Bioenergetics

Model answers and marking points

GCSE science 6-mark questions

This topic online

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1 Oliver measured the rate of photosynthesis of a pondweed at different light intensities and at two concentrations of carbon dioxide. The temperature was kept at 25 °C.

Light intensity in arbitrary units	Rate at low CO_2 in bubbles per minute	Rate at high CO_2 in bubbles per minute
1	6	6
2	12	12
3	15	18
4	15	24
5	15	26

Use the data to explain which factor limits the rate of photosynthesis at different light intensities. (6 marks)

Model answer

A limiting factor is the factor in shortest supply, which stops the rate of photosynthesis going any faster.

Between 1 and 2 units of light, the rate doubles from 6 to 12 bubbles per minute, and the two CO_2 columns are identical. Adding more carbon dioxide made no difference, so light intensity is the limiting factor here. Light provides the energy needed for photosynthesis, so more light gives a faster rate.

At low CO_2, the rate stops rising at 15 bubbles per minute from 3 units onwards. Increasing the light has no further effect, so carbon dioxide concentration has become the limiting factor.

At high CO_2, the rate keeps rising to 24 bubbles per minute at 4 units. This proves that the low CO_2 was holding the rate back in the other experiment.

At 5 units, the high CO_2 rate only rises from 24 to 26, so it is starting to level off. This suggests another factor, such as temperature or the amount of chlorophyll, is starting to limit the rate.

Marking points (credit any 6 relevant points, linked in a sensible order)

- a limiting factor is the factor in shortest supply that stops the rate increasing
- from 1 to 2 units the rate doubles from 6 to 12 at both CO_2 levels
- at low light intensities the two columns are the same, so light intensity is the limiting factor
- light provides the energy for photosynthesis, so more light means a faster rate
- at low CO_2 the rate levels off at 15 bubbles per minute from 3 units
- here increasing light has no effect, so CO_2 concentration is limiting
- at high CO_2 the rate carries on rising to 24 and 26
- this shows the extra CO_2 removed the limit set at low CO_2
- at high CO_2 the rate begins to level off at 5 units, so another factor, such as temperature or chlorophyll, may be starting to limit

How it is marked

- 5-6 marks: uses figures from the table to identify the limiting factor at low and at higher light intensities for both CO_2 levels, with reasons.
- 3-4 marks: identifies light as limiting at first and CO_2 as limiting later, with some data, but explanation is incomplete.
- 1-2 marks: describes a trend, such as more light gives a faster rate, with no idea of a limiting factor.

What loses marks

- describing the numbers without naming the limiting factor
- saying light is limiting where the rate has levelled off
- not quoting any figures

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2 **Higher tier**

Grace runs a 400 m race as fast as she can. At the end she is breathing very hard, and she keeps breathing deeply for several minutes after she has stopped.

Explain what happens in Grace's muscles during the race and why her deep breathing continues after it.

(6 marks)

Model answer

During the race, Grace's muscles are contracting hard and need a lot of energy. Her heart rate and breathing rate increase so more oxygen and glucose reach the muscles and more carbon dioxide is removed.

However, in a sprint like this, the blood cannot deliver oxygen fast enough. So her muscle cells also respire anaerobically:

glucose → lactic acid

Anaerobic respiration releases much less energy than aerobic respiration because the glucose is only partly broken down. Lactic acid builds up in the muscles, and the muscles become fatigued, so they stop contracting efficiently.

After the race, there is an oxygen debt. This is the extra amount of oxygen her body needs to react with the lactic acid and remove it from the cells. The lactic acid is carried in the blood to the liver, where it is converted back into glucose. This process needs oxygen.

Grace keeps breathing deeply and her heart rate stays high after she stops so that she can take in the extra oxygen to repay the oxygen debt and carry the lactic acid to her liver.

Marking points (credit any 6 relevant points, linked in a sensible order)

- during the race her muscles need a lot of energy for contraction
- heart rate and breathing rate increase to supply more oxygen and glucose and remove carbon dioxide
- the oxygen supply cannot meet the demand, so muscles also respire anaerobically
- anaerobic respiration: glucose to lactic acid
- anaerobic respiration releases much less energy than aerobic respiration, because glucose is only partly broken down
- lactic acid builds up and muscles become fatigued
- blood carries lactic acid to the liver
- in the liver lactic acid is converted back into glucose, which needs oxygen
- oxygen debt is the extra oxygen needed after exercise to react with the lactic acid and remove it from cells
- deep breathing continues to repay the oxygen debt

How it is marked

- 5-6 marks: explains the switch to anaerobic respiration, lactic acid build-up and fatigue, and the oxygen debt including the role of the liver.
- 3-4 marks: explains anaerobic respiration and lactic acid, with limited explanation of why deep breathing continues.
- 1-2 marks: states that she needs more oxygen or her muscles get tired.

What loses marks

- saying anaerobic respiration produces carbon dioxide or ethanol in muscles
- saying no energy is released anaerobically
- saying lactic acid is breathed out

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3 Respiration happens in human muscle cells and in yeast cells. It can be aerobic or anaerobic.

Compare aerobic respiration with anaerobic respiration in muscle cells and in yeast cells. (6 marks)

Model answer

All types of respiration are exothermic and transfer energy from glucose so cells can use it.

Aerobic respiration needs oxygen, whereas anaerobic respiration happens without oxygen. Aerobic respiration is the same in both muscle cells and yeast:

glucose + oxygen → carbon dioxide + water

Anaerobic respiration is different in the two types of cell. In muscle cells:

glucose → lactic acid

In yeast cells, anaerobic respiration is called fermentation:

glucose → ethanol + carbon dioxide

So yeast makes carbon dioxide in both aerobic and anaerobic respiration, but muscles only make carbon dioxide when respiring aerobically. Neither type of anaerobic respiration produces water.

Aerobic respiration releases much more energy from each glucose molecule than anaerobic respiration. This is because in anaerobic respiration glucose is only partly broken down, so some energy is left in the lactic acid or ethanol.

Muscles respire anaerobically during hard exercise when not enough oxygen arrives. Fermentation by yeast is useful to people, because the carbon dioxide makes bread rise and the ethanol is used in making beer and wine.

Marking points (credit any 6 relevant points, linked in a sensible order)

- respiration is an exothermic reaction that transfers energy from glucose
- aerobic respiration uses oxygen; anaerobic respiration does not
- aerobic respiration: glucose + oxygen to carbon dioxide + water
- aerobic respiration is the same in muscle and yeast cells
- anaerobic respiration in muscles: glucose to lactic acid
- anaerobic respiration in yeast: glucose to ethanol + carbon dioxide, called fermentation
- aerobic respiration releases much more energy per glucose molecule
- less energy is released anaerobically because glucose is only partly broken down
- muscles respire anaerobically when oxygen is in short supply, such as during hard exercise
- fermentation by yeast is used in making bread and alcoholic drinks

How it is marked

- 5-6 marks: compares aerobic with anaerobic in both cell types, giving the products of each, the oxygen requirement and the difference in energy released.
- 3-4 marks: gives correct products for at least two of the three types with some comparison.
- 1-2 marks: states one fact, such as aerobic uses oxygen.

What loses marks

- saying muscles produce ethanol or yeast produces lactic acid
- saying anaerobic respiration releases no energy
- giving oxygen as a product

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4 **Higher tier**

Mr Hussain grows tomatoes in a greenhouse in Lincolnshire during the winter. He records the yield per week under different conditions and the extra cost of each change.

Condition	Yield in kg per week	Extra cost per week in £
No changes	40	0
Extra lighting	44	30
Heater (15 to 25 °C)	52	45
Heater and extra CO_2	70	60

Tomatoes sell for £3 per kg. Evaluate which condition Mr Hussain should use. Give a justified conclusion.

(6 marks)

Model answer

The rate of photosynthesis depends on light intensity, temperature and carbon dioxide concentration. Whichever is in shortest supply limits the rate, and so limits the yield.

Extra lighting gives 4 kg more per week, which is 4 x £3 = £12 of extra income. It costs £30, so he loses £18 a week. This small increase shows that light was not the main limiting factor.

The heater gives 12 kg more, worth £36, but costs £45, so he loses £9 a week. Warmer conditions speed up the enzyme-controlled reactions of photosynthesis, but the gain is not enough to pay for the heating.

The heater with extra carbon dioxide gives 30 kg more, worth £90, for £60, so he makes £30 extra each week. Once the temperature was raised, carbon dioxide became the limiting factor, so adding it increased the rate a lot.

However, these figures are for one week only, and fuel prices or the price of tomatoes could change.

I would advise Mr Hussain to use the heater with extra carbon dioxide, because it is the only option where the extra income is greater than the extra cost.

Marking points (credit any 6 relevant points, linked in a sensible order)

- photosynthesis rate depends on light, temperature and carbon dioxide; the one in short supply is limiting
- extra lighting gives 4 kg more, worth £12, but costs £30, so a loss of £18
- lighting made little difference, so light was not the main limiting factor
- the heater gives 12 kg more, worth £36, but costs £45, so a loss of £9
- higher temperature increases the rate of enzyme-controlled reactions in photosynthesis
- heater and CO_2 give 30 kg more, worth £90, for £60, so a gain of £30
- with the heater on, CO_2 became limiting, so adding it raised the rate a lot
- the burner in a paraffin heater can also supply CO_2
- limitation: only one week of data, and prices and costs may change
- a justified conclusion: heater with CO_2 is the only profitable option

How it is marked

- 5-6 marks: calculates the extra income and profit or loss for each change, explains the results using limiting factors and reaches a conclusion based on the calculations.
- 3-4 marks: compares yields with some cost calculation and some reference to limiting factors.
- 1-2 marks: picks the condition with the highest yield with no consideration of cost.

What loses marks

- choosing the highest yield without working out profit
- comparing cost with mass of tomatoes instead of their value
- not linking the results to limiting factors

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5 An oak tree makes glucose by photosynthesis in its leaves.

Describe how the tree uses the glucose it makes. (6 marks)

Model answer

In photosynthesis, the leaves use light energy to turn carbon dioxide and water into glucose and oxygen. The tree then uses this glucose in several ways.

Some glucose is used in respiration in every living cell of the tree. This releases the energy the cells need, for example for building new molecules and taking up mineral ions by active transport.

Glucose is converted into starch for storage, for example in the roots over winter. Starch is insoluble, so it does not affect the movement of water into and out of cells by osmosis.

Glucose is used to make cellulose. Cellulose is needed to build cell walls, which strengthen the tree's cells and help it grow tall.

Some glucose is turned into fats and oils, which are stored, for example in the acorns as an energy store for the seed.

Glucose is also combined with nitrate ions, taken up from the soil by the roots, to make amino acids. These are joined together to make proteins, such as enzymes.

The sugars are carried from the leaves to other parts of the tree in the phloem.

Marking points (credit any 6 relevant points, linked in a sensible order)

- photosynthesis: carbon dioxide + water to glucose + oxygen, using light energy
- glucose is used in respiration to release energy for the tree's cells
- this energy is used, for example, to build larger molecules and to take up mineral ions by active transport
- glucose is converted into insoluble starch for storage, for example in roots and seeds
- starch is insoluble so it does not affect water movement by osmosis
- glucose is used to make cellulose, which strengthens cell walls
- glucose is used to produce fats and oils for storage, for example in acorns
- glucose is combined with nitrate ions from the soil to make amino acids
- amino acids are joined to make proteins, for example enzymes
- the sugars are carried around the tree in the phloem

How it is marked

- 5-6 marks: describes at least four uses of glucose with detail, including the need for nitrate ions to make protein.
- 3-4 marks: describes two or three uses, with some detail.
- 1-2 marks: names one or two uses with no detail.

What loses marks

- saying glucose is stored as glucose rather than starch
- saying proteins can be made from glucose alone without nitrate
- mixing up cellulose and starch

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