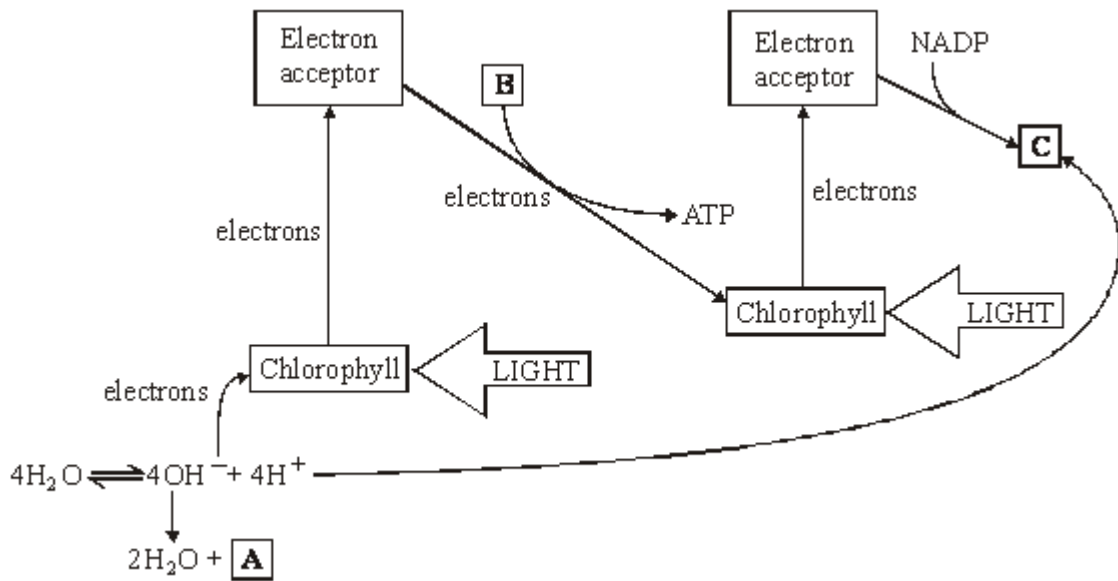


Q1.

The diagram shows the light-dependent reactions of photosynthesis.



(a) In which part of a chloroplast do the light-dependent reactions occur?

(1)

(b) Name the substances in boxes **A**, **B** and **C**.

A _____

B _____ + _____

C _____

(3)

(c) Use information in the diagram to explain

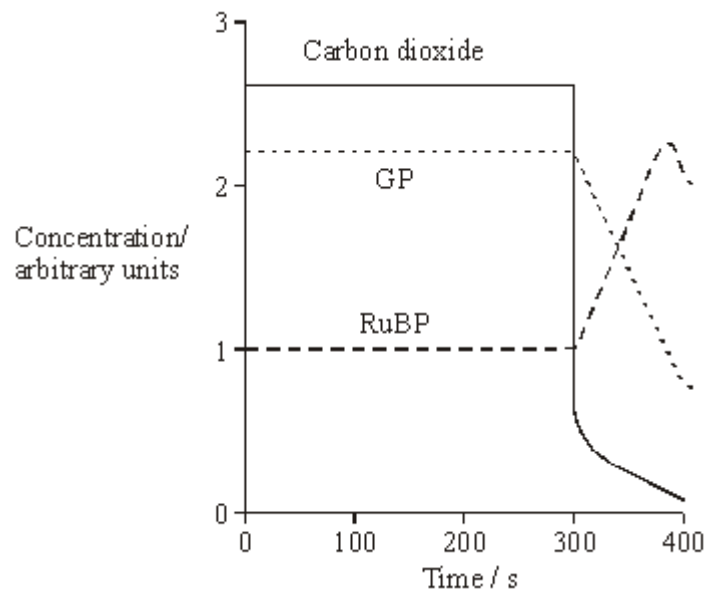
(i) the role of chlorophyll in photolysis;

(3)

(ii) how the energy of light is converted into chemical energy in the light-dependent reactions.

(3)

- (d) In an investigation, single-celled algae were kept in bright light and were supplied with carbon dioxide containing radioactive carbon atoms. After 300 seconds, the carbon dioxide supply was turned off. The graph shows how the concentrations of carbon dioxide, glycerate 3-phosphate (GP) and ribulose bisphosphate (RuBP) changed.



- (i) Explain why, between 0 seconds and 300 seconds, the concentration of radioactive GP remained constant.

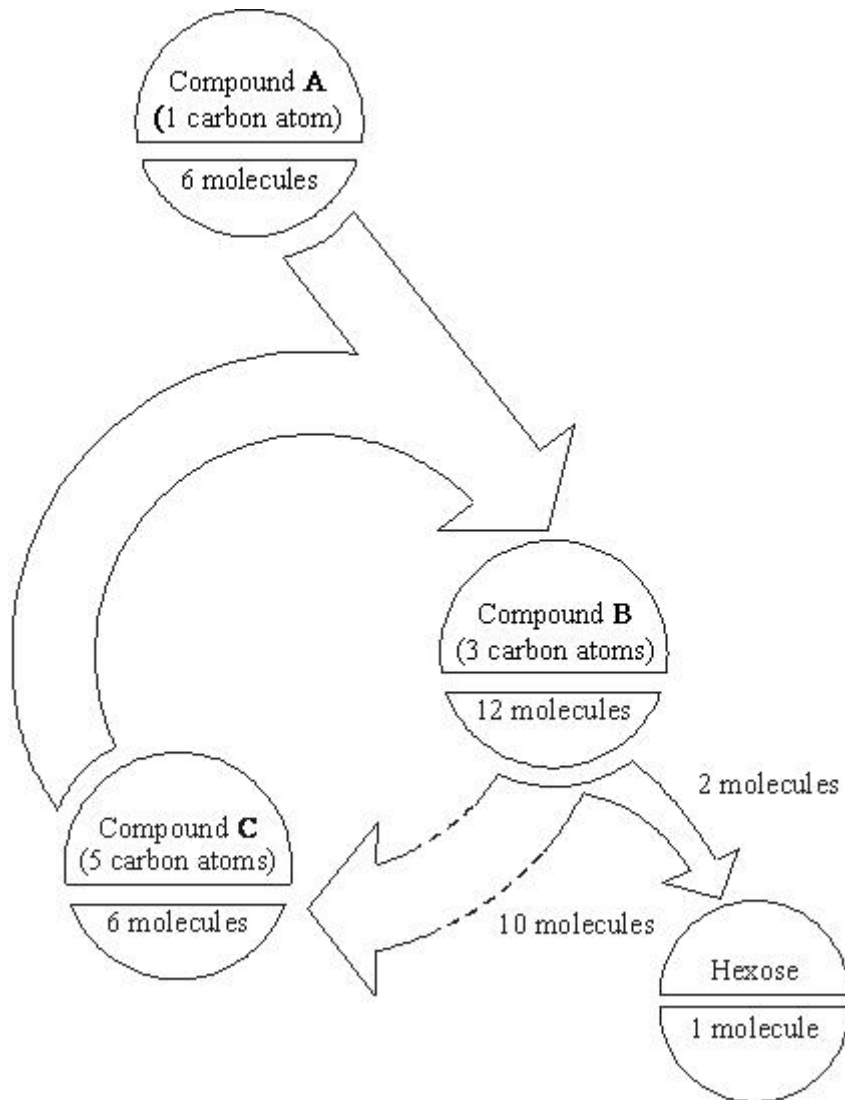
(3)

- (ii) Explain why, between 300 seconds and 380 seconds, the concentration of radioactive RuBP increased.

(2)
(Total 15 marks)

Q2.

The diagram represents some of the light-independent reactions of photosynthesis.



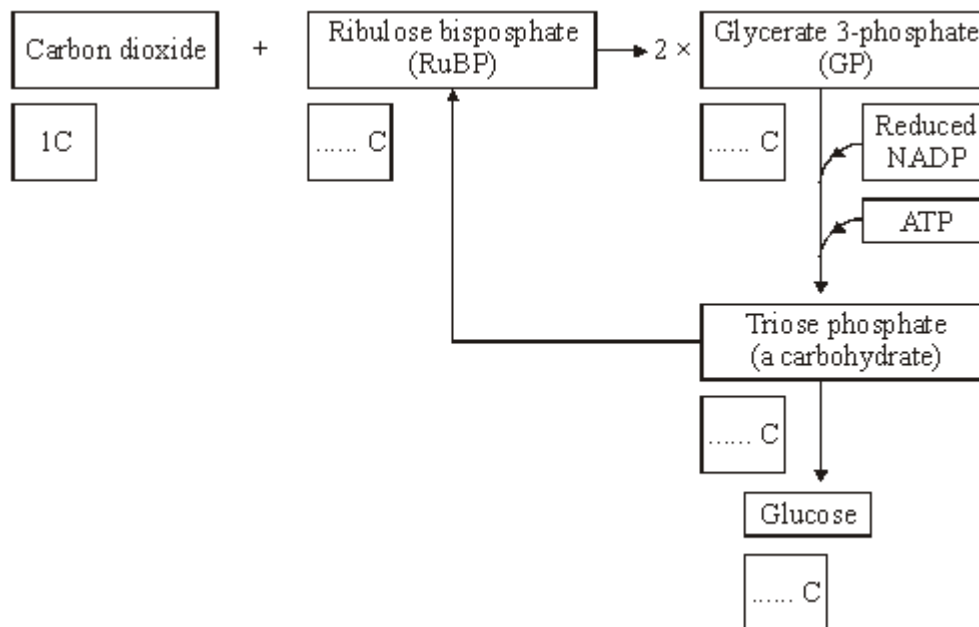
- (a) Describe the light-independent reactions of photosynthesis and explain how they allow the continued synthesis of hexose sugars. (6)
- (b) Describe the role of electron transport chains in the light-dependent reactions of photosynthesis. (6)
- (c) Explain why the increase in the dry mass of a plant over twelve months is less than

the mass of hexose produced over the same period.

(3)
(Total 15 marks)

Q3.

The diagram shows a summary of the light-independent reaction of photosynthesis.



- (a) (i) Complete the boxes to show the number of carbon atoms in the molecules. (2)
- (ii) In which part of a chloroplast does the light-independent reaction occur? (1)
- _____
- (iii) Which process is the source of the ATP used in the conversion of glycerate 3-phosphate (GP) to triose phosphate? (1)
- _____
- (iv) What proportion of triose phosphate molecules is converted to ribulose bisphosphate (RuBP)? (1)
- _____
- (b) Lowering the temperature has very little effect on the light-dependent reaction, but it slows down the light-independent reaction. Explain why the light-independent reaction slows down at low temperatures.
- _____
- _____

(2)
(Total 7 marks)

Q4.

Tomato plants were grown in two glasshouses, each with an area of 2000 m². The table shows the mean number of hours of sunshine per month during fruit production.

| | 1995 – 1997 (no extra carbon dioxide) | 1998 – 2000 (extra carbon dioxide) |
|--|--|---------------------------------------|
| Mean number of hours of sunshine per month | 148.91 | 147.00 |

- The scientists used heating to maintain the temperature inside the glasshouses above 18 °C. They opened the windows to keep the temperature below 30 °C.
 - From 1998 to 2000 they maintained the carbon dioxide concentration between 0.06 % and 0.08 % when the windows were closed and between 0.04 % and 0.05 % when the windows were open.
 - The carbon dioxide concentration in the air outside the glasshouse was 0.04 %.
- (a) The scientists monitored the number of hours of sunshine per month. Explain why they monitored the number of hours of sunshine.

(2)

- (b) The temperature, the use of fertiliser and the number of insect pests were controlled during this investigation. Name one other factor which should have been controlled during the investigation. Explain why variation in this factor would affect yield.

Factor _____

Explanation _____

(2)
(Total 4 marks)

Q5.

A scientist investigated the uptake of radioactively labelled carbon dioxide in chloroplasts. She used three tubes, each containing different components of chloroplasts. She measured the uptake of carbon dioxide in each of these tubes. Her results are shown in the table.

| Tube | Contents of tube | Uptake of radioactively labelled CO₂ / counts per minute |
|-------------|------------------------------|--|
| A | Stroma and grana | 96 000 |
| B | Stroma, ATP and reduced NADP | 97 000 |
| C | Stroma | 4 000 |

(a) Name the substance which combines with carbon dioxide in a chloroplast.

(1)

(b) Explain why the results in tube **B** are similar to those in tube **A**.

(1)

(c) Use the information in the table to predict the uptake of radioactively labelled carbon dioxide if tube **A** was placed in the dark. Explain your answer.

(2)

(d) Use your knowledge of the light-independent reaction to explain why the uptake of carbon dioxide in tube **C** was less than the uptake in tube **B**.

(2)

- (e) DCMU is used as a weed killer. It inhibits electron transfer during photosynthesis. The addition of DCMU to tube **A** decreased the uptake of carbon dioxide. Explain why.

(2)

(Total 8 marks)

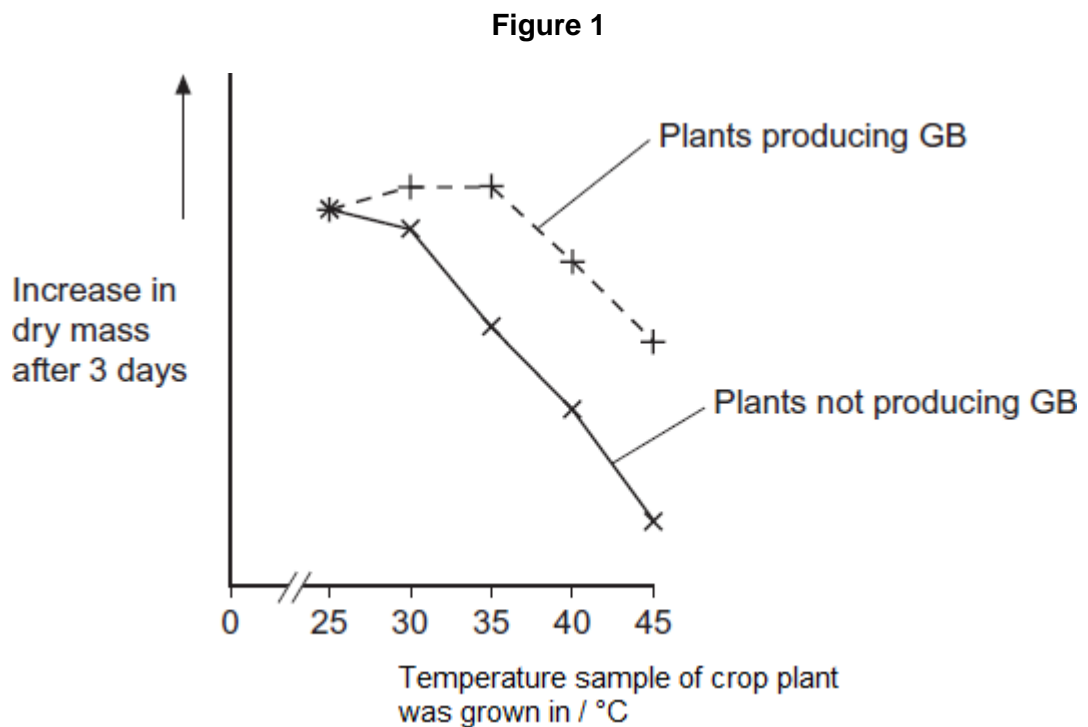
Q6.

Some species of crop plant produce a substance called glycinebetaine (GB).

Scientists transferred the gene for GB into a species of crop plant that does not normally produce GB. These genetically modified plants then produced GB.

The scientists grew large numbers of the same crop plant with and without the gene at different temperatures. After 3 days, they found the increase in dry mass of the plants.

Figure 1 shows their results.

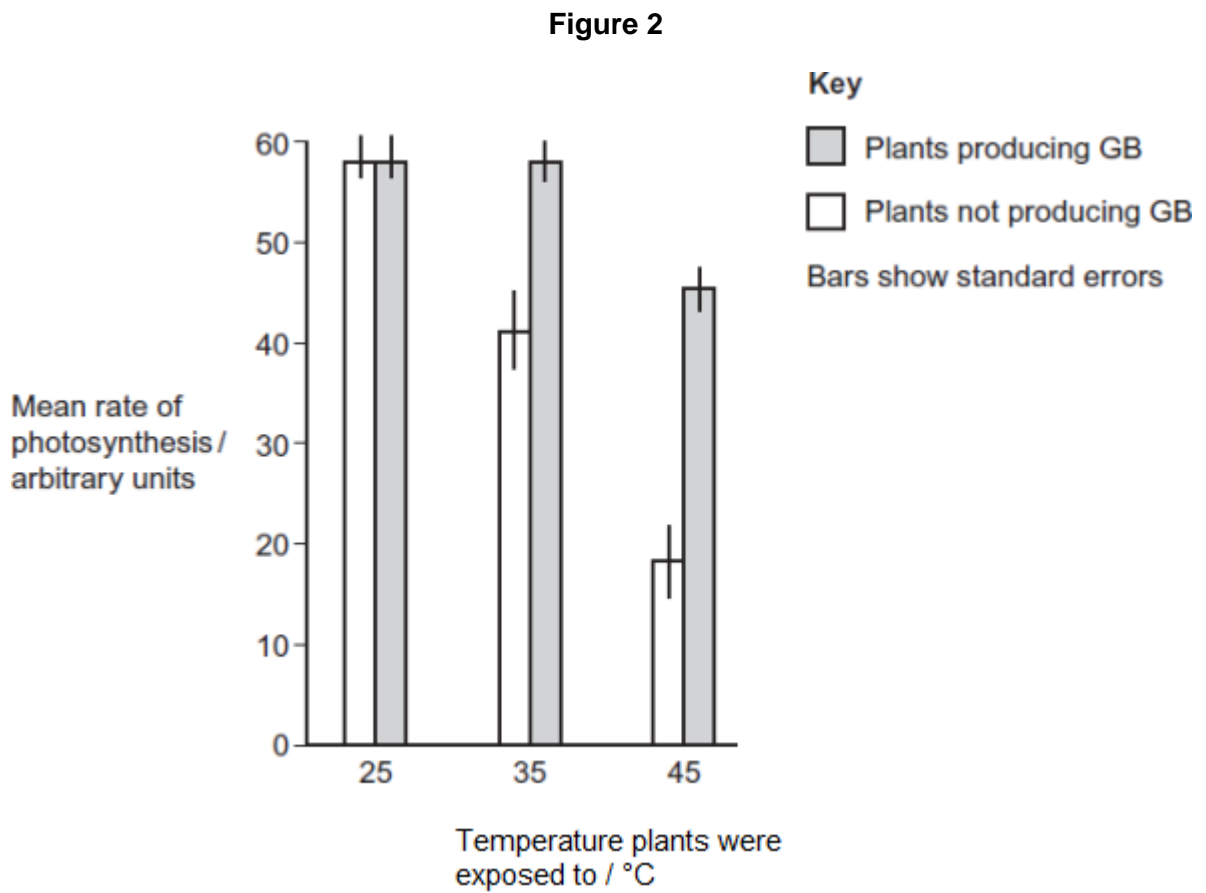


- (a) Describe the effect on growth of transferring the gene for GB into this plant.

(2)

- (b) The scientists measured the rate of photosynthesis in plants that produce GB and plants that do not produce GB at 25°C, 35°C and 45°C.

Figure 2 shows their results.

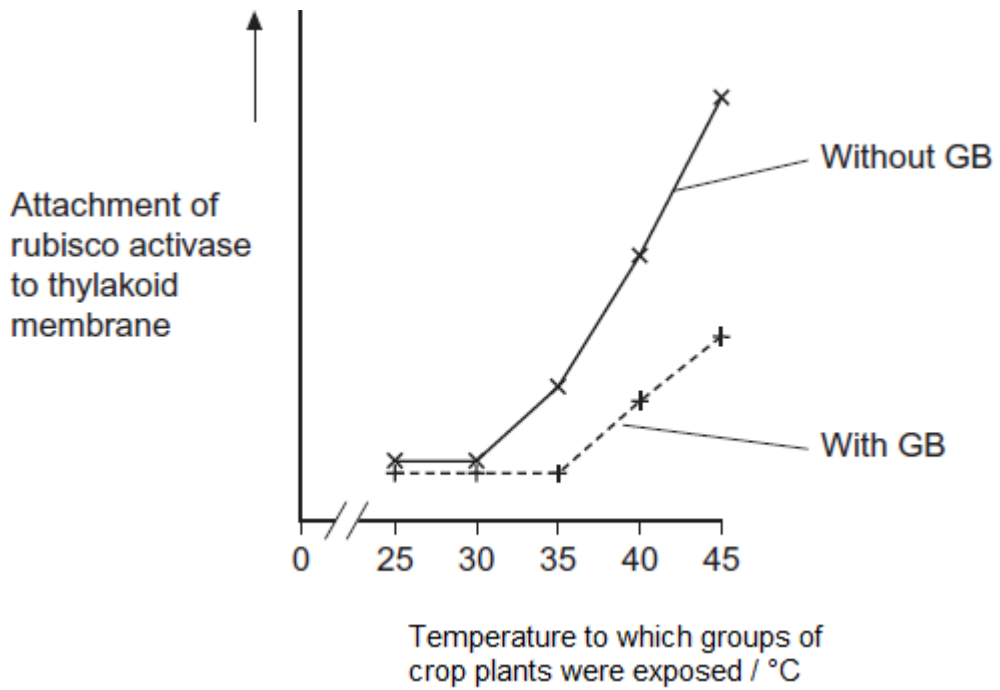


- (i) The scientists concluded that the production of GB protects photosynthesis from damage by high temperatures.

Use these data to support this conclusion.

(1)

- (ii) Use the data from **Figure 2** for plants that do not produce GB to explain the effect of temperature on changes in dry mass of the plants shown in **Figure 1**.



Use information from **Figure 2** and **Figure 3** to suggest how GB protects the crop plant from high temperatures.

(Extra space)

(4)

- (e) The scientists' hypothesis at the start of the investigation was that crop plants genetically engineered to produce GB would become more resistant to high environmental temperatures. The scientists developed this hypothesis on the basis of previous research on crops that are grown in hot climates.

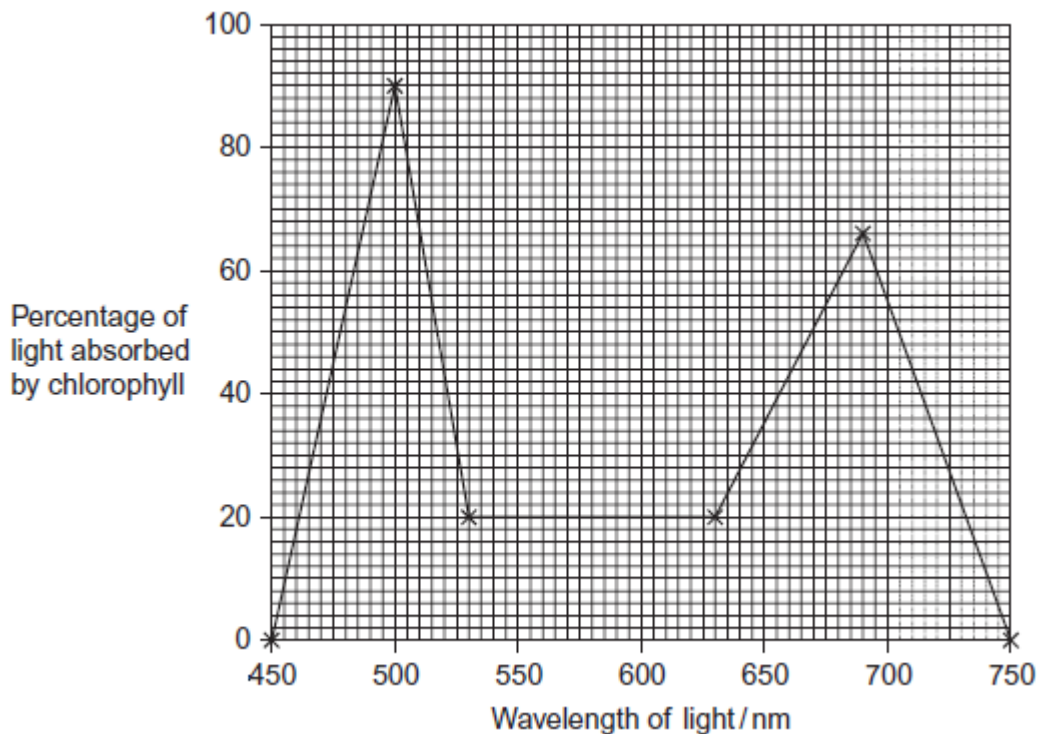
Suggest how the scientists arrived at their hypothesis.

(2)
(Total 15 marks)

Q7.

Figure 1 shows the effect of wavelength on the percentage of light absorbed by the chlorophyll from these seaweeds.

Figure 1



Some scientists investigated the growth of these seaweeds in artificial conditions. They investigated the effect of different lamps on the rate of photosynthesis of the seaweeds.

- Lamp **P** produced light containing all wavelengths of visible light. (450 to 750 nm)
- Lamp **Q** only produced light of wavelength 460 nm.

The scientists measured photosynthesis by recording the rate of oxygen production. Their results are shown in **Figure 2**.

Figure 2

Mean rate of photosynthesis/arbitrary units (\pm standard deviation)

| Species | Lamp P Light of all wavelengths of visible light | Lamp Q Light of wavelength 460nm |
|----------------------------|---|-------------------------------------|
| <i>Ulva pertusa</i> | 1300.9 (± 125.4) | 776.6 (± 105.6) |
| <i>Mastocarpus yendoii</i> | 318.9 (± 69.5) | 299.6 (± 83.2) |

- (a) Between 500 and 700 nm, what range of wavelengths of light is absorbed least by chlorophyll?

_____ (1)

- (b) The scientists measured the oxygen produced by the light-dependent reaction of photosynthesis. Name **two** other substances produced by the light-dependent reaction.

1. _____
2. _____ (2)

- (c) (i) The scientists measured the rate of photosynthesis of the seaweeds in this investigation in terms of oxygen produced. Suggest the units they should use.

_____ (2)

- (ii) This investigation was carried out in bright light. Explain why reducing the light intensity would affect the amount of oxygen released by the seaweeds.

(Extra space) _____

_____ (3)

- (d) In this investigation, the scientists kept the temperature at 15 °C. A student suggested that repeating the investigation at 20 °C would not affect the amount of oxygen released by the seaweed. Evaluate this suggestion.

(Extra space)

(3)

- (e) (i) Did the type of lamp used affect the rate of photosynthesis in *M. yendoi*? Explain the evidence for your answer.

(2)

- (ii) The different lamps resulted in different rates of photosynthesis by *U. pertusa*. Explain why there was a higher rate of photosynthesis when the seaweed was illuminated with lamp **P**.

(Extra space)

(3)

(Total 16 marks)

Q8.

A student isolated chloroplasts from spinach leaves into a solution to form a chloroplast suspension. He used the chloroplast suspension and DCPIP solution to investigate the light-dependent reaction of photosynthesis. DCPIP solution is blue when oxidised and colourless when reduced.

The student set up three test tubes as follows:

- **Tube 1** – 1 cm³ of solution without chloroplasts and 9 cm³ of DCPIP solution in light.
- **Tube 2** – 1 cm³ of chloroplast suspension and 9 cm³ of DCPIP solution in darkness.
- **Tube 3** – 1 cm³ of chloroplast suspension and 9 cm³ of DCPIP solution in light.

The student recorded the colour of the DCPIP in each of the tubes at the start and after the tubes had been left at 20 °C for 30 minutes.

His results are shown in the table.

| Tube | Colour of DCPIP in tube | |
|------|-------------------------|------------------|
| | At start | After 30 minutes |
| 1 | blue | blue |
| 2 | blue | blue |
| 3 | blue | colourless |

- (a) The solution that the student used to produce the chloroplast suspension had the same water potential as the chloroplasts.

Explain why it was important that these water potentials were the same.

(2)

- (b) Explain why the student set up **Tube 1**.

(2)

- (c) Explain the results in **Tube 3**.

(2)

- (d) The student evaluated the effectiveness of different chemicals as weed-killers by assessing their ability to prevent the decolourisation of DCPIP in chloroplast suspensions.

He added different concentrations of each chemical to illuminated chloroplast suspensions containing DCPIP. He then determined the IC_{50} for each chemical. The IC_{50} is the concentration of chemical which inhibits the decolourisation of DCPIP by 50%.

Explain the advantage of the student using the IC_{50} in this investigation.

(1)

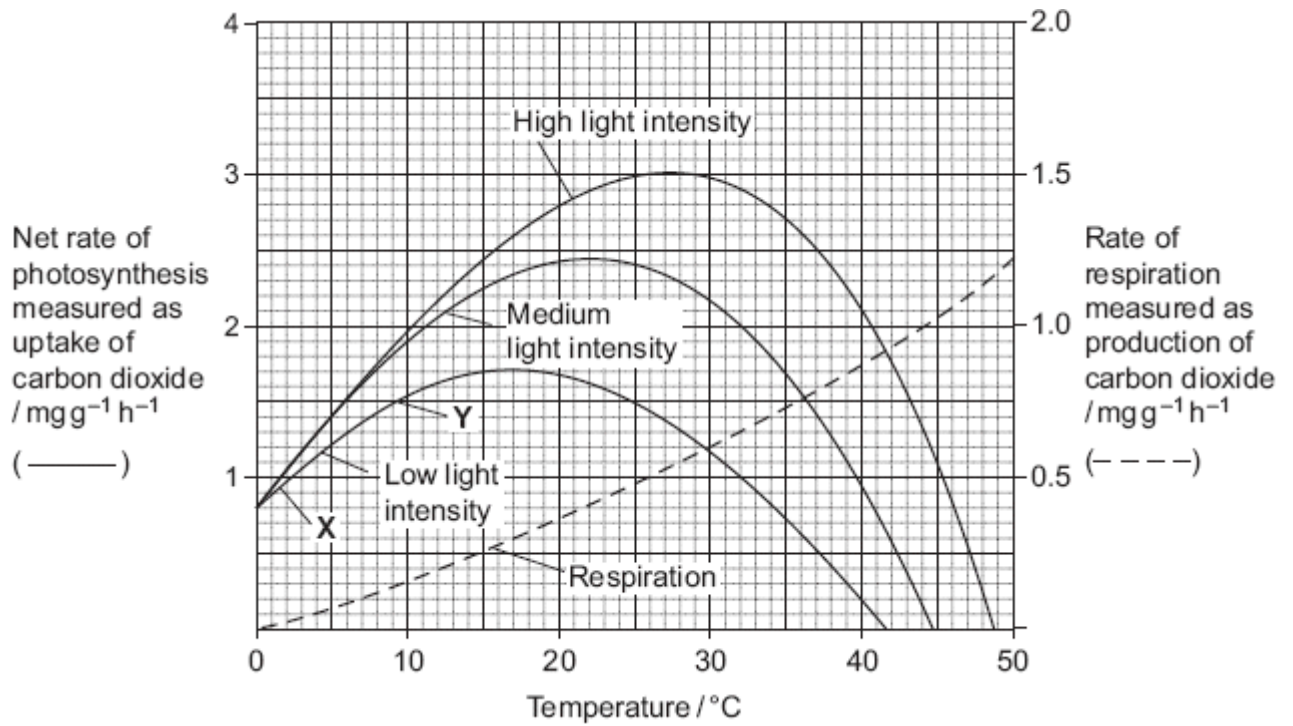
- (e) Explain how chemicals which inhibit the decolourisation of DCPIP could slow the growth of weeds.

(2)

(Total 9 marks)

Q9.

Scientists investigated the effects of temperature and light intensity on the rate of photosynthesis in creeping azalea. They investigated the effect of temperature on the net rate of photosynthesis at three different light intensities. They also investigated the effect of temperature on the rate of respiration. The graph shows the results.



(a) (i) Name the factors that limited the rate of photosynthesis between X and Y.

(1)

(ii) Use information from the graph to explain your answer.

(2)

(b) Use information from the graph to find the gross rate of photosynthesis at 20°C and medium light intensity.

Answer _____

(1)

(c) Creeping azalea is a plant which grows on mountains. Scientists predict that in the area where this plant grows the mean summer temperature is likely to rise from 20 °C to 23 °C. It is also likely to become much cloudier. Describe and explain how

these changes are likely to affect the growth of creeping azalea.

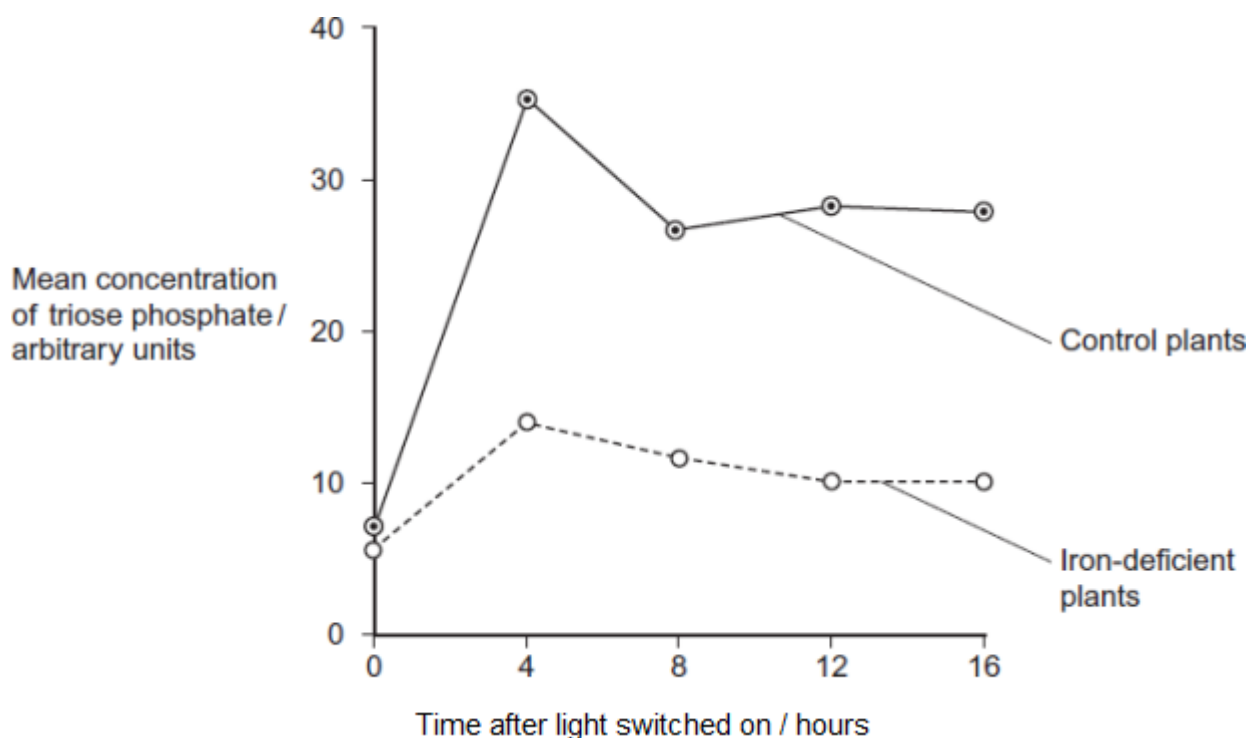
(3)
(Total 7 marks)

Q10.

Scientists investigated the effect of iron deficiency on the production of triose phosphate in sugar beet plants. They grew the plants under the same conditions with their roots in a liquid growth medium containing all the necessary nutrients. Ten days before the experiments, they transferred half the plants to a liquid growth medium containing no iron. The scientists measured the concentration of triose phosphate produced in these plants and in the control plants:

- at the end of 6 hours in the dark
- then for 16 hours in the light.

Their results are shown in the graph.



- (a) (i) The experiments were carried out at a high carbon dioxide concentration. Explain why.

(2)
(Total 9 marks)

Mark schemes

Q1.

- (a) Grana / thylakoids / lamellae; 1
- (b) **A** = oxygen / O₂
B = ADP and phosphate / P_i / phosphoric acid / correct formula;
C = reduced NADP; ALLOW NADPH / NADPH₂ / NADPH + H⁺ 3
- (c) (i) Absorbs light / energy;
Loses electrons / becomes positively charged / is oxidised;
Accepts electrons from water / from OH⁻ which causes more water
to dissociate / pulls equilibrium to the right; 3
- (ii) Electrons raised to higher energy level / electrons excited;
Use of electron carriers / cytochromes / acceptors;
For production of ACT
[REJECT 'energy production'] 3
- (d) (i) GP formed from RuBP + CO₂;
GP → TP / sugar-phosphate / sugar / to RuBP;
GP formed at same rate as it is used; 3
- (ii) No CO₂ to combine with / not enough CO₂ to combine with RuBP
RuBP not changed into GP / TP RuBP reformed from GP / TP; 2

[15]

Q2.

- (a) 1 5C / RuBP combines with CO₂;
2 to form 3C compound / TP / GP;
3 using ATP;
4 and reduced NADP / eq;
5 2 molecules of 3C compound / TP / GP form hexose;
6 all RuBP is regenerated;
7 10 molecules of 3C / TP / GP form 6 molecules of 5C / RuBP; 6 max
- (b) 1 electron transport chain accepts excited electrons;
2 from chlorophyll / photosystem;
3 electrons lose energy along chain;

- 4 ATP produced;
- 5 from ADP and Pi;
- 6 reduced NADP formed;
- 7 when electrons (from transport chain) and H⁺ combine with NADP;
- 8 H⁺ from photolysis;

6 max

- (c) 1 some hexose / biomass / eq. used in respiration;
growth cancels this point
- 2 CO₂ produced (is lost to air);
- 3 some parts of the plant are eaten / some parts lost to decomposers
/ in leaf fall;

3

[15]

Q3.

- (a) (i) RuBP – 5; GP – 3; TP – 3; Glucose – 6;
(all correct = 2 marks; 3 or 2 correct = 1 mark)
- (ii) stroma;
- (iii) light-dependent reaction / (photo)phosphorylation;
(accept photolysis)
- (iv) 5 out of 6 / 83% / equivalent;
- (b) enzymes involved / not a photochemical reaction;
slow rate of enzyme / chemical reaction at low temperature /
less kinetic energy / fewer collisions;

2

1

1

1

2

[7]

Q4.

- (a) To see if a difference in hours of sunshine was present / because it is necessary to monitor factors which cannot be controlled;
So that they could eliminate this factor from affecting the yield (with /without extra carbon dioxide);
OR
Duration of light influences length of time for photosynthesis / temperature in glasshouse;
Higher photosynthesis results in higher yield / more carbohydrates / sugars / proteins produced;
- (b) Named factor;
Explanation of why the factor is important;

2 max

E.g.
 Density of planting;
 Competition for named resource;
 or
 Same variety of tomato;
 Yield will vary with different varieties / with different genotypes;
 or
 Water (application);
 Water needed for expansion of fruit / maintain leaf turgidity / maintain stomatal opening / replace water lost in transpiration / water used in photosynthesis;
For named resource accept 'nutrient' but not 'food'

2

[4]

Q5.

- (a) Ribulose biphosphate / RuBP;

*Accept Ribulose biphosphate or Ribulose diphosphate
 Accept phonetic spellings
 Accept any variation in upper or lower case for RuBP*

1

- (b) ATP and reduced NADP are produced in grana / thylakoids / present in A / both tubes;

*Must be reduced NADP but accept any alternative which show hydrogen attached to NADP
 Must be reduced NADP not reduced NAD*

1

- (c) 1. 4 000;

Accept 'same as in (tube) C', but not 'same' on its own

2. Light-dependent reaction does not occur / ATP and reduced NADP are not produced;

Accept converse for mark point 2

2

- (d) 1. (Less) GP converted to TP;

GP = glycerate 3-phosphate

TP = triose phosphate but abbreviations are sufficient

2. (Less) TP converted to RuBP;

Accept GALP as TP

2

- (e) 1. No / less ATP / ATP produced (during electron transport);

Must be reduced NADP but accept any alternative which shows hydrogen attached to NADP

2. No / less reduced NADP / reduced NADP produced (during electron transport)

2

[8]

Q6.

- (a) 1. No effect at 25°C
The question only refers to plants with GB
1. *Reject same mass*
2. Keeps growing at 30°C and 35°C / up to 35°C (more than without GB);
3. Above 35°C, falls but grows more than plant without GB;
3. *Accept at all temperatures above 25°C more growth than without GB*
- 2 max
- (b) (i) Significantly different / SEs do not overlap ;
Accept converse without GB
- 1
- (ii) (As temperature increases,)
1. Enzyme activity reduced / (some) enzymes denatured;
2. Less photosynthesis, so fewer sugars formed;
3. Less respiration / less energy / ATP for growth;
4. Less energy for named function associated with growth
4. *Eg mitosis, uptake of mineral ions*
- 4
- (c) 1. (Rubisco activase attaches to thylakoid and) this changes shape / tertiary structure (of enzyme) / blocks active site / changes active site;
Note - question states enzyme stops working when it attaches to thylakoid, not before
1. *Accept rubisco in this context*
2. (This) prevents substrate / RuBP entering active site / binding;
2. *Accept prevents ES complex forming*
2. *Accept no longer complementary to substrate / RuBP*
- 2
- (d) 1. GB prevents / reduces binding of rubiscoactivase to (thylakoid membrane);
1. *Accept enzyme instead of rubiscoactivase. Accept rubisco*
2. (Prevents it) up to 35°C;
3. (So) rubiscoactivase / enzyme remains active;
4. (So) photosynthesis / light-independent stage still happens;
4. *Accept descriptions of light-independent stage*
5. Above 35°C, some binding still occurs but less than without GB, so less reduction in growth;
- 4 max
- (e) 1. Looked for information / journals, on crop plants that grow at high temperatures;

1. "other research" is minimum accepted
 1. Accept previous experiments research with temperature resistant crops
 Ignore simple references to looking at previous studies / other plants - need to relate to this context

2. (Crop plants cited in this research) contain / make GB;
3. So assumed making plants produce GB makes them resistant to high temperatures;

2 max

[15]

Q7.

- (a) 530 to 630; 1
- (b) 1. Reduced NADP;
Accept NADPH or rNADP
2. ATP;
Reduced NAD is incorrect 2
- (c) (i) 1. Unit of volume and unit of time;
Accept any reasonable unit of volume
E.g. cm³ or ml
Accept any reasonable unit of time
E.g. s, min or h
2. Unit of area / mass;
Accept any reasonable unit of area or mass
E.g. cm² or g
Symbols should be correct. Do not accept m for minutes. 2
- (ii) 1. (Light intensity) limiting factor;
2. Fewer electrons (released) from chlorophyll;
3. Less photolysis therefore (less) oxygen from water; 3
- (d) Will not affect (no mark):
1. Photolysis / splitting of water does not use enzymes;
- Will affect (no mark):
2. May increase respiration;
3. Respiration uses oxygen; 3
- (e) (i) 1. Overlap in standard deviations;

2. Unlikely that any difference is significant; 2
- (ii) 1. **P** / visible light has more wavelengths;
2. **Q** has only light of wavelength 460 nm;
3. Wavelengths over 460 nm can also be used for photosynthesis / wavelengths over 460 nm can also be absorbed; 3

[16]

Q8.

- (a) 1. Osmosis does not occur;
2. Chloroplast / organelle does not burst / lyse / shrivel / shrink;
1. *Accept: osmosis would occur if water potentials were not the same.*
- 1 and 2, *Accept: correct reference to osmotic lysis for 2 marks.*
2. *Accept: chloroplast would burst / lyse / shrivel / shrink if water potentials were not the same.*
2. *Reject: 'cell bursts/shrivels'*
2. *Ignore: damage to chloroplasts on its own is not enough for a mark.*
3. *Reject: becomes turgid / flaccid.* 2
- (b) 1. To show light does not affect DCPIP;
2. To show chloroplasts are required;
- Ignore: comparison with other tubes.* 2
- (c) 1. Reduction of DCPIP by electrons;
2. (From) chlorophyll / light dependent reaction;
1. *Accept: hydrogen / H for electrons but not protons / hydrogen ions / H* on their own.*
2. *Accept: from chloroplasts / photosystems / water.* 2
- (d) Provides a standard / reference point
- OR**
- Can compare different chemicals/weed-killers
- OR**
- Can compare different concentrations of chemicals / weed-killers;
- Accept: decolourises quicker than 100% or saves time waiting for complete decolourisation.*
- Note: comparisons must be qualified.*
- Accept: find the most effective weed-killer or the most effective concentration.*
- Accept: answers relating to cost effectiveness.* 1
- (e) 1. Less / no ATP produced;
2. Less / no reduced NADP produced;

3. Less / no GP reduced / converted to TP;
 2, Accept: less / no NADPH / NADPH₂ / NADPH + H

2 max

[9]

Q9.

- (a) (i) Temperature and light; 1
- (ii) Increase in temperature causes increase in rate of photosynthesis / uptake of carbon dioxide;
 Increase in light / more / medium / high light (intensity) causes increase in rate of photosynthesis / uptake of carbon dioxide; 2
- (b) 2.75 – 2.81 (mg g⁻¹ hr⁻¹)
 Accept answers in range 2.75 – 2.81 1
- (c) 1. Growth will decrease (at higher temperature);
 2. Rate of respiration will increase at higher temperature;
 3. Photosynthesis decreases as limited by light / as there is less light;
 Ignore references to effect of temperature on rate of photosynthesis 3

[7]

Q10.

- (a) (i) So it / CO₂ is not a limiting factor (on growth / photosynthesis);
 Accept: CO₂ is a limiting factor 1
- (ii) So any difference is due to iron (deficiency);
 Accept: iron is the variable 1
- (iii) Amount of triose phosphate / TP will be similar / same / low (at start);
 Accept: to allow triose phosphate to stabilise / become constant
 Reject: so all triose phosphate is used up
 Reject: so no triose phosphate 1
- (b) 1. (Less) ATP produced;
 Accept: alternatives for reduced NADP ie NADP with hydrogen / s attached
2. (Less) reduced NADP produced;
3. ATP / reduced NADP produced during light-dependent reaction;

4. (Less) GP to triose phosphate / TP; 4
- (c) 1. Less triose phosphate converted to RuBP;
Accept: less triose phosphate so less RuBP
2. CO₂ combines with RuBP; 2

[9]