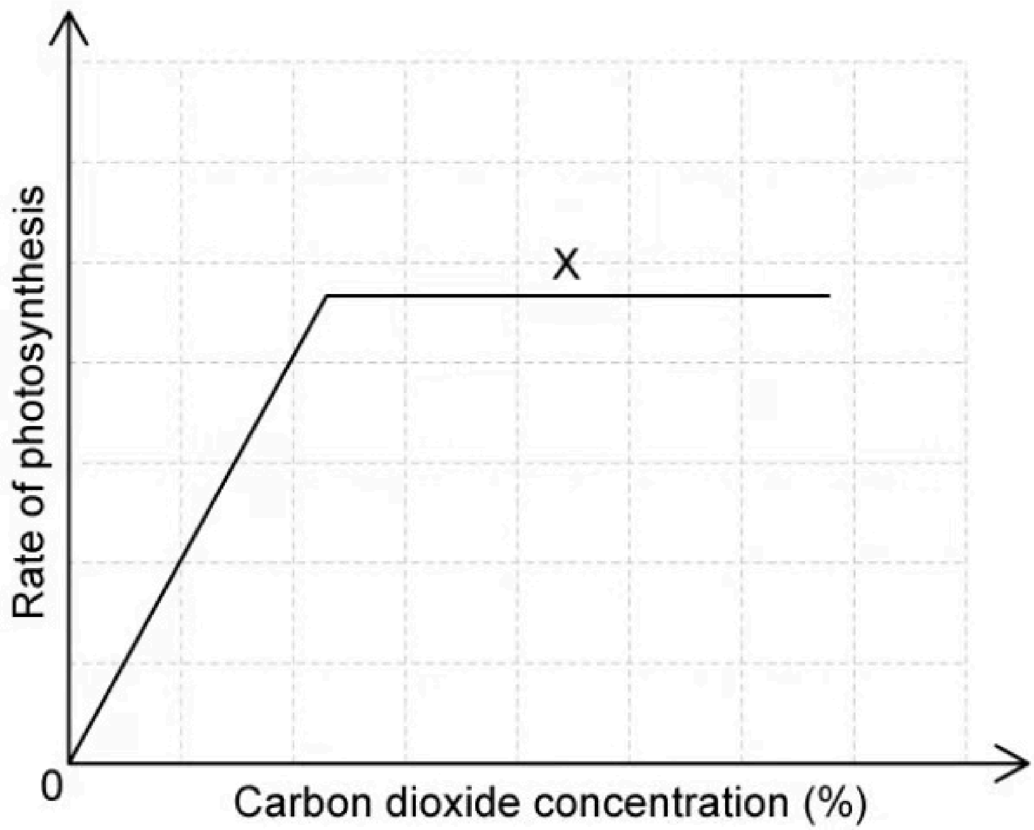
(2 marks)

(b) The graph below shows the relationship between carbon dioxide concentration and the rate of photosynthesis.



Describe the relationship between carbon dioxide concentration and the rate of photosynthesis shown in the graph.

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(2 marks)

(c) Identify a possible limiting factor at the point labelled **X** in the graph in part b).

(1 mark)

(d) Sketch a graph of the rate of photosynthesis against temperature.

(3 marks)

4 (a) A student made the following statement:

> *"Visible light has wavelengths between 200 and 900 μm. Red is the shortest wavelength and violet is the longest."*

Identify the errors in this statement.

(3 marks)

(b) A plant is grown in increasing concentrations of carbon dioxide whilst other factors are kept constant.

Describe what will happen to the rate of photosynthesis as carbon dioxide concentration increases.

(2 marks)

(c) The plant in part b) is an aquatic plant. Before starting the experiment the student conducting the study boiled and then cooled the water that the plant would be placed in.

Explain why the student did this.

(1 mark)

(d) Describe how the student could have measured the rate of photosynthesis in the study described in parts b) and c).

(2 marks)

5 (a) Outline how photosynthesis in early life forms caused changes to early Earth.

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(5 marks)

(b) Describe the process of photosynthesis.

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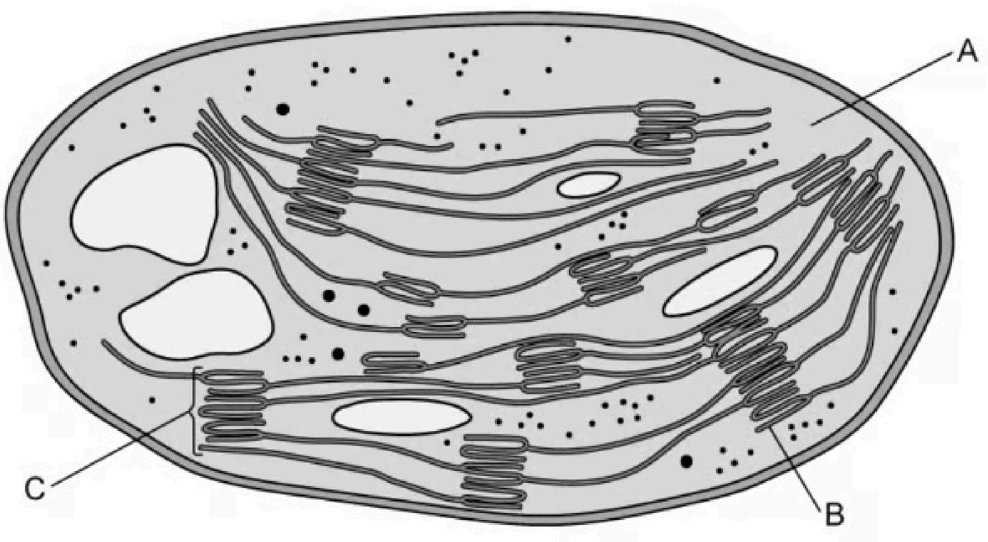
(6 marks)

6 (a) The diagram below shows a chloroplast.



Identify Structure A and state the reaction that takes place there.

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(2 marks)

(b) State two products of the light independent stage of photosynthesis.

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(2 marks)

(c) ATP is required to drive the light independent reactions of photosynthesis.

Name the process which produces this ATP to be used in the light independent reactions?

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(1 mark)

(d) The light independent reactions are affected by temperature changes. Lowering the temperature slows down the light independent reactions.

Explain why a low temperature slows down the light independent reactions.

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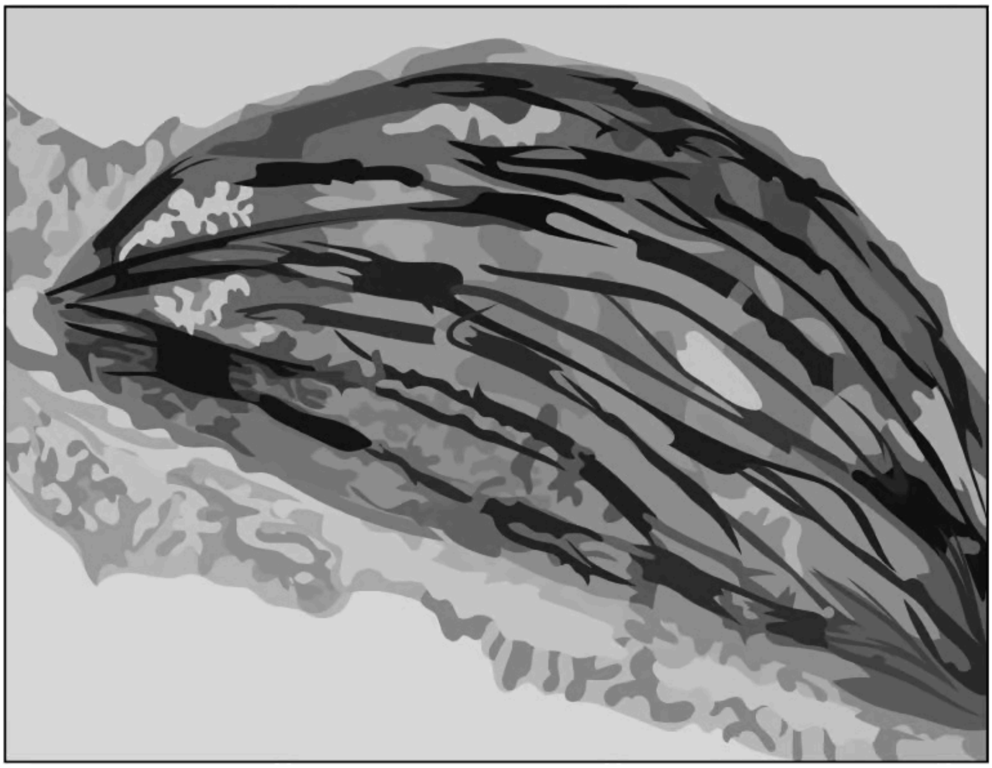
(2 marks)

7 (a) The diagram shows an electron micrograph of a chloroplast.

Annotate the diagram with the letter X to show the location of the light dependent stages of photosynthesis.



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(1 mark)

(b) The photolysis of water is an important part of the process of light dependent stages of photosynthesis.

Describe what happens in the photolysis of water.

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(2 marks)

(c) Chloroplasts contain more than one photosynthetic pigment.

Suggest why chloroplasts contain more than one photosynthetic pigment.

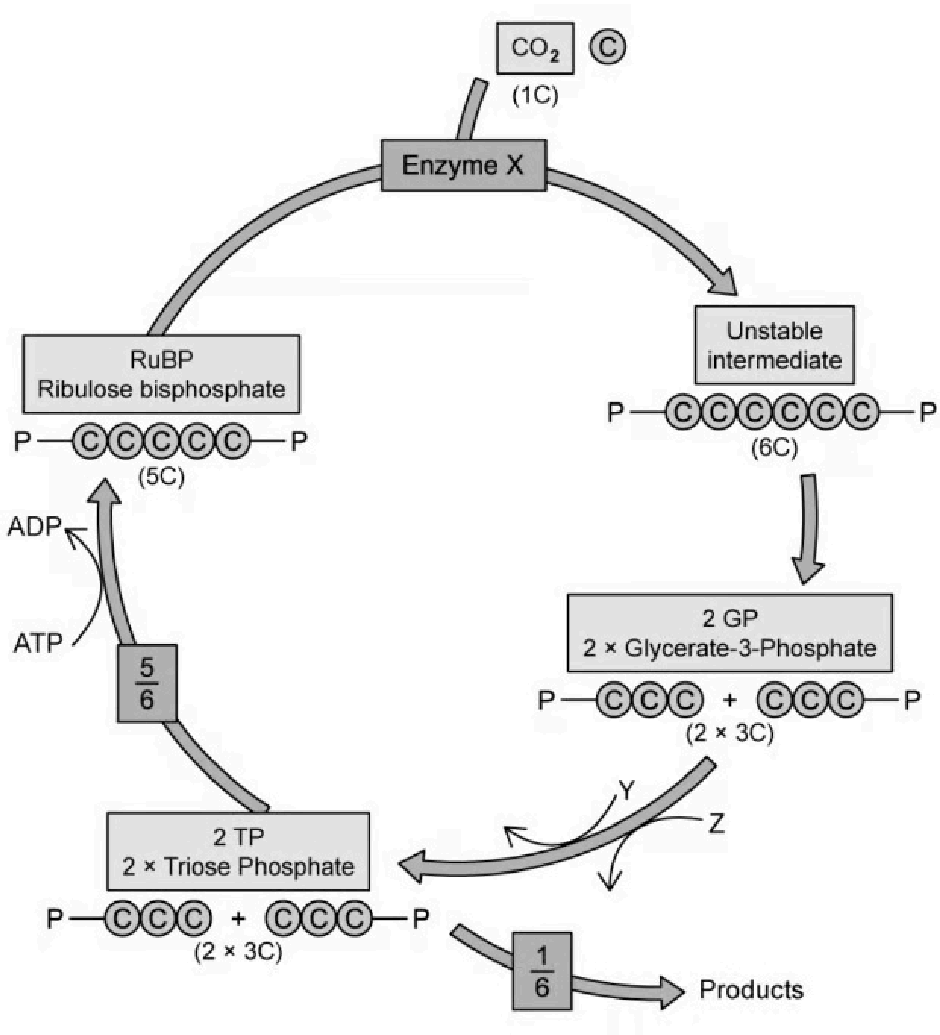
(1 mark)

(d) Describe a structure of the chloroplast that enables maximum absorption of light.

(2 marks)

8 (a) The diagram below shows the Calvin cycle.

State the name of enzyme X shown in the diagram.



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(1 mark)

(b) The molecules labelled Y and Z on the diagram are used to convert GP to TP.

Identify the molecules labelled Y and Z.

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(2 marks)

(c) One sixth of the TP is converted into usable products for the plant. One of these is hexose sugars.

State **two** uses of hexose sugars by plant cells.

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(2 marks)

(d) One sixth of TP is converted into usable products for the plant. The remaining five sixths remain in the Calvin cycle.

Explain why it is important that not all the TP is converted to usable products.

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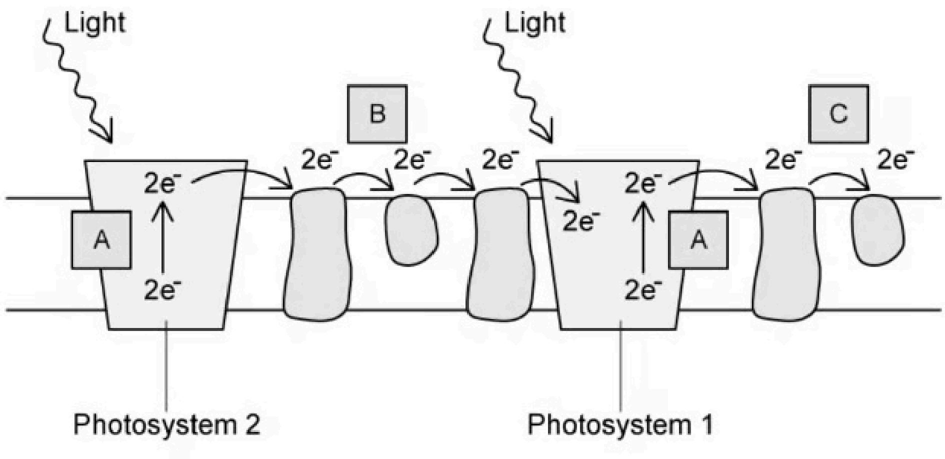
(2 marks)

9 (a) The diagram below shows some of the reactions taking place in the light dependent stages of photosynthesis.

State the exact location of the reactions shown.



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(1 mark)

(b) Describe the process that occurs at location A in the diagram.

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(2 marks)

(c) The diagram from part **a)** shows the electron transport chain in the light dependent reaction.

At stage **B,** the electrons are involved in a series of reactions fundamental in the process of chemiosmosis.

State the type of reactions that take place at stage **B.**

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(1 mark)

(d) The diagram from part a) shows the movement of electrons through the electron transport chain.

(i) Identify the product labelled C.

[1]

(ii) Describe the role of the electrons in the formation of product C.

[2]

(3 marks)

10 (a) During the light independent stage of photosynthesis, carbon dioxide is converted into organic substances.

Describe how.

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(6 marks)

(b) ATP and NADPH are two products of the light-dependent reactions.

Describe the functions of each of these substances in the light-independent reactions.

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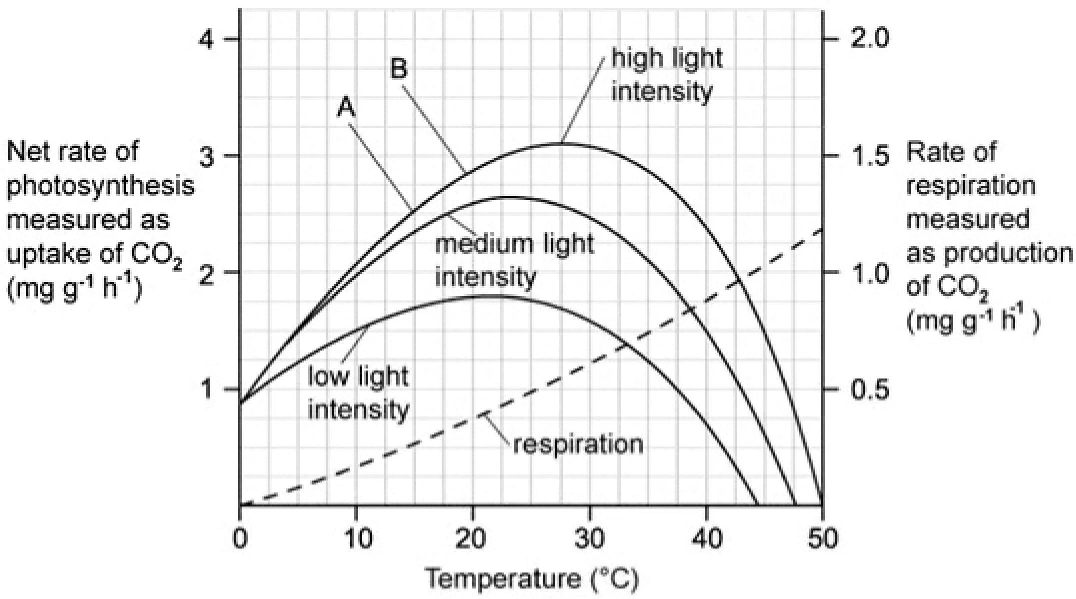
(3 marks)

Medium Questions

1 (a) Lab technicians wanted to determine the effects of light intensity and temperature on the rate of photosynthesis in Rhododendrons. They recorded the effect of different temperatures on the net rate of photosynthesis at various light intensities. Their experiment also recorded the rate of respiration at the different temperatures. The graph below shows the results from their experiment.



Identify, with a reason, the factor which is limiting the rate of photosynthesis between **A** and **B**.

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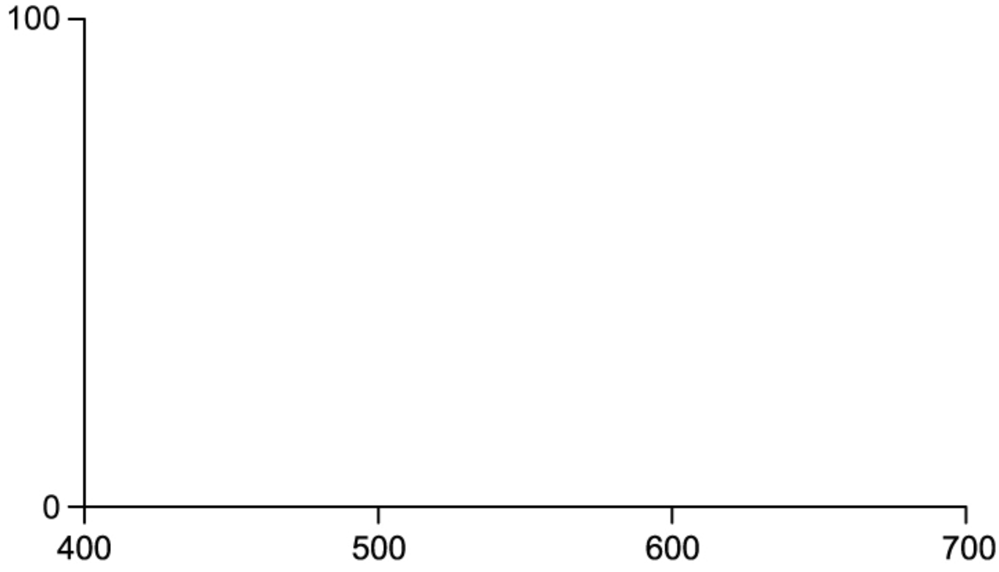
(2 marks)

(b) Add labels to the axis below and sketch an action spectrum for photosynthesis of the rhododendron plant exposed to high light intensity.



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(2 marks)

(c) Rhododendrons have been found in several alpine regions. Ecologists noted that in one of the plant's natural habitats the average summer temperature across a 20 year period rose from 21°C to 24°C, while the cloud cover increased.

Describe and explain how these changes would impact the growth of Rhododendrons.

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(3 marks)

(d) Name **two** variables, other than temperature and light intensity, that could act as limiting factors for the rate of photosynthesis in rhododendrons.

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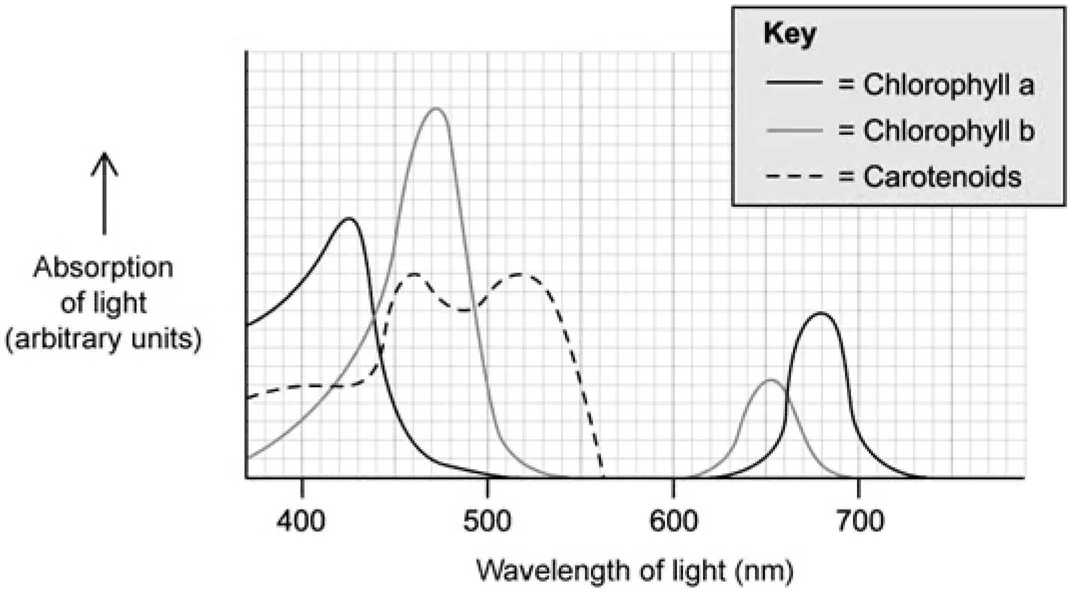
(2 marks)

2 (a) Plants possess a collection of photosynthetic pigments that allow for the absorption of light energy. This group of pigments includes two types of chlorophyll and multiple carotenoids. Different species of plants possess different quantities of each pigment. The combination and quantity of each pigment that each plant species possesses is an adaptation to their habitat and behaviour. The graph below demonstrates how different wavelengths of light are absorbed by chlorophyll a, chlorophyll b and carotenoids from a particular plant species.



Explain the absorption of light at different wavelengths by pigment chlorophyll a.

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(2 marks)

(b) Suggest why it is beneficial for plants to possess multiple photosynthetic pigments such as chlorophyll a, chlorophyll b and carotenoids

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(2 marks)

(c) A researcher investigating the wavelengths of light that hit the ground in a woodland area found that the majority of the light energy reaching the ground sat within the 500-600 nm wavelength part of the spectrum. They also noted that a reduced number of species were found on the ground below the tall trees.

Suggest, with reference to the light energy spectrum, why few species of plant would be found below tall trees in woodland areas.

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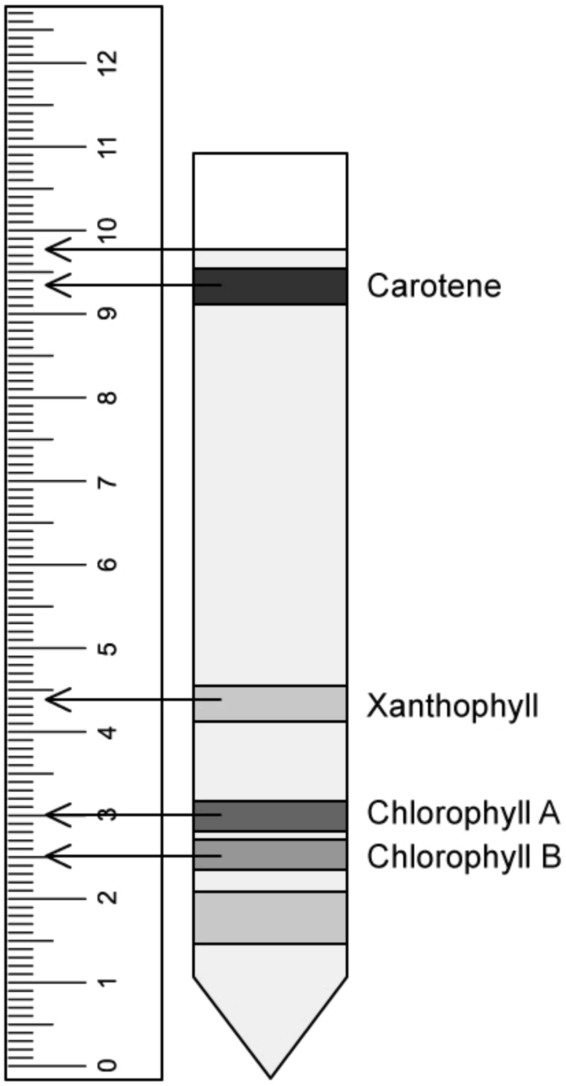
(3 marks)

3 (a) Some students used paper chromatography to separate out the photosynthetic pigments in a leaf. The resulting chromatogram can be seen below.



Using the measurements made by the students, calculate the R_f values for carotene and chlorophyll B and complete the table below.

Pigment	R_f value
Carotene	
Chlorophyll B	

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(2 marks)

(b) Explain what the results in part **(a)** show about the properties of the photosynthetic pigments.

(2 marks)

(c) The method used to prepare the photosynthetic pigments for chromatography requires the use of propanone. As a health and safety precaution, a student using this method decided to use water instead of propanone.

State what the student's results would have shown and explain why..

(3 marks)

4 (a) *Triticum aestivum* is a species of wheat which has been genetically modified to synthesize more chlorophyll B as a way of increasing yield for farmers.

Explain how an increase in chlorophyll B may lead to an increased yield from this genetically modified crop.

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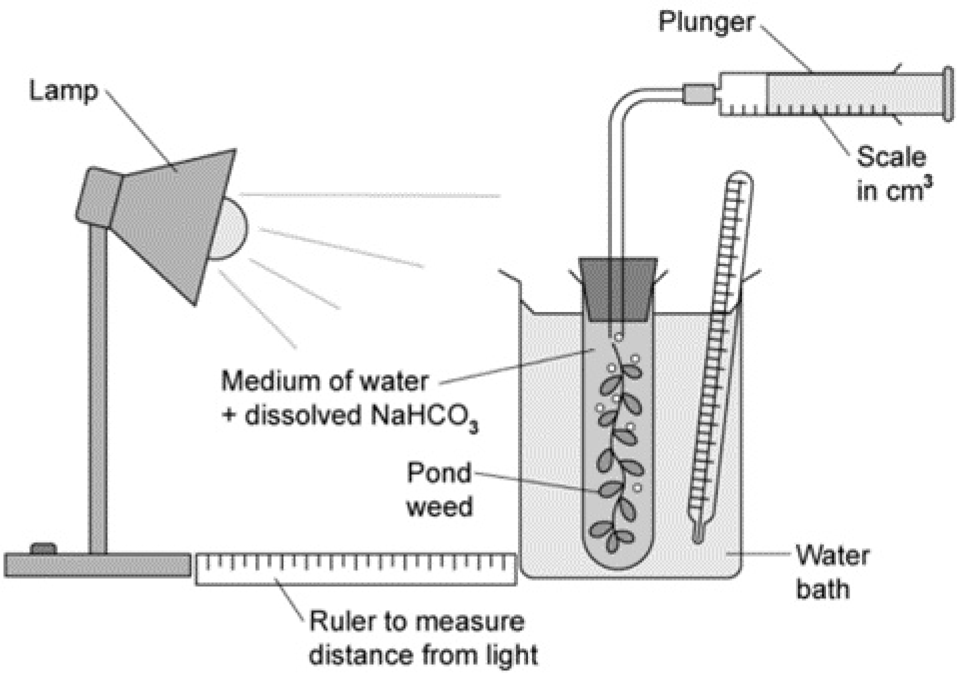
(4 marks)

(b) A student set up the following investigation to establish the relationship between light intensity and photosynthesis.



Identify the dependent variable and **one** control variable for this investigation.

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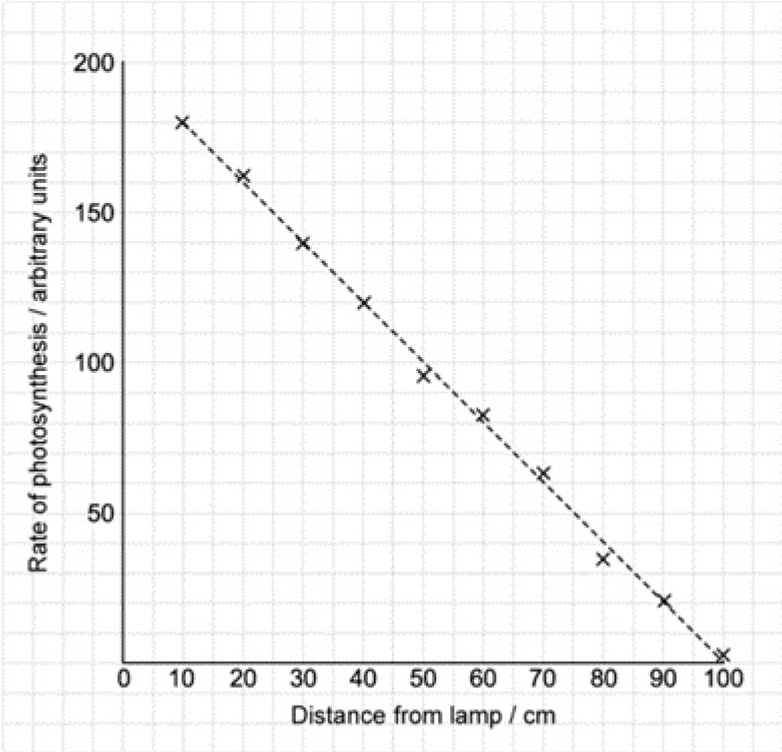
(2 marks)

(c) The graph below shows the results obtained by the student.



A second student suggested that they should position a sheet of blue transparent perspex in between the lamp and the pondweed.

(i) Draw another line on the graph to show how this may alter the results achieved by the students.

(ii) Explain your answer to part **(i)**

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(3 marks)

5 (a) Sketch and annotate a graph to describe the effect of increasing carbon dioxide levels on the rate of photosynthesis.

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(4 marks)

(b) Outline the process which results in the release of oxygen in photosynthesis.

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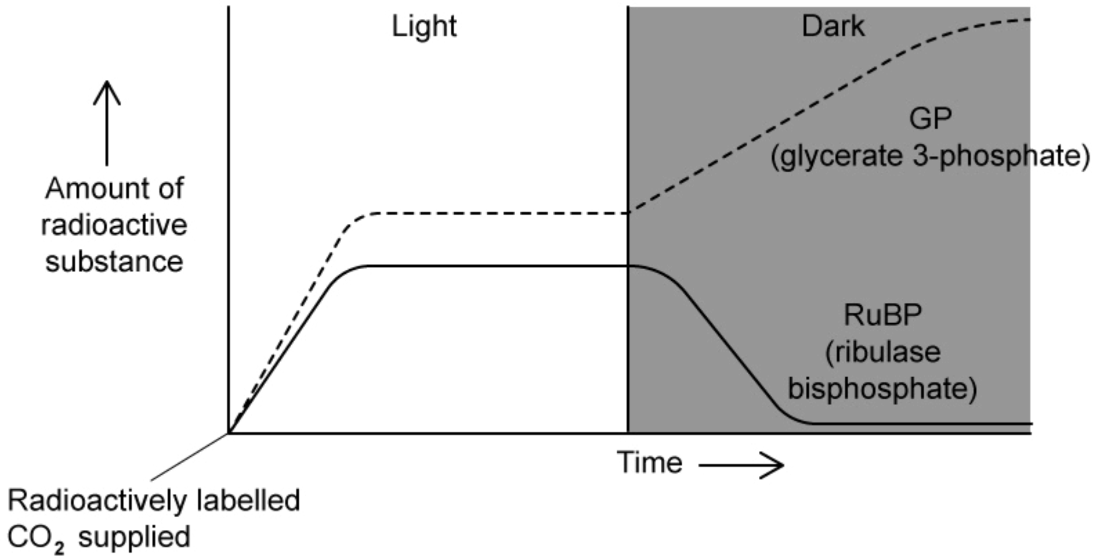
(4 marks)

6 (a) An experiment using radioactive carbon was carried out by scientists to investigate the Calvin Cycle. The algae *Chlorella* was exposed to radioactive carbon for different amounts of time. The algae was then analysed for radioactive compounds. The graph below shows the results.



Explain the changes in the amount of radioactive substances in the dark.

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(3 marks)

(b) Radioactive GP (glycerate 3-phosphate) was detected more rapidly than radioactive RuBP (ribulose bisphosphate).

Use your knowledge of the Calvin cycle to explain this finding.

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(2 marks)

7 (a) When plants are exposed to extremely high or low temperatures for a continued period of time, they are put under a lot of stress. This stress greatly impacts the rate of photosynthesis, in particular the light-dependent reaction of photosynthesis.

Explain why extreme cold leads to a decrease in the light-independent reaction.

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(3 marks)

(b) State the precise location of light-independent reactions in photosynthetic plants.

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(1 mark)

(c) Extreme cold can also cause a decrease in rubisco activity.

Explain why a decrease in the activity of the enzyme rubisco limits the rate of photosynthesis.

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(2 marks)

(d) Describe the exact role of ribulose bisphosphate (RuBP) in the Calvin cycle.

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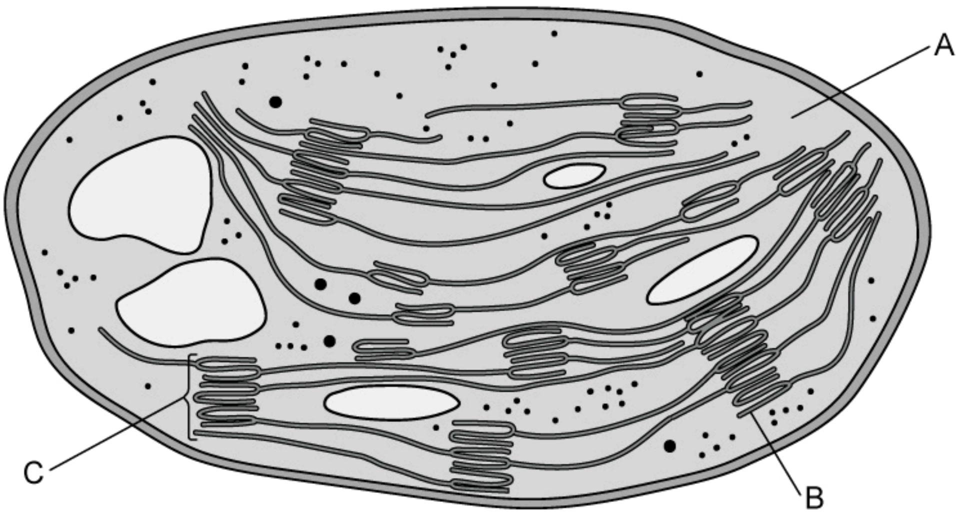
(2 marks)

8 (a) The diagram below shows a diagram of a chloroplast.



Identify the structures of a chloroplast labelled **A-C** in the diagram.

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(3 marks)

(b) Describe the adaptations of structures **A** and **B** from the diagram in part a).

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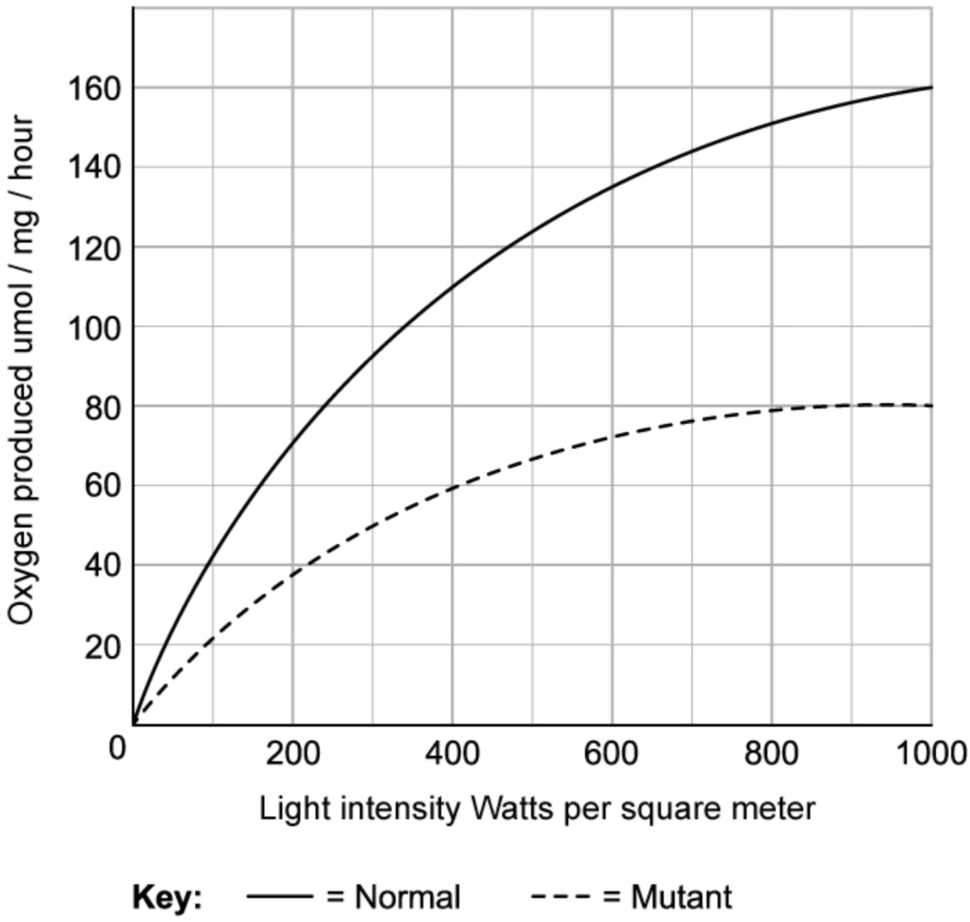
(2 marks)

(c) Plants can contain more than one type of chlorophyll, a and b. Scientists grew plants that contained a mutant version of chlorophyll a. They investigated the effect of this mutation on the rate of photosynthesis.

The scientists

- Grew the mutant and normal plants in a range of light intensities
- Isolated the chloroplasts from both types of plants
- Measured the oxygen produced by the chloroplasts over a period of 20 minutes

Their results are shown in the graph below:



Explain why the scientists used the oxygen produced as a measure of the rate of photosynthesis.

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(2 marks)

(d) Use the graph to calculate the difference in oxygen produced by the chloroplasts from normal plants compared to the mutant plants at a light intensity of 400 Watts/m^2.

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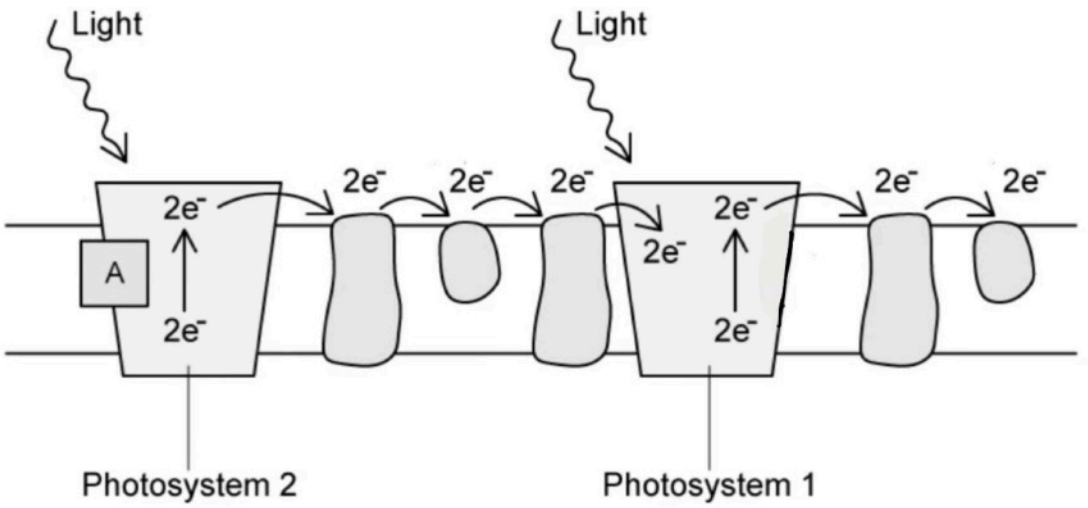
(2 marks)

9 (a) The diagram below shows a representation of some of the reactions taking place during the light dependent reactions of photosynthesis.



Explain the process that occurs at label **A**.

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(3 marks)

(b) The diagram from part a) shows the loss of electrons from photosystem 2, but does not show how these electrons are replaced.

State and explain the source of the electrons that replace those lost at stage **A**.

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(2 marks)

10 (a) Crops absorb and use light energy for the production of photosynthetic products.

Describe how light energy is used by crop plants during the light-dependent reaction.

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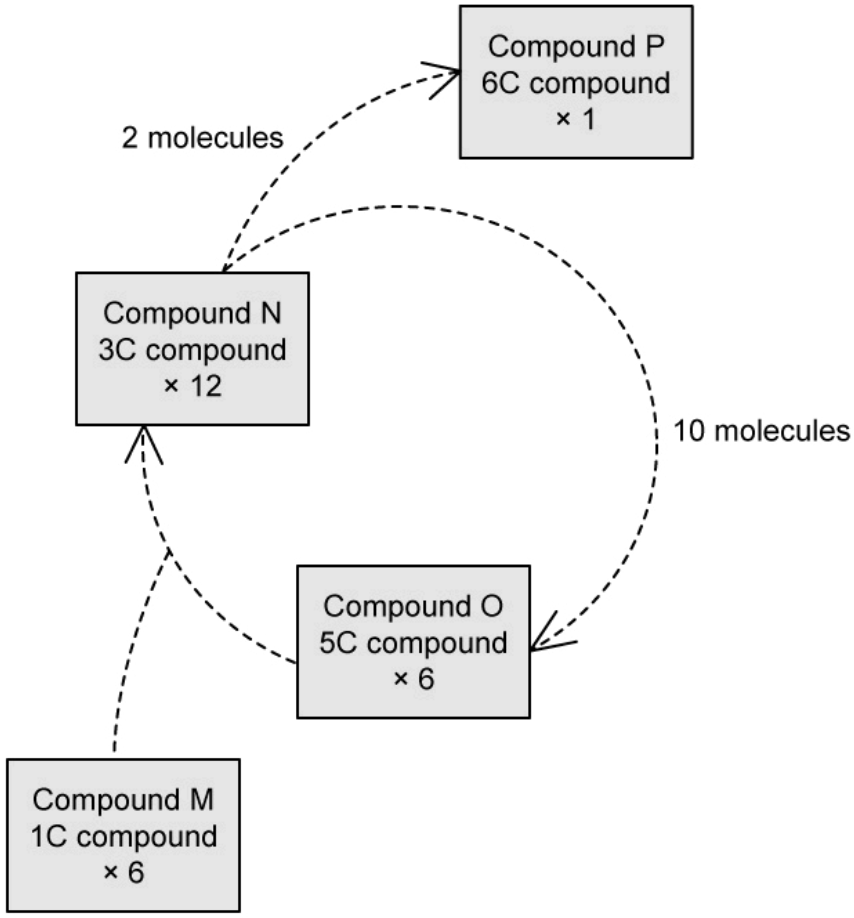
(5 marks)

(b) The diagram below depicts the light-independent reactions of photosynthesis.



Describe the mechanism of these reactions and explain how they allow for the continuous synthesis of 6-carbon sugars.

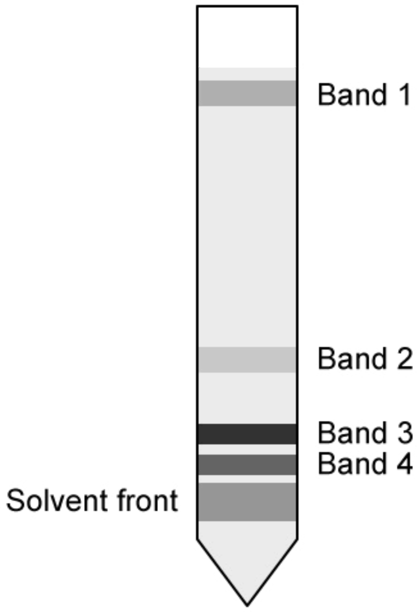
(7 marks)

(c) Explain the role of protons in the light dependent reaction of photosynthesis.

(3 marks)

Hard Questions

1 (a) Paper chromatography can be used to separate photosynthetic pigments obtained from chloroplasts. The chromatography strip below shows distinct pigment bands.



The teacher explains that the four bands represent four pigments: chlorophyll a, chlorophyll b, xanthophylls and carotenes (but not necessarily in that order). The teacher asks a student to suggest which bands most likely represent the two chlorophyll pigments. The student suggests bands 3 and 4.

Explain why this is the correct choice.

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(2 marks)

(b) Describe how someone could accurately identify the pigments in the chromatogram shown in part a).

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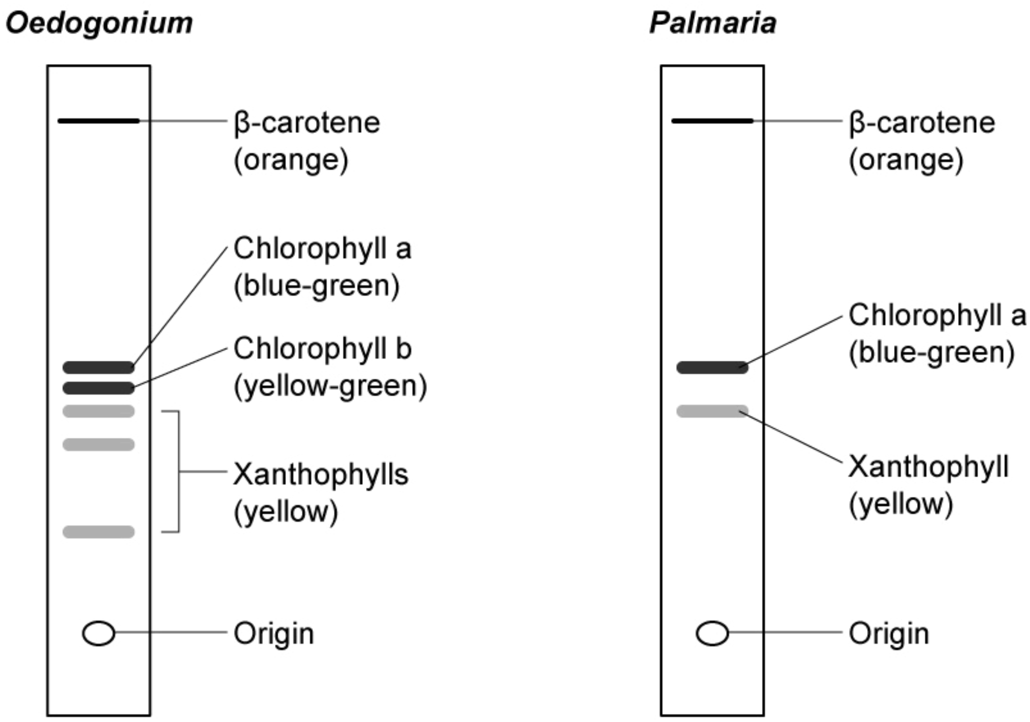
(3 marks)

(c) The photosynthetic pigments from two aquatic algae, green alga genus *Oedogonium* and red alga genus *Palmaria,* were separated by thin layer chromatography. The chromatograms are shown below.



Palmaria also contain a red pigment known as phycoerythrin. The pigment appears red because it absorbs blue light and reflects red light. The pigment phycoerythrin is absent from the chromatogram above.

Suggest why this might be.

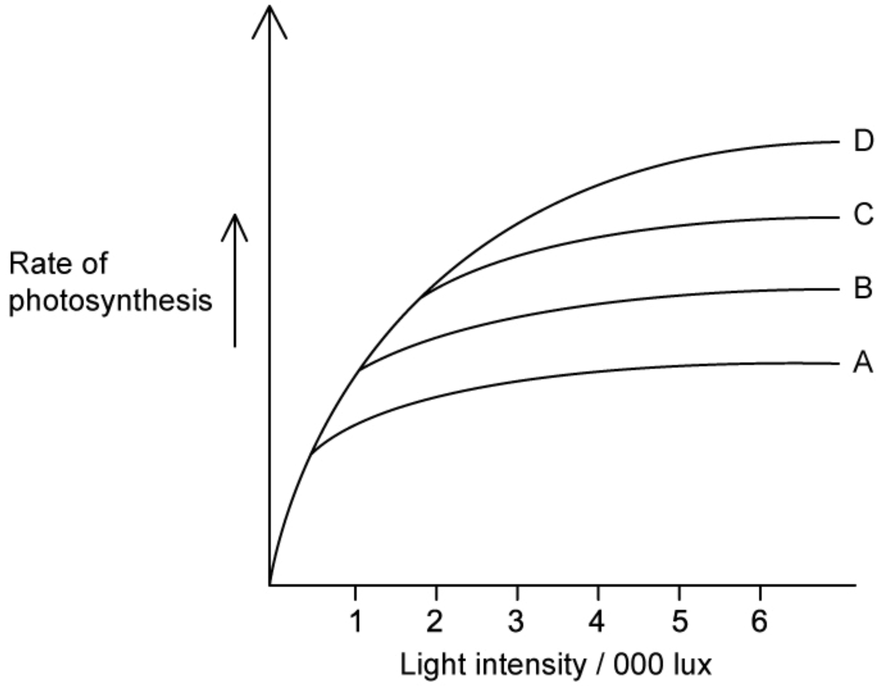
(1 mark)

(d) Light of shorter wavelengths penetrates water to greater depths than light of longer wavelengths.

Using information here and from part c), suggest why red algae such as *Palmaria* can live at greater depths than many other aquatic algae.

(2 marks)

2 (a) The graph below shows the effect of light intensity, carbon dioxide, and temperature on the rate of photosynthesis.



A - 0.04 % carbon dioxide at 15 °C

B - 0.04 % carbon dioxide at 25 °C

C - 0.04 % carbon dioxide at 35 °C

D - 0.1 % carbon dioxide at 25 °C

State **three** factors that could be measured to allow an estimate of the **rate** of photosynthesis in this experiment.

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(3 marks)

(b) A commercial farmer growing peppers keeps her greenhouses at 25 °C and circulates air around the greenhouses. Air has a CO_2 concentration of 0.04 % and the ambient light intensity is 3 000 lux.

(i) Use the graph in part a) to state whether the farmer would be more likely to achieve higher pepper yields by raising the carbon dioxide concentration to 0.1 % **or** by raising the temperature to 35 °C.

[1]

(ii) Explain your answer to part i).

[2]

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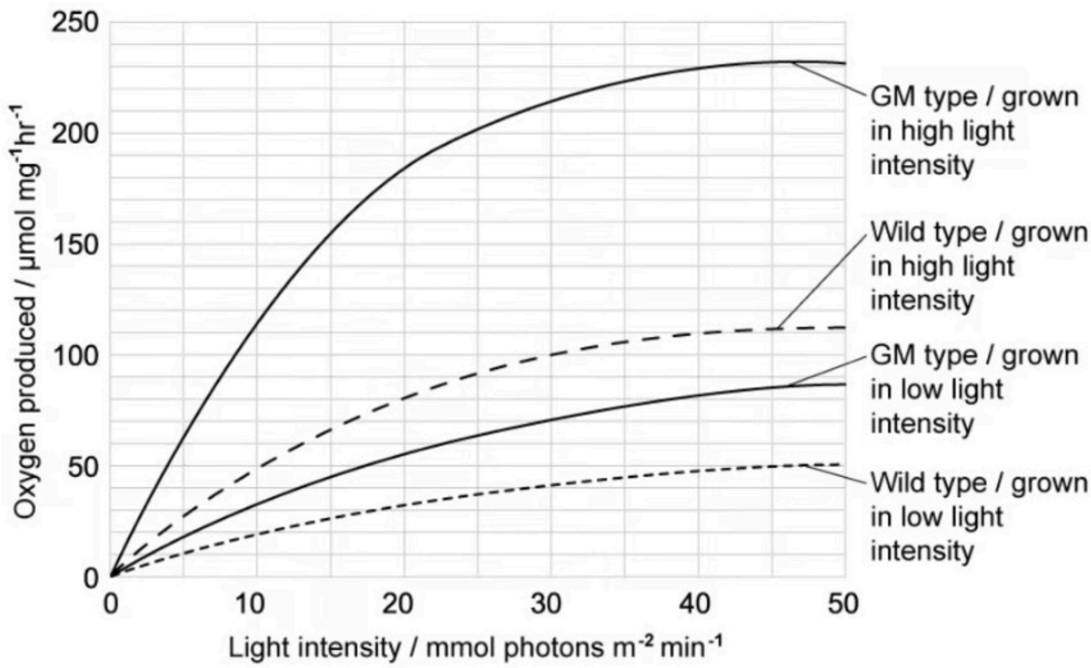
(3 marks)

(c) There are two types of chlorophyll in chloroplasts, chlorophyll a and chlorophyll b. Researchers created a genetically-modified (GM) vine plant with an allele that caused them to synthesise higher levels of chlorophyll b than wild-type vine plants. They investigated the effect of this new allele on the rate of plant growth.

The researchers grew wild-type and GM vines. They grew some of each in low light intensity and grew others in high light intensity. They extracted chloroplasts from mature plants of both types. Finally, they measured oxygen production at different light intensities by the chloroplasts they had extracted from the plants.



(i) Oxygen production here is used as a measure of the rate of photosynthesis.

State why this is possible.

[1]

(ii) Calculate the percentage improvement in oxygen production caused by the genetic modification for vines grown at high light intensity at an experimental light intensity of 20 mmol photons m^{-2} min^{-1}. Give your answer to 3 significant figures.

[2]

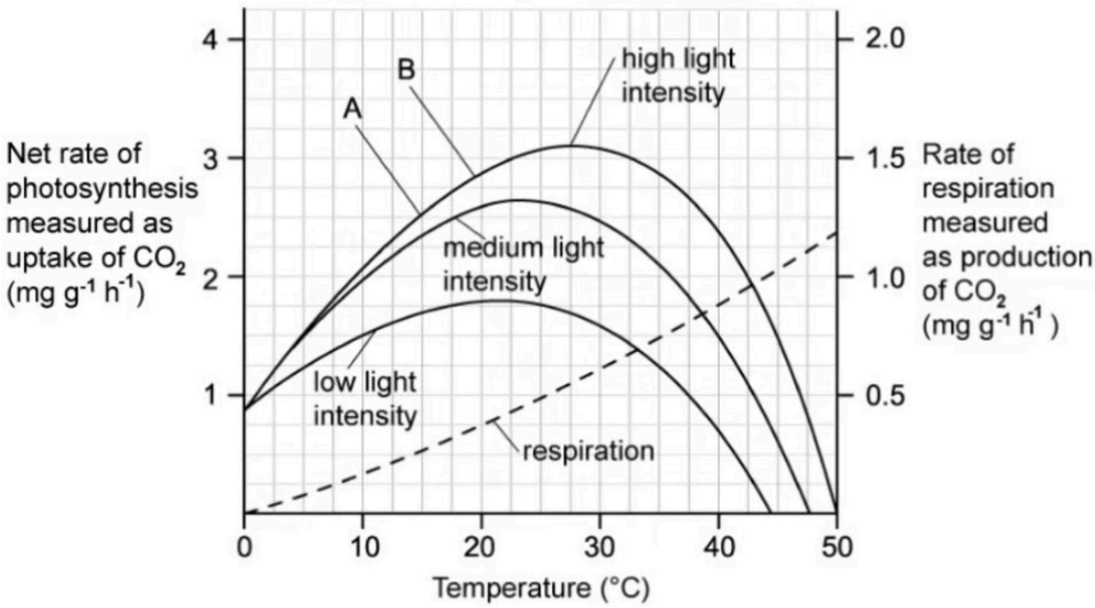
(3 marks)

(d) The researchers suggested that GM plants producing more chlorophyll b would grow faster than wild-type plants in all light intensities.

Explain how the data in part c) support this suggestion.

(3 marks)

3 (a) Lab technicians wanted to determine the effects of light intensity and temperature on the rate of photosynthesis in rhododendron plants growing in parks and gardens. They recorded the effect of different temperatures on the net rate of photosynthesis at various light intensities. Their experiment also recorded the rate of respiration at the different temperatures. The graph below shows the results from their experiment.



Explain the increase in the net rate of photosynthesis between points **A** and **B** on the graph.

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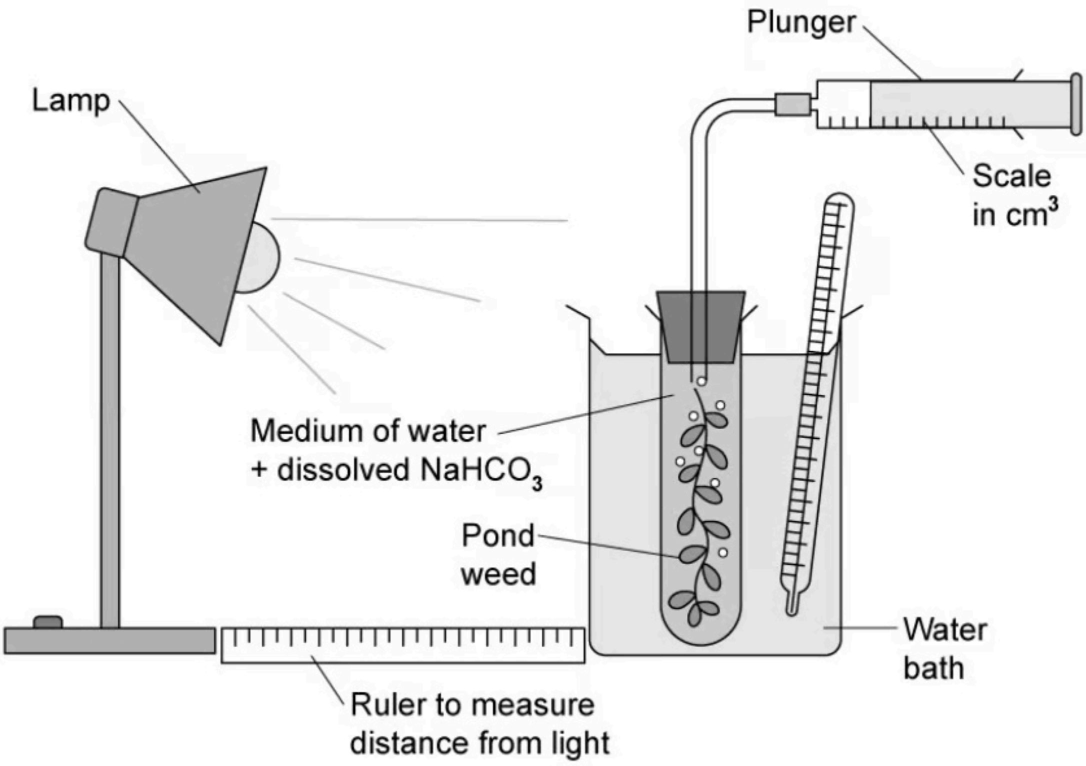
(3 marks)

(b) In another experiment a student looked at the effect of light intensity on the rate of photosynthesis in pond weed. They set up the investigation as shown below and altered the light intensity by changing the distance between the lamp and the pondweed.



Identify **four** variables that need to be controlled in this investigation.

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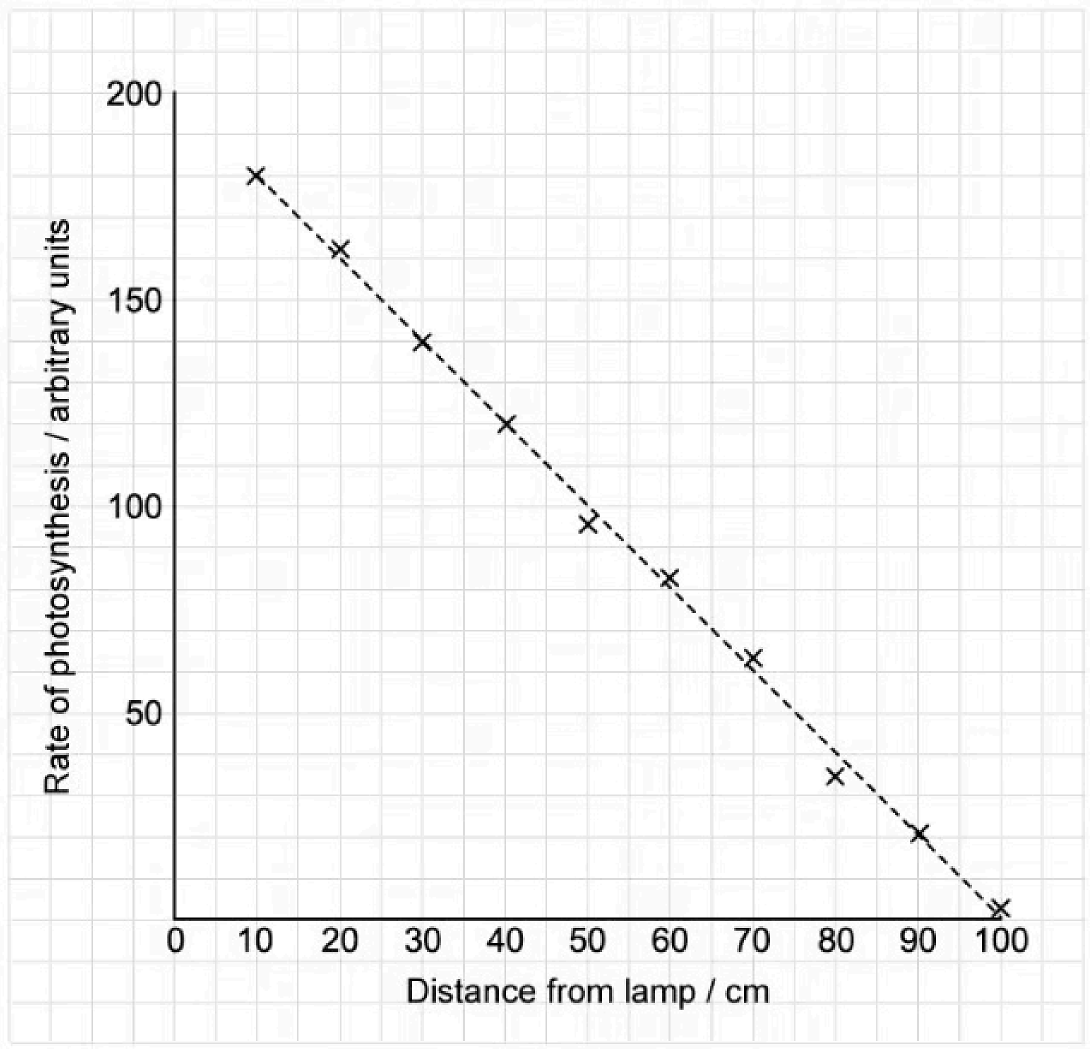
(4 marks)

(c) The graph below shows the student's results from their investigation in part b).



Calculate the percentage decrease in the rate of photosynthesis that takes place when the distance from the lamp is 10 cm compared to when it is 90 cm. Show your working.

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(2 marks)

(d) Identify, with a reason, **one** challenge that would be faced by the technicians in a) that would not be faced by the student in part b) when carrying out their experiments.

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(2 marks)

A variegated plant was grown in a laboratory by a student. One of its leaves is shown below (Fig. 1). The student left the whole plant in the dark for 12 hours to inhibit photosynthesis. After this time they covered part of the leaf with a rectangle of black card (Fig. 2). Following the exposure of the plant to sunlight for a further 3 hours the student removed the black card and then removed the leaf from the plant before testing the whole leaf for starch (Fig. 3).

Fig. 1 Fig. 2 Fig. 3

4 (a) Suggest why photosynthesis was inhibited for 12 hours.

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(1 mark)

(b) From Fig. 3 in part a) identify the following:

(i) The **two** areas of the leaf from **A-D** that the student could use to show that light is required for photosynthesis.

[1]

(ii) The **two** areas of the leaf from **A-D** that the student could use to show that chlorophyll is required for photosynthesis.

[1]

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(2 marks)

(c) The student concluded that the detection of starch was proof that photosynthesis had occurred in the leaf during the experiment.

Suggest why this conclusion may not be correct.

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(2 marks)

5 (a) Explain how researchers could prepare an initial concentrated solution containing photosynthetic pigments for separation during thin layer chromatography.

(6 marks)

(b) In a woodland the concentration of carbon dioxide gas in the air changes during a 24-hour period. It can also vary depending on the height above the ground at which a gas measurement is taken.

Explain the variation in carbon dioxide concentration in a woodland over time and at different heights. Assume that there is no air movement caused by wind throughout the 24-hour period.

(5 marks)

6 (a) Explain why the light independent reactions of photosynthesis stop in the absence of light.

(2 marks)

(b) Some species of bacteria that live on the ocean floor do not have access to light for photosynthesis. Instead, they use the process of chemosynthesis to make glucose using energy stored in substances such as methane, hydrogen sulfide (H_2S) and carbon dioxide. A simplified equation of one such reaction is shown below.

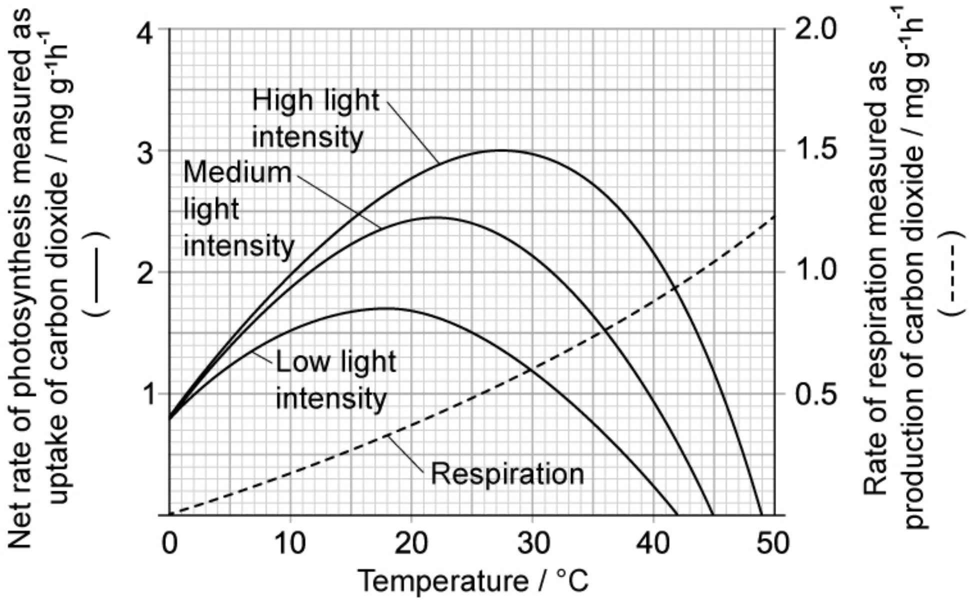
carbon dioxide + water + hydrogen sulfide → glucose + sulfur + sulfur compounds

Use your knowledge of photosynthesis to suggest what hydrogen sulfide is used for in the process of chemosynthesis.

(3 marks)

(c) The rate of photosynthesis can be expressed as either gross or net rates. Gross photosynthesis is the total rate of carbon fixation (reduction of CO_2) without considering that some of the CO_2 is lost in respiration. Net photosynthesis is the carbon fixation rate minus the rate of CO_2 loss in respiration.

The graph below shows the effect of temperature on the net rate of photosynthesis at three different light intensities and the effect of temperature on the rate of respiration.



Use the graph to calculate the gross rate of photosynthesis at 15°C and low light intensity.

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(1 mark)

(d) The average global temperature is 14°C. Scientists predict that over the course of the next 100 years, the average temperature could increase by up to 4°C. It is also predicted to become cloudier in many regions.

Use the graph to describe and explain how these changes are likely to affect the growth of plants.

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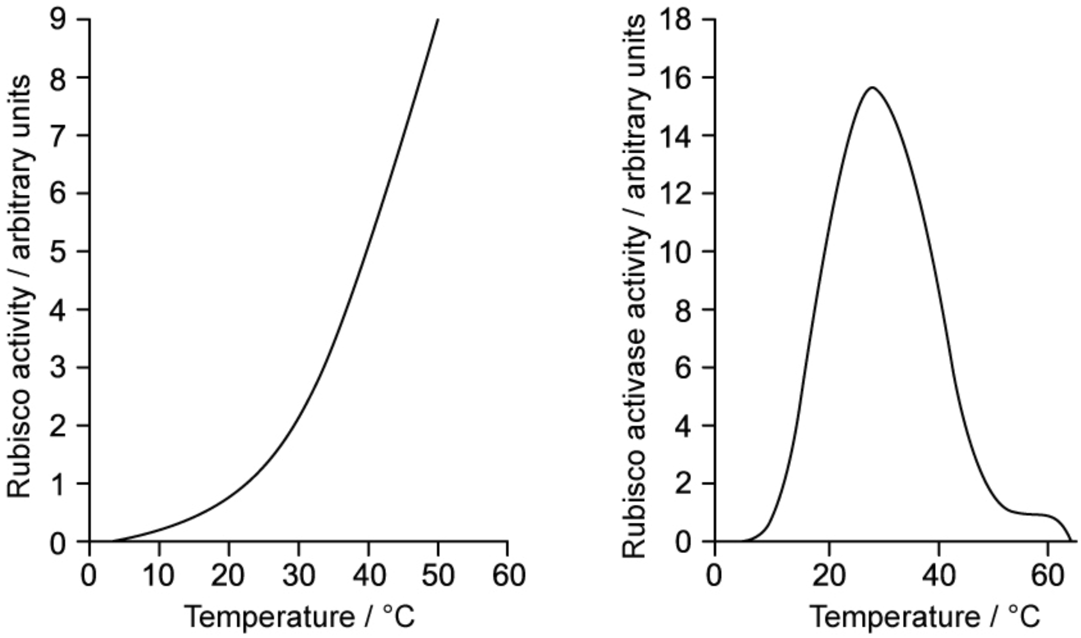
(3 marks)

7 (a) Researchers investigated the activity of two enzymes isolated from the leaf cells of lavender plants.

The two enzymes were:

- Rubisco
- Rubisco activase

The results of the investigation are shown in the graphs below.



The scientists concluded that heat stress reduces the activity of rubisco in plant leaves by affecting rubisco activate.

Use the data to evaluate their conclusion.

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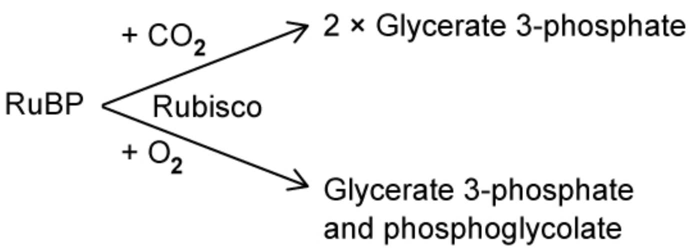
(4 marks)

(b) The enzyme rubisco catalyses the reaction between RuBP and carbon dioxide to form two molecules of glycerate-3-phosphate (GP). Rubisco can also catalyse a reaction between RuBP and oxygen to form one molecule of GP and one molecule of phosphoglycolate.

The reactions are shown in the diagram below.



Use the diagram to deduce to number of carbon atoms in one molecule of phosphoglycolate.

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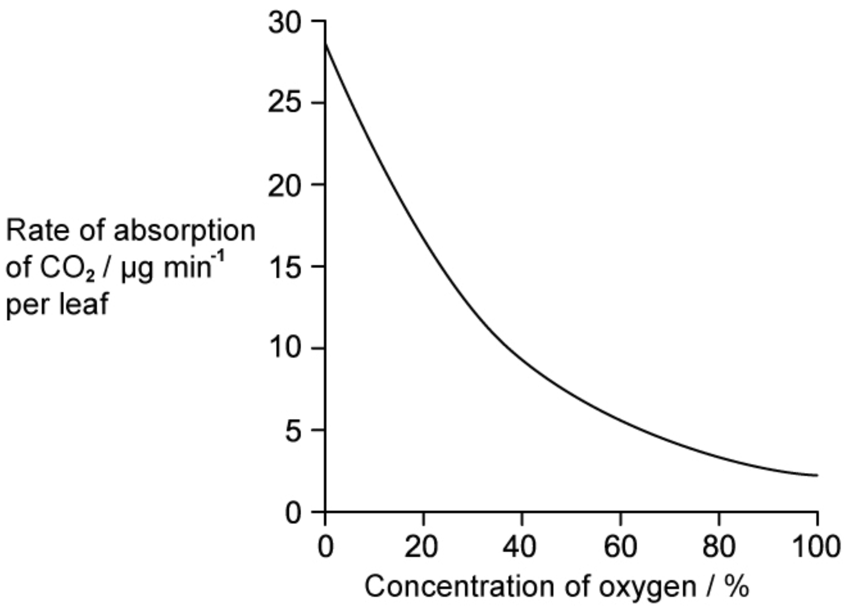
(1 mark)

(c) The scientists investigated the effect oxygen concentration had on the absorption of carbon dioxide in leaves from tomato plants. The graph below shows their results.



Explain the results in the graph above using the diagram and information from part b) of the question.

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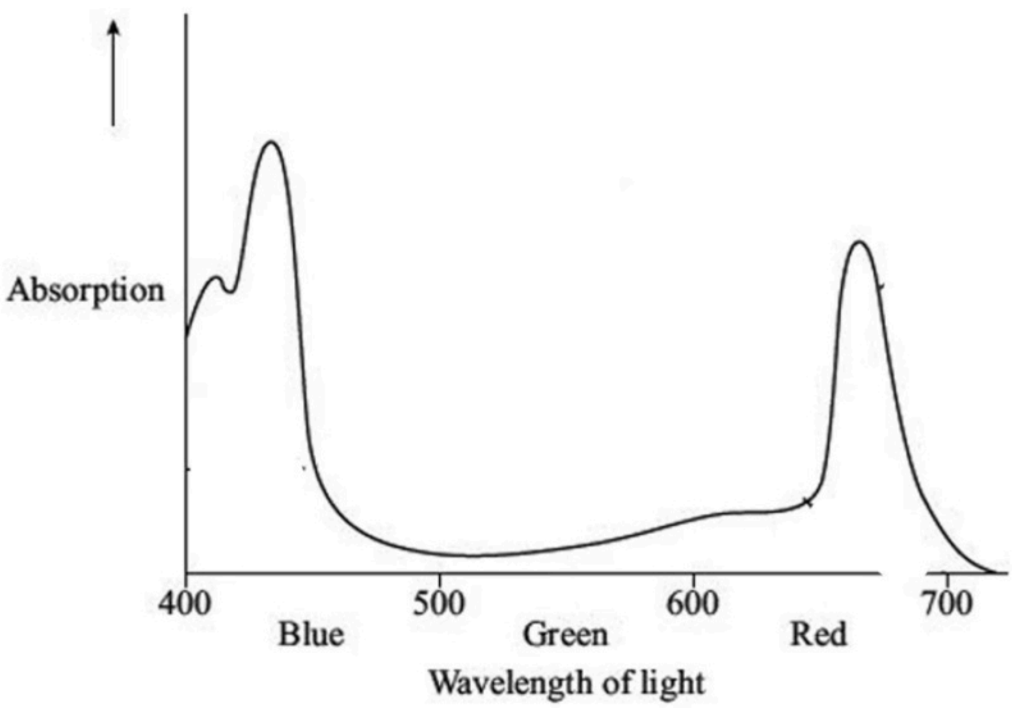
(2 marks)

(d) Use all the information provided and your knowledge of the light-independent reaction to explain why the yield from tomato plants decreases at higher concentrations of oxygen. Note: Phosphoglycolate is not used in the light-independent reaction.

(3 marks)

8 (a) Some scientists were investigating photosynthesis in seaweed. During their investigation, they applied lights of different wavelengths to study the amount of light absorbed by the seaweed species.

Their results can be seen in the graph below.



State, with a reason, the types of pigments found in these species of seaweed.

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(1 mark)

(b) The scientists also measured the rate of the light-dependent reactions in the seaweed at each of the different wavelengths.

Species	**Mean rate of photosynthesis / arbitrary units**	
	Lamp X **400 - 700 nm**	**Lamp Y** **430 nm**
A	1 250.3 (± 115.6)	920.2 (± 95.1)
B	290.4 (± 55.6)	276.6 (± 69.6)

Suggest how the scientists measured the rate of the light-dependent reactions.

(2 marks)

(c) The scientists repeated the investigation twice more under the following conditions

1. They increased light intensity from lamps X and Y
2. They increased the temperature of the investigation from 15 °C to 20 °C.

Discuss how these changes may affect the amount of oxygen produced by the seaweed

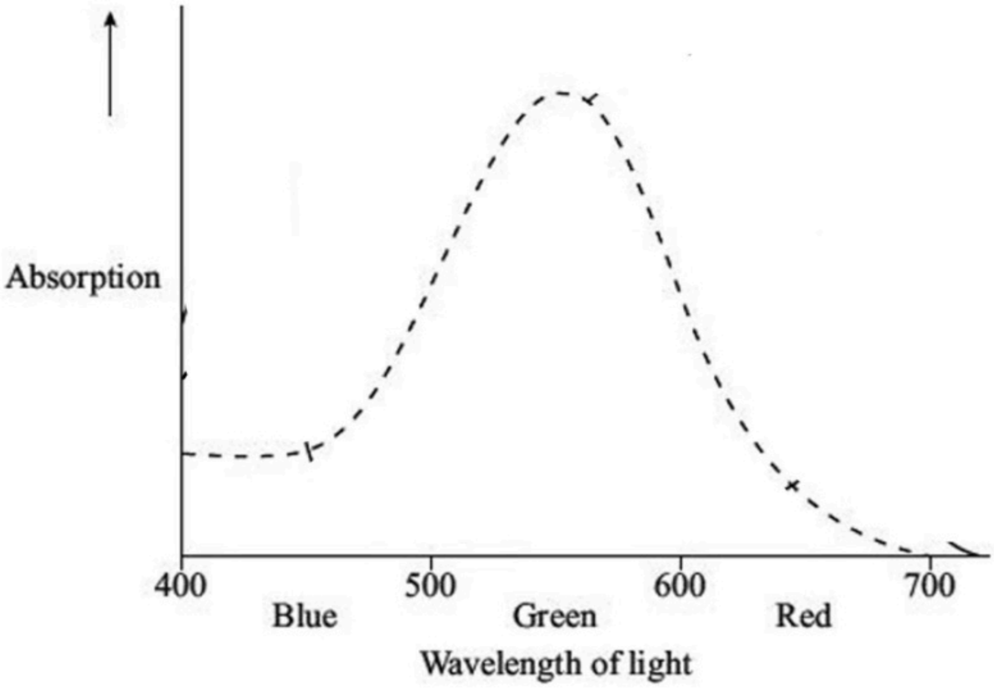
(6 marks)

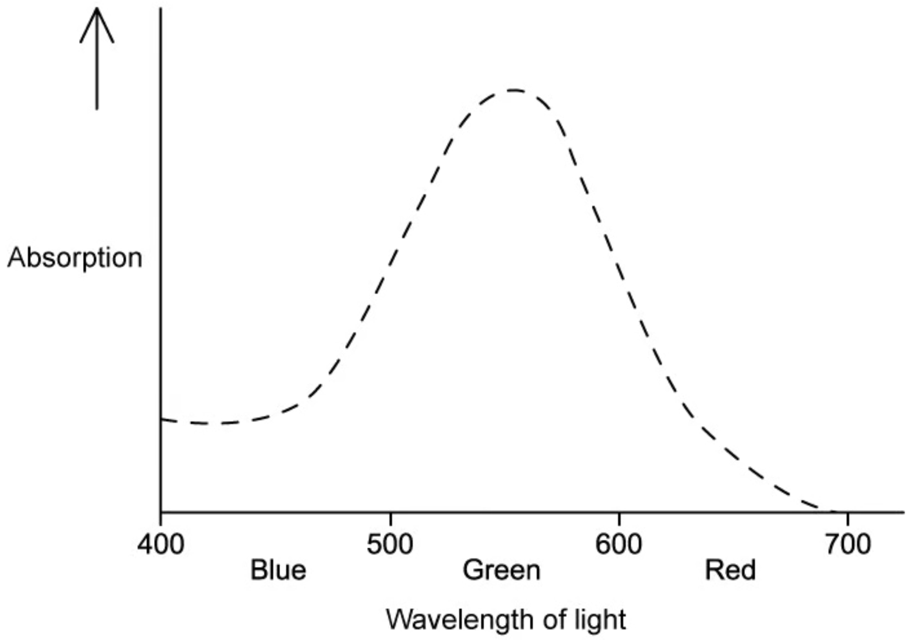
(d) The scientists concluded that both species of seaweed showed increased rates of photosynthesis under lamp X compared to lamp Y.

Evaluate this conclusion.

(2 marks)

(e) The scientists also isolated a species of bacteria found to absorb light at the bottom of the ocean habitat where the seaweed were found. They found these bacteria absorbed light as shown by the absorption spectrum below:





Suggest the selective advantage to the bacteria of absorbing light as shown in this absorption spectrum.

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(3 marks)

9 (a) 'Weed wonder' is a weed killer designed to inhibit plastoquinone protein in chloroplasts of weeds.

Explain how this would affect the growth of weeds.

(5 marks)

(b) Compare and contrast the processes that occur in the electron transport chain (ETC) of the light dependent reaction with the electron transport chain in respiration.

(6 marks)

(c) Oxidation and reduction are key to the metabolic pathways seen in photosynthesis.

Complete the table to indicate which substances are oxidised and which are reduced during the stages of photosynthesis.

Stage	Substance	Oxidised / reduced
Light-dependent	NADP	
	PSII after photoexcitation	
Light-independent	GP	
	NADPH	

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(2 marks)

10 (a) The concentrations of carbon dioxide in the air at different heights above ground in a forest changes over a period of 24 hours.

Use your knowledge of photosynthesis to describe and explain these changes. You can assume there is no air movement through wind throughout the 24 hour period.

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(5 marks)

(b) Certain types of ultraviolet radiation may induce the production of ATP in isolated plant cells by interacting with electrons found in photosystems.

Use your knowledge of phosphorylation to explain how.

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(5 marks)

(c) Water absorbed by plants at the roots is carried to the leaves to be used in photosynthesis.

Explain the role of water in photosynthesis.

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(5 marks)