

Interactive Example Candidate Responses

Paper 4 (May/June 2016), Question 2

Cambridge International AS & A Level

Biology 9700

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2 The concentration of carbon dioxide in the atmosphere and the light intensity often limit the rate of photosynthesis.

(a) Explain what is meant by a *limiting factor* in relation to photosynthesis.

When a reaction involves more than one factor (e.g. light intensity, CO₂ concentration) the factor present in its lowest concentration limits the rate of the reaction.

[2]

(b) Investigations were carried out in Florida, USA, into the effect of different concentrations of atmospheric carbon dioxide and of light intensity on the rate of photosynthesis of soybean plants.

Plants were grown from seed in outdoor, computer-controlled growth chambers at different concentrations of carbon dioxide. The upper parts of the chambers were transparent so that the plants received natural sunlight.

After the seedlings emerged, the air in the soil was separated from the air around the leaves by a gas-tight seal in each chamber.

Suggest why the air in the soil and the air around the leaves of the plants were separated.

The leaves begin the ~~respiration~~ photosynthesis and produce ~~CO₂~~ O₂ by using up CO₂ whereas the ~~top~~ parts of the plant beneath the soil only respire to give off CO₂ by using O₂.

[2]

(c) In one investigation, two sets of plants, A and B, were grown from seed at different concentrations of carbon dioxide:

- A – normal atmospheric concentration of carbon dioxide (0.033%)
- B – normal atmospheric concentration of carbon dioxide x2 (0.066%).

Then, keeping each set of plants in its particular concentration of carbon dioxide, measurements were made of their rates of photosynthesis at different light intensities.

The results are shown in Fig. 2.1 on page 5.

Your
Mark

2(a)

2(b)

2(c)(i)

2(c)(ii)

2(d)

Q2	Mark scheme
(a)	at lowest value / in shortest supply ; I insufficient supply / not enough (the) one factor of several that affects rate ; A one factor of several prevents increase in rate [2]
(b)	to keep out unwanted CO ₂ (in air around leaves) ; A to stop CO ₂ increasing / entering (upper chamber) ref. to respiration of soil organisms ; A respiration of bacteria / fungi / seeds ref. to respiration of plant roots ; [max 2]
(c)(i)	I ref. to set B throughout / time references at low(er) light intensity / light intensity up to a figure in range 6 – 7 au 1 rate increases as light intensity increases ; 2 light intensity is (main) limiting factor ; mp1 and mp2 need to be in correct context at high light intensity / light intensity above a figure in range 6 – 7 au 3 rate, levels off / reaches plateau / remains constant ; A rate unaffected (by light intensity) 4 another (named) factor / not light intensity, is limiting ; A CO ₂ concentration / temperature mp3 and mp4 need to be in correct context [max 3]
(c)(ii)	more CO ₂ available in B / less CO ₂ in A ; A CO ₂ concentration in B is double that of A ref. to fixation / Calvin cycle / light independent reactions ; A description, e.g. CO ₂ combines with RuBP CO ₂ concentration is limiting factor in set A ; A CO ₂ concentration is limiting at a higher light intensity in B [max 2]
(d)	accept ora throughout 1 D , adapted to high CO ₂ / can use more CO ₂ (per unit leaf area) ; A plants in D have, adjusted / accommodated, to high CO ₂ 2 D have more, chloroplasts / chlorophyll ; 3 D have more, rubisco / RuBP ; 4 D have more stomata ; 5 D have thinner leaves ; 6 AVP ; e.g. ref. to <u>diffusion</u> of CO ₂ [max 4] [Total: 13]

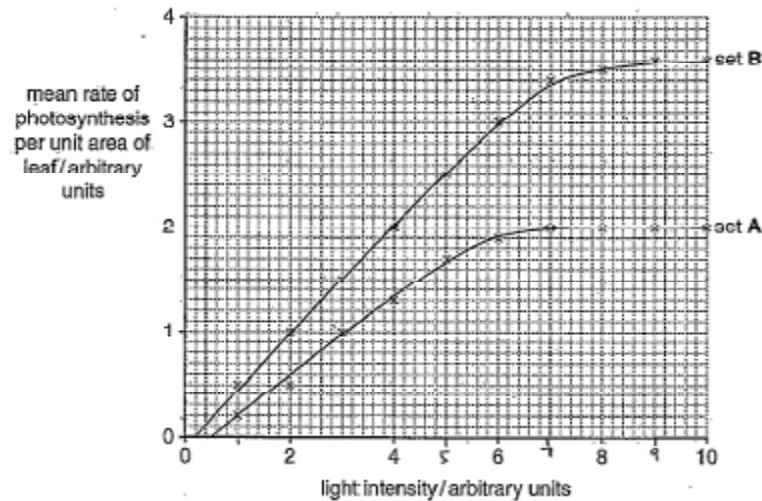


Fig. 2.1

With reference to Fig. 2.1:

- (i) describe and explain, in terms of limiting factors, the results from the plants in set A.
- At lower light intensities (0 to around 7) the light intensity was the limiting factor. As an increase in light intensity caused an increase in rate of photosynthesis from 0.2 (at 1 au light intensity) to 2 (at 7 au light intensity). As light intensity increases beyond 7, the CO_2 concentration becomes the limiting factor. Light dependent reactions may increase in rate but light independent reactions using CO_2 is limited because of limited CO_2 on the leaf. So rate stays at 2. [3]
- (ii) explain the difference between the results of set A and set B at high light intensities.
- In set B, CO_2 concentration (cm^3) is twice as high as in set A. CO_2 concentration becomes a limiting factor at higher light intensities and reaches a greater rate of photosynthesis since more CO_2 for light independent reactions (the Calvin cycle) in the stroma. [2]

Your
Mark

2(a)

2(b)

2(c)(i)

2(c)(ii)

2(d)

Q2	Mark scheme
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(d) In a second investigation, two sets of plants, **C** and **D**, were grown from seed, as before, in different carbon dioxide concentrations:

- **C** – normal atmospheric concentration of carbon dioxide (0.033%)
- **D** – normal atmospheric concentration of carbon dioxide $\times 2$ (0.066%).

When the plants matured, conditions in the growth chambers were changed to investigate the rate of photosynthesis of each set of plants in different concentrations of carbon dioxide.

The results are shown in Fig. 2.2.

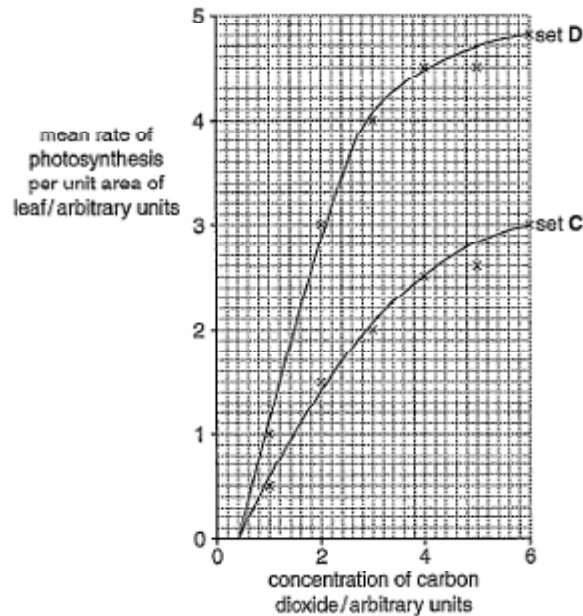


Fig. 2.2

Your
Mark

2(a)

2(b)

2(c)(i)

2(c)(ii)

2(d)

Q2	Mark scheme
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(c)(i)	I <i>ref. to</i> set B throughout / time references at low(er) light intensity / light intensity up to a figure in range 6 – 7 au 1 rate increases as light intensity increases ; 2 light intensity is (main) limiting factor ; <i>mp1 and mp 2 need to be in correct context</i> at high light intensity / light intensity above a figure in range 6 – 7 au 3 rate, levels off / reaches plateau / remains constant ; A rate unaffected (by light intensity) 4 another (named) factor / not light intensity, is limiting ; A CO ₂ concentration / temperature <i>mp3 and mp4 need to be in correct context</i> [max 3]
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(d)	<i>accept ora throughout</i> 1 D , adapted to high CO ₂ / can use more CO ₂ (per unit leaf area) ; A plants in D have, adjusted / accommodated, to high CO ₂ 2 D have more, chloroplasts / chlorophyll ; 3 D have more, rubisco / RuBP ; 4 D have more stomata ; 5 D have thinner leaves ; 6 AVP ; e.g. <i>ref. to</i> <u>diffusion</u> of CO ₂ [max 4] [Total: 13]

Suggest explanations for the higher rate of photosynthesis per unit area of leaf shown by the plants in set D compared with those in set C.

Plants in set D grown in twice the CO_2 concentration may have more chloroplasts per unit area of leaf. ^{than set C} More chloroplasts mean more photosynthetic machinery leading to a greater rate of photosynthesis overall in set D than in C. In set C, the limiting factor is the number of chloroplasts so fewer light dependent and independent reactions occur. ^{Plants in} ~~Plant D~~ ^{Part D} may also have a ~~higher~~ ^{more} number of stomata ^(per unit area of leaf) for CO_2 to diffuse into the leaf whereas in C the number of stomata may also be a limiting factor.

[4]

[Total: 13]

Your
Mark

2(a)

2(b)

2(c)(i)

2(c)(ii)

2(d)

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2 The concentration of carbon dioxide in the atmosphere and the light intensity often limit the rate of photosynthesis.

(a) Explain what is meant by a limiting factor in relation to photosynthesis.

Limiting factor means in a series of reaction is limited by the slowest in this reaction. For instance if we increased the carbon dioxide concentration the rate of photosynthesis increase till it reaches a plateau where other factors such as light intensity is affecting the reaction so carbon dioxide is no longer a limiting factor. [2]

(b) Investigations were carried out in Florida, USA, into the effect of different concentrations of atmospheric carbon dioxide and of light intensity on the rate of photosynthesis of soybean plants.

Plants were grown from seed in outdoor, computer-controlled growth chambers at different concentrations of carbon dioxide. The upper parts of the chambers were transparent so that the plants received natural sunlight.

After the seedlings emerged, the air in the soil was separated from the air around the leaves by a gas-tight seal in each chamber.

Suggest why the air in the soil and the air around the leaves of the plants were separated.

air in the soil contained greater amount of oxygen as waste of photosynthesis that will not be taken up by the leaves of the plant so it doesn't affect the experiment. [2]

(c) In one investigation, two sets of plants, A and B, were grown from seed at different concentrations of carbon dioxide:

- A – normal atmospheric concentration of carbon dioxide (0.033%)
- B – normal atmospheric concentration of carbon dioxide $\times 2$ (0.066%).

Then, keeping each set of plants in its particular concentration of carbon dioxide, measurements were made of their rates of photosynthesis at different light intensities.

The results are shown in Fig. 2.1 on page 5.

Your
Mark

2(a)

2(b)

2(c)(i)

2(c)(ii)

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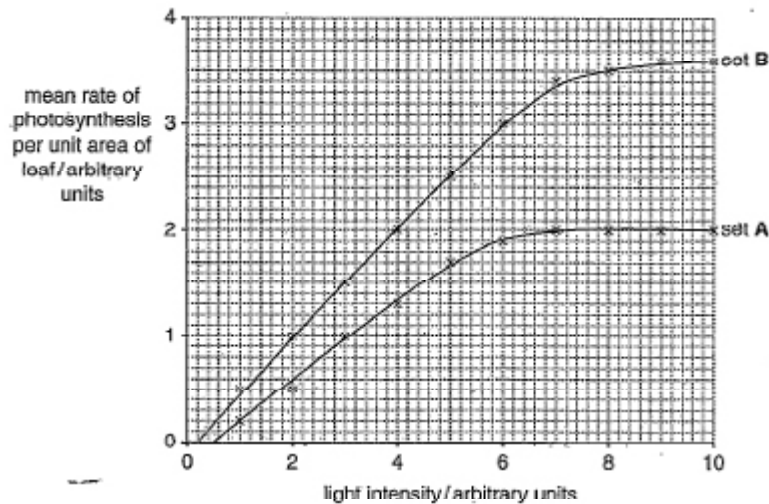


Fig. 2.1

With reference to Fig. 2.1:

- (i) describe and explain, in terms of limiting factors, the results from the plants in set **A**.
- As the light intensity increases, the mean rate of photosynthesis per unit area of leaf increases from 0 arbitrary units till 2 arbitrary units at light intensity of 7 arbitrary units. beyond that it became a plateau till 10 arbitrary units at 2 arbitrary unit. As up till 7 arbitrary units light was the limiting factor in the experiment, 7 arbitrary units onward till light intensity of 10 arbitrary unit. Concentration of Carbon dioxide became the limiting factor, not the light intensity.
- (ii) explain the difference between the results of set A and set B at high light intensities.
- It undergo more photosynthesis due to presence of more carbon dioxide than A. It absorbs light better than set A.

[2]

Your
Mark

2(a)

2(b)

2(c)(i)

2(c)(ii)

2(d)

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(d) In a second investigation, two sets of plants, C and D, were grown from seed, as before, in different carbon dioxide concentrations:

- C – normal atmospheric concentration of carbon dioxide (0.033%)
- D – normal atmospheric concentration of carbon dioxide $\times 2$ (0.066%).

When the plants matured, conditions in the growth chambers were changed to investigate the rate of photosynthesis of each set of plants in different concentrations of carbon dioxide.

The results are shown in Fig. 2.2.

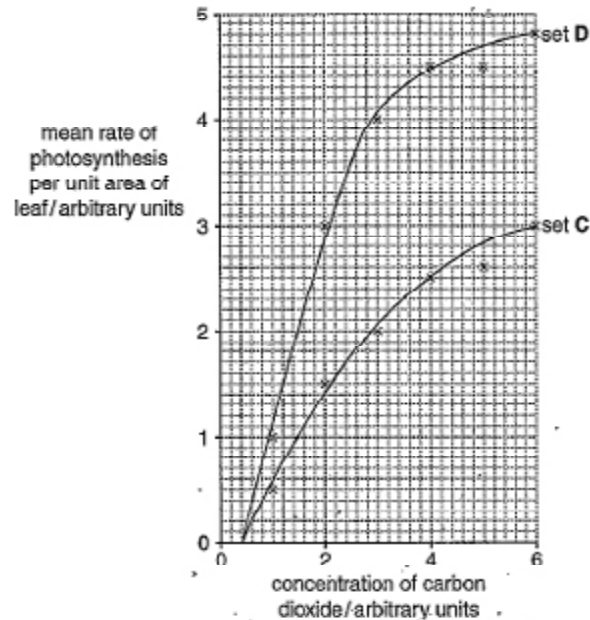


Fig. 2.2

Your
Mark

2(a)

2(b)

2(c)(i)

2(c)(ii)

2(d)

Q2	Mark scheme
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Suggest explanations for the higher rate of photosynthesis per unit area of leaf shown by the plants in set D compared with those in set C.

As more concentration of ~~low~~ Carbon dioxide increases the mean rate of photosynthesis per unit area of leaf.
As more carbon binds with more RuBP (ribulose biphosphate) and so more Calvin cycle and more GP produced that is reduced into more TP and more RuBP regenerated than C that took less amount of carbon dioxide.

[4]

[Total: 13]

Your
Mark

2(a)

2(b)

2(c)(i)

2(c)(ii)

2(d)

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2 The concentration of carbon dioxide in the atmosphere and the light intensity often limit the rate of photosynthesis.

(a) Explain what is meant by a *limiting factor* in relation to photosynthesis.

A limiting factor is an environmental factor, which in short supply / scarcity limits the rate of photosynthesis.

[2]

(b) Investigations were carried out in Florida, USA, into the effect of different concentrations of atmospheric carbon dioxide and of light intensity on the rate of photosynthesis of soybean plants.

Plants were grown from seed in outdoor, computer-controlled growth chambers at different concentrations of carbon dioxide. The upper parts of the chambers were transparent so that the plants received natural sunlight.

After the seedlings emerged, the air in the soil was separated from the air around the leaves by a gas-tight seal in each chamber.

Suggest why the air in the soil and the air around the leaves of the plants were separated.

They have different concentrations of CO₂ so they are separated to avoid confusion and make it clear on which concentration has caused the rate of photosynthesis.

[2]

(c) In one investigation, two sets of plants, A and B, were grown from seed at different concentrations of carbon dioxide:

- A – normal atmospheric concentration of carbon dioxide (0.033%)
- B – normal atmospheric concentration of carbon dioxide $\times 2$ (0.066%).

Then, keeping each set of plants in its particular concentration of carbon dioxide, measurements were made of their rates of photosynthesis at different light intensities.

The results are shown in Fig. 2.1 on page 5.

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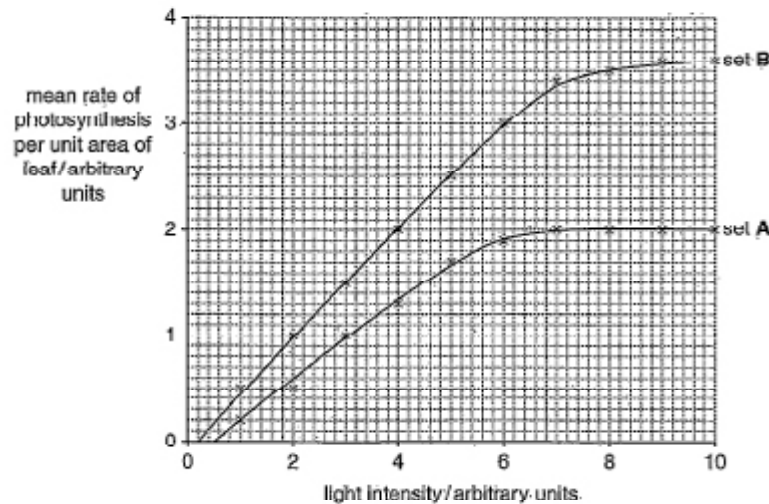


Fig. 2.1

With reference to Fig. 2.1:

- (i) describe and explain, in terms of limiting factors, the results from the plants in set A

At low light intensity, CO_2 concentration is not the limiting factor, light intensity is. So as light intensity increases, the rate of photosynthesis also increases. Then, when light intensity is 7 arbitrary units, a plateau is reached. No matter how much light intensity increases, the rate of photosynthesis remains constant. This is due to light intensity not being the limiting factor anymore, CO_2 is probably limiting.

- (ii) explain the difference between the results of set A and set B at high light intensities.

At high light intensities, set B has a higher rate of photosynthesis because the concentration of CO_2 is higher (twice as much), so it takes longer for CO_2 concentrations to be limiting in set B.

Your
Mark

2(a)

2(b)

2(c)(i)

2(c)(ii)

2(d)

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(c)(i)	I ref. to set B throughout / time references at low(er) light intensity / light intensity up to a figure in range 6 – 7 au 1 rate increases as light intensity increases ; 2 light intensity is (main) limiting factor ; mp1 and mp 2 need to be in correct context at high light intensity / light intensity above a figure in range 6 – 7 au 3 rate, levels off / reaches plateau / remains constant ; A rate unaffected (by light intensity) 4 another (named) factor / not light intensity, is limiting ; A CO_2 concentration / temperature mp3 and mp4 need to be in correct context [max 3]
(c)(ii)	more CO_2 available in B / less CO_2 in A ; A CO_2 concentration in B is double that of A ref. to fixation / Calvin cycle / light independent reactions ; A description, e.g. CO_2 combines with RuBP CO_2 concentration is limiting factor in set A ; A CO_2 concentration is limiting at a higher light intensity in B [max 2]
(d)	accept ora throughout 1 D , adapted to high CO_2 / can use more CO_2 (per unit leaf area) ; A plants in D have, adjusted / accommodated, to high CO_2 2 D have more, chloroplasts / chlorophyll ; 3 D have more, rubisco / RuBP ; 4 D have more stomata ; 5 D have thinner leaves ; 6 AVP ; e.g. ref. to diffusion of CO_2 [max 4] [Total: 13]

(d) In a second investigation, two sets of plants, **C** and **D**, were grown from seed, as before, in different carbon dioxide concentrations:

- **C** – normal atmospheric concentration of carbon dioxide (0.033%)
- **D** – normal atmospheric concentration of carbon dioxide $\times 2$ (0.066%).

When the plants matured, conditions in the growth chambers were changed to investigate the rate of photosynthesis of each set of plants in different concentrations of carbon dioxide.

The results are shown in Fig. 2.2.

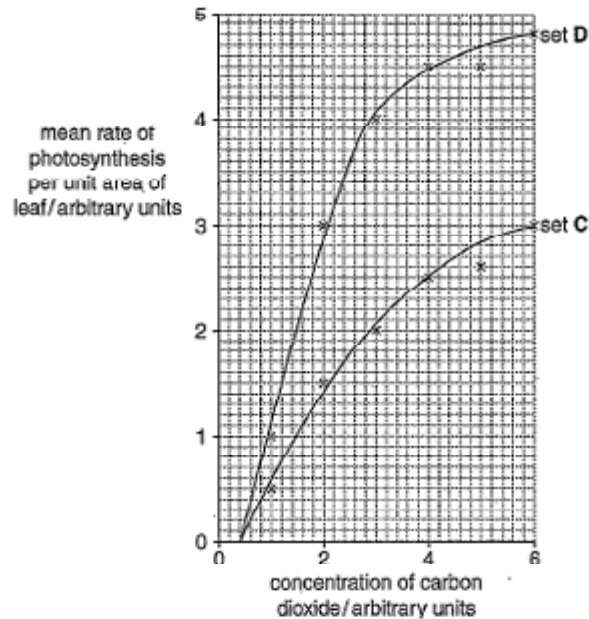


Fig. 2.2

Your
Mark

2(a)

2(b)

2(c)(i)

2(c)(ii)

2(d)

Q2	Mark scheme
(a)	at lowest value / in shortest supply ; I insufficient supply / not enough (the) one factor of several that affects rate ; A one factor of several prevents increase in rate [2]
(b)	to keep out unwanted CO ₂ (in air around leaves) ; A to stop CO ₂ increasing / entering (upper chamber) ref. to respiration of soil organisms ; A respiration of bacteria / fungi / seeds ref. to respiration of plant roots ; [max 2]
(c)(i)	I ref. to set B throughout / time references at low(er) light intensity / light intensity up to a figure in range 6 – 7 au 1 rate increases as light intensity increases ; 2 light intensity is (main) limiting factor ; mp1 and mp 2 need to be in correct context at high light intensity / light intensity above a figure in range 6 – 7 au 3 rate, levels off / reaches plateau / remains constant ; A rate unaffected (by light intensity) 4 another (named) factor / not light intensity, is limiting ; A CO ₂ concentration / temperature mp3 and mp4 need to be in correct context [max 3]
(c)(ii)	more CO ₂ available in B / less CO ₂ in A ; A CO ₂ concentration in B is double that of A ref. to fixation / Calvin cycle / light independent reactions ; A description, e.g. CO ₂ combines with RuBP CO ₂ concentration is limiting factor in set A ; A CO ₂ concentration is limiting at a higher light intensity in B [max 2]
(d)	accept ora throughout 1 D , adapted to high CO ₂ / can use more CO ₂ (per unit leaf area) ; A plants in D have, adjusted / accommodated, to high CO ₂ 2 D have more, chloroplasts / chlorophyll ; 3 D have more, rubisco / RuBP ; 4 D have more stomata ; 5 D have thinner leaves ; 6 AVP ; e.g. ref. to <u>diffusion</u> of CO ₂ [max 4] [Total: 13]

Suggest explanations for the higher rate of photosynthesis per unit area of leaf shown by the plants in set D compared with those in set C.

As seeds from plant C were used to carrying out photosynthesis at slightly lower levels of CO₂ concentration than plant D, when CO₂ concentrations increase, the rate of photosynthesis also increases, but less steeply than in D.

Carbon dioxide can't be fixed that fast by rubisco than in D.

Light intensity might be ^{more} limited for C than D.

[4]

[Total: 13]

Your
Mark

2(a)

2(b)

2(c)(i)

2(c)(ii)

2(d)

Q2	Mark scheme
(a)	at lowest value / in shortest supply ; I insufficient supply / not enough (the) one factor of several that affects rate ; A one factor of several prevents increase in rate [2]
(b)	to keep out unwanted CO ₂ (in air around leaves) ; A to stop CO ₂ increasing / entering (upper chamber) <i>ref. to</i> respiration of soil organisms ; A respiration of bacteria / fungi / seeds <i>ref. to</i> respiration of plant roots ; [max 2]
(c)(i)	I <i>ref. to</i> set B throughout / time references at low(er) light intensity / light intensity up to a figure in range 6 – 7 au 1 rate increases as light intensity increases ; 2 light intensity is (main) limiting factor ; <i>mp1 and mp 2 need to be in correct context</i> at high light intensity / light intensity above a figure in range 6 – 7 au 3 rate, levels off / reaches plateau / remains constant ; A rate unaffected (by light intensity) 4 another (named) factor / not light intensity, is limiting ; A CO ₂ concentration / temperature <i>mp3 and mp4 need to be in correct context</i> [max 3]
(c)(ii)	more CO ₂ available in B / less CO ₂ in A ; A CO ₂ concentration in B is double that of A <i>ref. to</i> fixation / Calvin cycle / light independent reactions ; A description, e.g. CO ₂ combines with RuBP CO ₂ concentration is limiting factor in set A ; A CO ₂ concentration is limiting at a higher light intensity in B [max 2]
(d)	<i>accept ora throughout</i> 1 D , adapted to high CO ₂ / can use more CO ₂ (per unit leaf area) ; A plants in D have, adjusted / accommodated, to high CO ₂ 2 D have more, chloroplasts / chlorophyll ; 3 D have more, rubisco / RuBP ; 4 D have more stomata ; 5 D have thinner leaves ; 6 AVP ; e.g. <i>ref. to</i> <u>diffusion</u> of CO ₂ [max 4] [Total: 13]

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