Model Answers: Medium

1a

a) i) Volume of oxygen produced can be used as a measure of the rate of photosynthesis because...

- (Oxygen is produced as) a product of photolysis / from the breakdown of water during the light dependent reaction; [1 mark]

a) ii) The precise location at which photolysis occurs is...

- The thylakoid membrane / photosystem II; [1 mark]

[Total: 2 marks]

The splitting of water during photolysis at photosystem II on the thylakoid membrane releases hydrogen ions, electrons, and oxygen. Oxygen is given off by the plant as a waste product and can be easily collected from aquatic plants as it bubbles to the surface of the water.

1b

b) Three variables that need to be controlled in the investigation shown in Fig. 1 include:

Any **three** of the following:

- The temperature of the water bath; [1 mark]
- The wavelength of the light / colour of the bulb; [1 mark]
- The species of pond weed/aquatic plant used; [1 mark]
- The length/size of the piece of pond weed/aquatic plant used; [1 mark]
- Concentration of dissolved $NaHCO_3$ /sodium hydrogen carbonate; [1 mark]
- Light coming from other sources / carrying out investigation in a darkened room; [1 mark]
- Length of time gas is collected for; [1 mark]
- Pondweed given same amount of time to adjust to new light level each time intensity changes; [1 mark]

[Total: 3 marks]

1c

c) The percentage decrease in the rate of photosynthesis is...

- 160 ÷ 180; [1 mark]
- 88.9 / 88.89 (%); [1 mark]

Full marks can be awarded for the correct answer in the absence of other calculations.

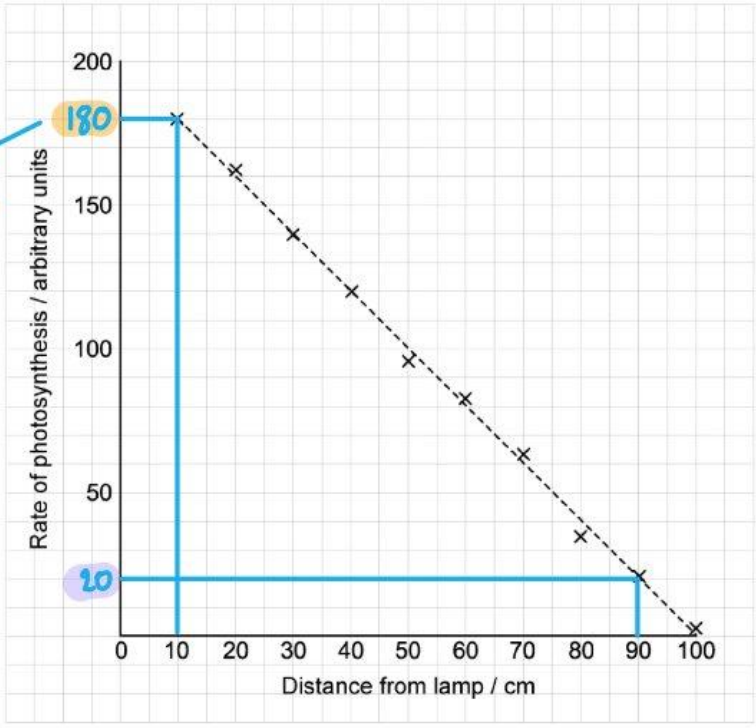
[Total: 2 marks]

percentage decrease can be calculated as follows:

$$\text{percentage decrease} = \frac{\text{change}}{\text{starting point}} \times 100$$

calculate the change in rate:

The rate decreases from this point so this is the starting point



180 - 20 = 160

substitute numbers into the equation:

$$\text{percentage decrease} = \frac{160}{180} \times 100$$

[1 mark]

$$= 88.89$$

$$= 88.9\ \%$$

OR [1 mark]

1d
d) The rate of photosynthesis decreases when light intensity is reduced because...

Any **three** of the following:

- Light energy is needed for photoactivation / to excite electrons / to raise electrons to a higher energy level / electrons to enter the electron transport chain; [1 mark]
- As electrons move down the electron transport chain they release energy which enables/powers chemiosmosis / the production of ATP / the action of ATP synthase; [1 mark]
- The splitting of water (in photolysis) provides hydrogen ions to reduce NADP; [1 mark]
- If the light dependent reactions cannot take place then no ATP/NADPH/reduced NADP can be passed to the Calvin cycle/light independent reactions **OR** there will be no ATP/NADPH/reduced NADP to convert GP into TP; [1 mark]

[Total: 3 marks]

Light energy is required for the light dependent reactions of photosynthesis to take place; both to excite electrons and pass them down the electron transport chain, and to supply hydrogen ions from photolysis. If these reactions cannot take place then the products ATP and NADPH will not be produced and cannot pass into the Calvin cycle, meaning that GP cannot be converted into TP and the useful products of photosynthesis cannot be produced.
2a
a) The rate of photosynthesis for white, red, and blue bulbs are...

[1 mark] to be awarded collectively for:

- White = 0.17
- Red = 0.08
- Blue = 0.02

[Total: 1 mark]

The calculation is provided for you in the table, along with one correct answer for the green light bulb. All you need to do is divide 1 by the ET_{50} for each bulb.

Colour of bulb	ET_{50} (s)	Rate of photosynthesis (1 / ET_{50})
White	6	
Red	12	
Blue	55	
Green	92	0.01

Rate can be calculated by dividing 1 by ET_{50}

Divide 1 by ET_{50} for each bulb:

White = 1 ÷ 6 = 0.17
Red = 1 ÷ 12 = 0.08
Blue = 1 ÷ 55 = 0.02

[1 mark]

Round to the same number of decimal places as for green bulb already shown

2b
b) Sodium hydrogen carbonate solution was used because...

- This increases the availability of carbon dioxide (in the water/solution surrounding the leaf discs); [1 mark]
- This prevents carbon dioxide from becoming a limiting factor; [1 mark]

[Total: 2 marks]
2c
c) The results in Table 1 can be explained as follows...

Any **five** of the following:

- Light energy is absorbed by (photosynthetic) pigments / photosystems; [1 mark]

- Photolysis occurs / water is split, releasing hydrogen ions/H^+/protons, electrons, and oxygen; [1 mark]
- Oxygen gas accumulates in the leaf air spaces, causing (the discs) to float; [1 mark]
- White light (contains all wavelengths of visible light so) can be absorbed by all pigments **SO** provides a lot of / the most energy (for photolysis); [1 mark]
- Red/blue light is only absorbed by some pigments / not absorbed by all pigments **SO** provides less energy (for photolysis than white light); [1 mark]
- Green light is not absorbed by most pigments / is only absorbed by carotenoid pigments **SO** provides little energy (for photolysis); [1 mark]

Ignore *attempts to explain the low rate of photosynthesis under blue light.*

[Total: 5 marks]

The low rate of photosynthesis here for blue light doesn't really make much sense given what you will have learned about absorption spectra so far; this question doesn't require you to explain this other than noting that blue light alone has a lower rate of photosynthesis than white light.

2d

d) The role of accessory pigments is to...

Any **two** of the following:

- Absorb light energy for photolysis / photoactivation / to excite electrons; [1 mark]
- Funnel/channel/pass light energy to the primary pigment / reaction centre / chlorophyll a; [1 mark]
- Absorb light wavelengths not absorbed by chlorophyll a / additional light energy **OR** to increase the efficiency of light absorption; [1 mark]

[Total: 2 marks]

3a

a) i) The limiting factor between points **A** and **B** is...

- Temperature; [1 mark]

a) ii) The reason for this is that...

- As temperature increases (on the x axis), so the rate of photosynthesis / uptake of carbon dioxide increases; [1 mark]

[Total: 2 marks]

Light intensity is high between **A** and **B**, so this cannot be a limiting factor.

3b

b) Increasing light intensity affects the rate of photosynthesis in the following ways...

Any **three** of the following:

- At higher light intensities the rate of photosynthesis is always higher / the plant at the highest light intensity has the highest rate of photosynthesis **and** the plant with the lowest light intensity has the lowest rate of photosynthesis; [1 mark]
- The higher the light intensity, the higher the optimum temperature for photosynthesis / the higher the temperature when the maximum rate of photosynthesis is reached **OR** the plant at the highest light intensity has the highest optimum temperature for photosynthesis / reaches its maximum rate at the highest temperature **and** the plant with the lowest light intensity has the lowest optimum temperature / reaches its maximum rate at the lowest temperature; [1 mark]
- The higher the light intensity, the higher the temperature when the rate of photosynthesis drops to zero **OR** the rate of photosynthesis for the plant at the highest light intensity reaches zero at the highest temperature **and** the rate of photosynthesis for the plant at the lowest light intensity reaches zero at the lowest temperature; [1 mark]
- Data points correctly quoted from Fig. 4.1 to support any of the above points; [1 mark]

[Total: 3 marks]

It is always a good idea to back up any descriptions of data with numbers to support your point.

3c

c) The effect of temperature on the rate of photosynthesis is due to...

- At high temperatures (in this case about around 30 degrees) proteins/enzymes denature; [1 mark]
- (Photosynthesis relies on the action of) rubisco/electron transport proteins/electron carriers/ATP synthase; [1 mark]

AND

Any **one** relevant point from the following:

- In the absence of functioning rubisco, carbon dioxide cannot be fixed / combined with RuBP to make GP; [1 mark]

- In the absence of functioning electron transport proteins/electron carriers energy cannot be released as electrons pass down the electron transport chain / hydrogen ions cannot be pumped across the thylakoid membrane / NADP cannot be reduced; [1 mark]
- In the absence of functioning ATP synthase ATP cannot be produced during chemiosmosis; [1 mark]

Accept *correct answers relating to the breakdown of membrane structure at high temperatures.*

[Total: 3 marks]

Photosynthesis relies on the action of several essential proteins, such as the proteins of the electron transport chain, ATP synthase, and rubisco. If these proteins denature at high temperatures then the process of photosynthesis will become less efficient and eventually stop

3d

d) Carbon dioxide uptake does not give a true measure for the rate of photosynthesis because...

- Carbon dioxide is produced during respiration; [1 mark]
- This reduces the amount of carbon dioxide that needs to be taken up from the atmosphere / enables the plant to photosynthesise at a higher rate than its atmospheric uptake would suggest; [1 mark]

[Total: 2 marks]

It is essential to remember that plants respire as well as carry out photosynthesis. These reactions are the reverse of each other, so at certain rates of reaction they cancel each other out, meaning that the plant will neither release nor take up carbon dioxide; this is known as the compensation point. It is worth noting that during the day when light is available the reaction of photosynthesis will always have a greater impact on gas uptake and production than respiration.

4

a) The term limiting factor refers to...

Any **seven** of the following:

- Photosynthesis is affected by several factors (e.g. light intensity, carbon dioxide concentration); [1 mark]
- (The limiting factor is) the factor that is in shortest supply; [1 mark]
- (Therefore) preventing the rate (of photosynthesis) from increases / restricting rate; [1 mark]

Knowledge of limiting factors is used to increase crop yields in glasshouses

- Light intensity **AND** temperature **AND** carbon dioxide concentration; [1 mark]
- Artificial light / lamps to provide light at night; [1 mark]
- Use heaters / control ventilation; [1 mark]
- CO2 from cylinders / dry ice / combustion; [1 mark]
- Automation / computerised control (to keep levels constant); [1 mark]
- Optimum conditions; [1 mark]
- Sprinklers **OR** humidity control **OR** fertiliser; [1 mark]

[Total: 7 marks]

This question asks for practical applications of knowledge of limiting factors, so you should **give examples** of how this knowledge might affect the methods used to maximise growth in a greenhouse.

5

a) You would carry out an investigation into the effect of wavelength of light on the rate of photosynthesis of a plant, using a redox indicator such as DCPIP, as follows...

Any **eight** of the following:

- (The reaction is known as the) Hill reaction; [1 mark]
- Oxidised DCPIP is blue; [1 mark]
- DCPIP is colourless when reduced; [1 mark]
- Crush leaves in an isolation medium (to make a chloroplast extract); [1 mark]
- (Isolation medium should) contain a buffer solution / have the same water potential as the chloroplasts; [1 mark]
- Expose the chloroplasts and DCPIP to a (specific) wavelength of light; [1 mark]
- Measure the time taken for the blue colour to disappear **OR** leave solution for a fixed amount of time and measure with a colorimeter; [1 mark]
- Calculate the rate of reaction as 1/t **OR** calculate the change in colour value (from colorimeter) divided by time; [1 mark]
- Test (at least) five wavelengths; [1 mark]
- Carry out (at least) three repeats **OR** calculate a mean result (for each wavelength); [1 mark]
- Plot wavelength on *x*-axis against rate on *y*-axis; [1 mark]

[Total: 8 marks]

Note that this question wants you to provide an **experimental method**, not an explanation of the biochemistry of the Hill reaction. You need to describe the steps that you would take, including ways of changing your **independent variable** (light wavelength), measuring your **dependent variable** (time taken for colour change), and ensuring that your results would be **valid** (e.g. carrying out repeats and calculating a mean).