

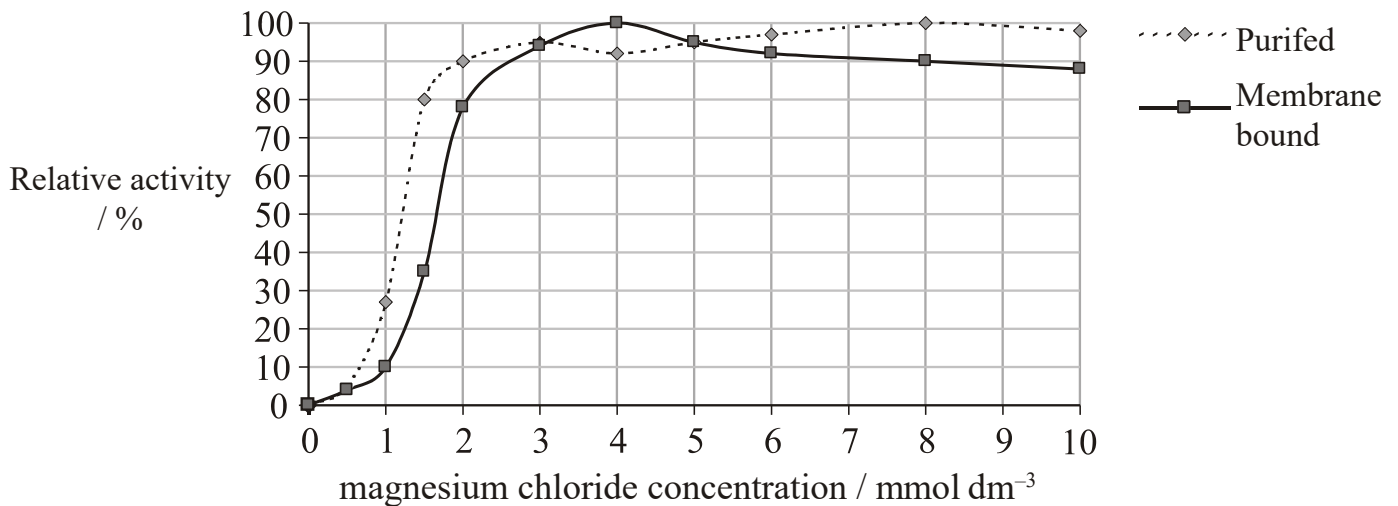
TOPIC 3 – METABOLISM

Immobilised Enzymes (7 marks)

The hydrolysis of inorganic phosphate (P_i) by phosphatase enzyme provides energy for a wide range of reactions. A phosphatase (PPase) occurs bound to thylakoid membranes. This enzyme was purified from the thylakoid membranes of spinach leaves using chromatography. The activity of the membrane bound enzyme and the purified enzyme was measured.

The effect of the concentration of magnesium ions (Mg²⁺) on the relative activity of these enzymes was determined using different concentrations of magnesium chloride. The concentration of inorganic phosphate used in both cases was of 1 mmol dm⁻³.

Activity of phosphatase (arbitrary units)	
Membrane bound	Purified
12 618	1215



a. State the percentage of relative activity of the purified enzyme based on the concentration of magnesium chloride. (2 marks)

- i. 1 mmol dm⁻³
- ii. 2 mmol dm⁻³

b. Outline the effect of magnesium chloride on the relative activity of membrane bound enzymes. (2 marks)

.....

.....

.....

.....

c. Calculate the approximate ratio of inorganic phosphate to magnesium chloride concentration needed to achieve maximum activity in membrane bound enzymes. (1 mark)

.....

d. State the difference in phosphatase activity when membrane bound and when purified. (1 mark)

.....

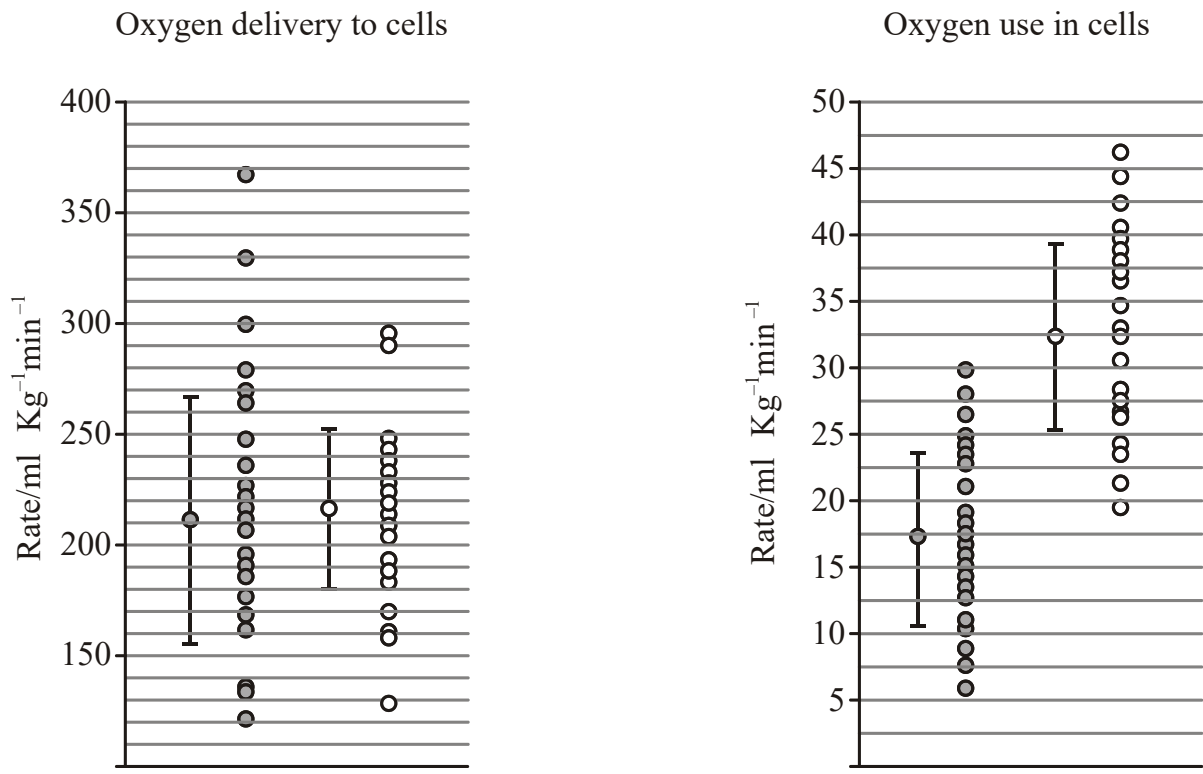
e. Suggest a reason for this difference. (1 mark)

.....

.....

Mitochondrial Myopathy (5 marks)

Mitochondrial electron transport defects (called mitochondrial myopathy) cause tiredness at low levels of exercise and varies from mild to severe. Scientists measured oxygen delivery to cells and oxygen use in cells of thirty-five patients with mitochondrial myopathy. The results were compared to a control group of thirty-two healthy individuals. The results are shown in the two charts below.



Key: ● mitochondrial myopathy group ○ control group

a. State the mean value for oxygen delivery to cells in patients suffering mitochondrial myopathy. (1 mark)

.....

b. Calculate the percentage difference of the oxygen use in cells by the control group compared to oxygen use in cells of patients with mitochondrial myopathy. (1 mark)

.....

c. Discuss why people with mitochondrial myopathy tire more easily than healthy individuals. (3 marks)

.....

.....

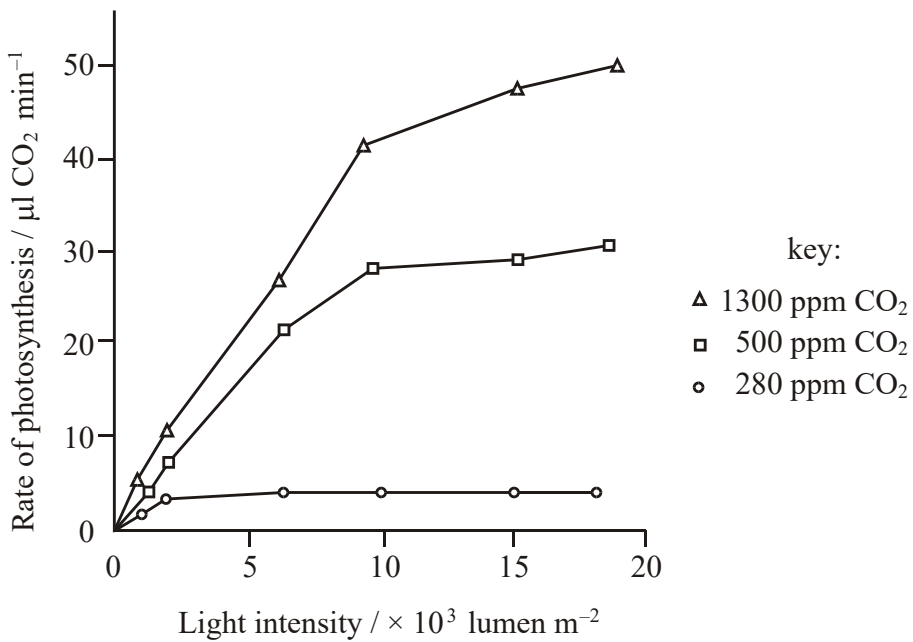
.....

.....

.....

Light Intensity (10 marks)

There are many abiotic factors that affect the rate of photosynthesis in plants. Wheat is an important cereal crop in many parts of the world. Wheat seedlings were grown at three different concentrations of carbon dioxide (in parts per million) and the rate of photosynthesis was measured at various light intensities.



a. Describe the relationship between the rate of photosynthesis and light intensity for wheat seedlings grown at a CO₂ concentration of 500 ppm. (2 marks)

.....

.....

.....

b. Outline the effect of CO₂ concentration on the rate of photosynthesis of the wheat seedlings. (3 marks)

.....

.....

.....

.....

.....

c. The normal atmospheric concentration of CO₂ is 370 ppm. Deduce the effect of doubling the CO₂ concentration to 740 ppm on the growth of wheat plants. (2 marks)

.....

.....

.....

.....

Leaf area and chlorophyll levels were measured in sun leaves and shade leaves of *Hedera helix* (English Ivy) and *Prunus laurocerasus* (Cherry Laurel). Sun leaves developed under maximal sunlight conditions while shade leaves developed at reduced sunlight levels in the shadow of other leaves.

Species	Leaf Type	Chlorophyll/ mg ml⁻¹	Leaf Area/ cm²
Ivy	Shade	4.3	72.6
	Sun	3.8	62.9
Laurel	Shade	4.7	38.7
	Sun	4.2	25.7

d. Calculate the percentage increase in the amount of chlorophyll in shade leaves of ivy compared to sun leaves of ivy. (1 mark)

.....

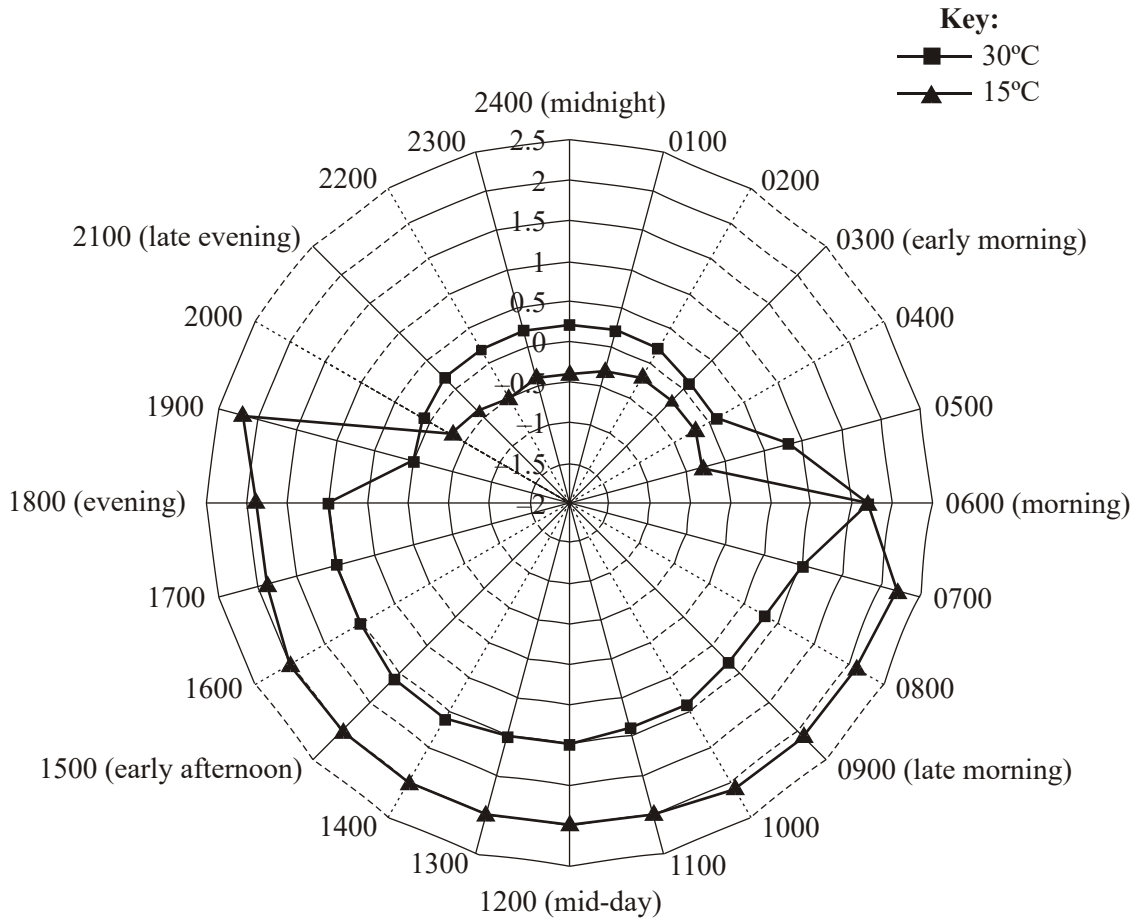
e. Suggest a reason for the differences in chlorophyll concentration and leaf area in sun and shade leaves in these two species. (2 marks)

.....

.....

Carbon Dioxide Uptake (6 marks)

The rate of carbon dioxide uptake by the green succulent shrub *Aeonium goochiae* can indicate the amount of photosynthesis taking place in the plant. This rate was measured at 15°C and 30°C over a 24-hour period. The units of carbon dioxide absorption are $\text{mg CO}_2 \text{ h}^{-1}$. The results are shown below. The centre of the graph corresponds to $-2 \text{ mg CO}_2 \text{ h}^{-1}$ and the outer ring is $+2.5 \text{ mg CO}_2 \text{ h}^{-1}$.



a. Identify a time that carbon dioxide uptake was the same at both temperatures. (1 mark)

.....

b. State the maximum rate of carbon dioxide uptake at 15°C. (1 mark)

.....

c. Compare the rate of carbon dioxide uptake at each temperature in daylight and darkness. (3 marks)

.....

.....

.....

.....

.....

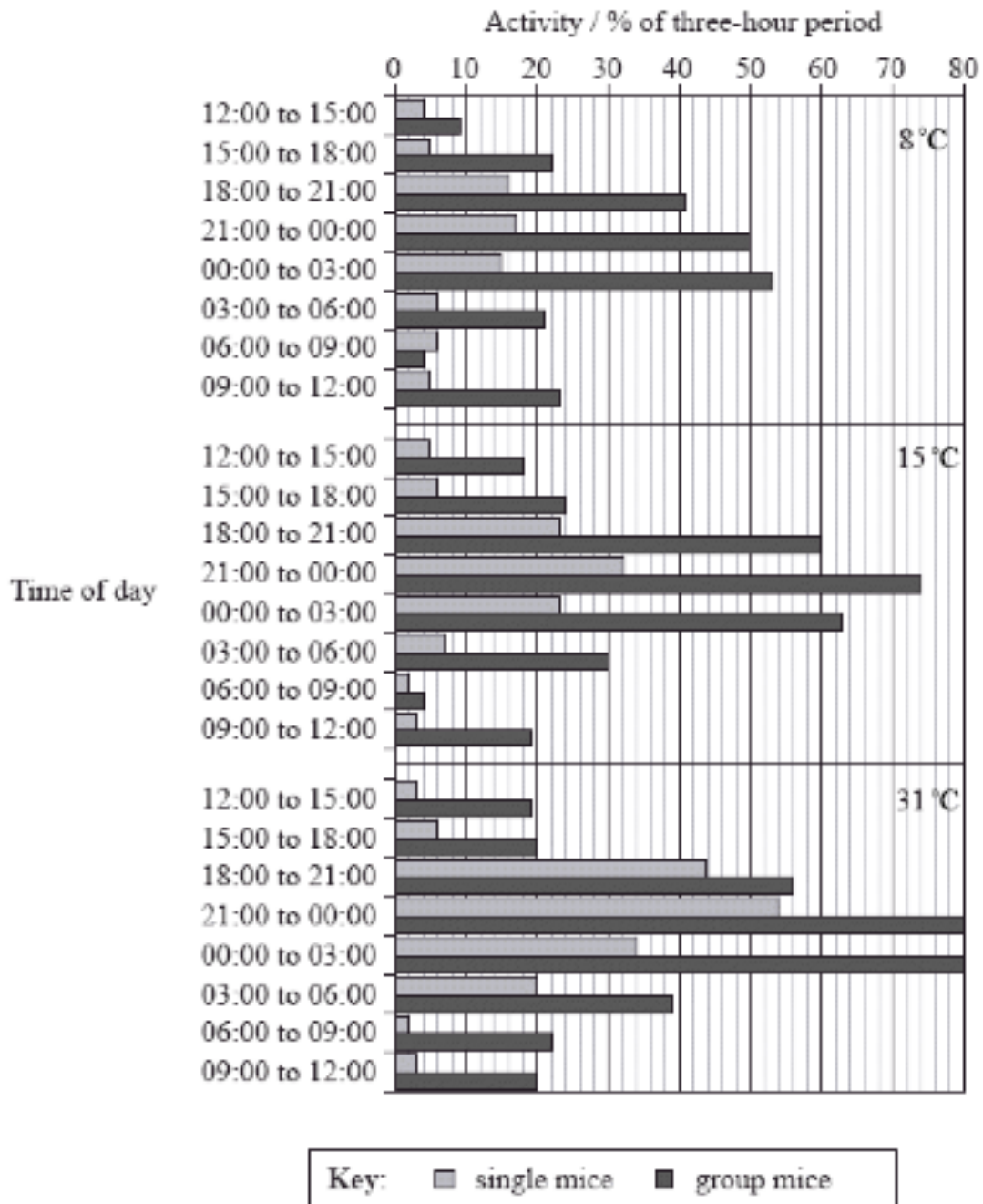
.....

d. Suggest why the carbon dioxide uptake may at times be negative. (1 mark)

.....

Metabolic Rate (11 marks)

Investigators carried out experiments to find the relationship between the energy used by mice (the metabolic rate) and their activity. They found that the amount of time mice are active depends on the time of day, whether they are single or in groups and on the temperature of their surroundings. The bar chart below shows the percentage of time mice were active during three-hour periods at three different temperatures.



a. Calculate how many minutes the group mice are active between 21:00 and 00:00 at 8 °C. (1 mark)

.....

.....

b. Outline the relationship between activity and temperature from 21:00 to 03:00 in all of the mice. (1 mark)

.....

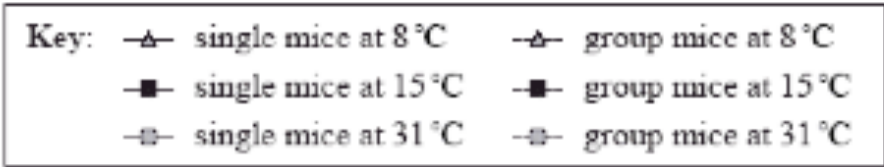
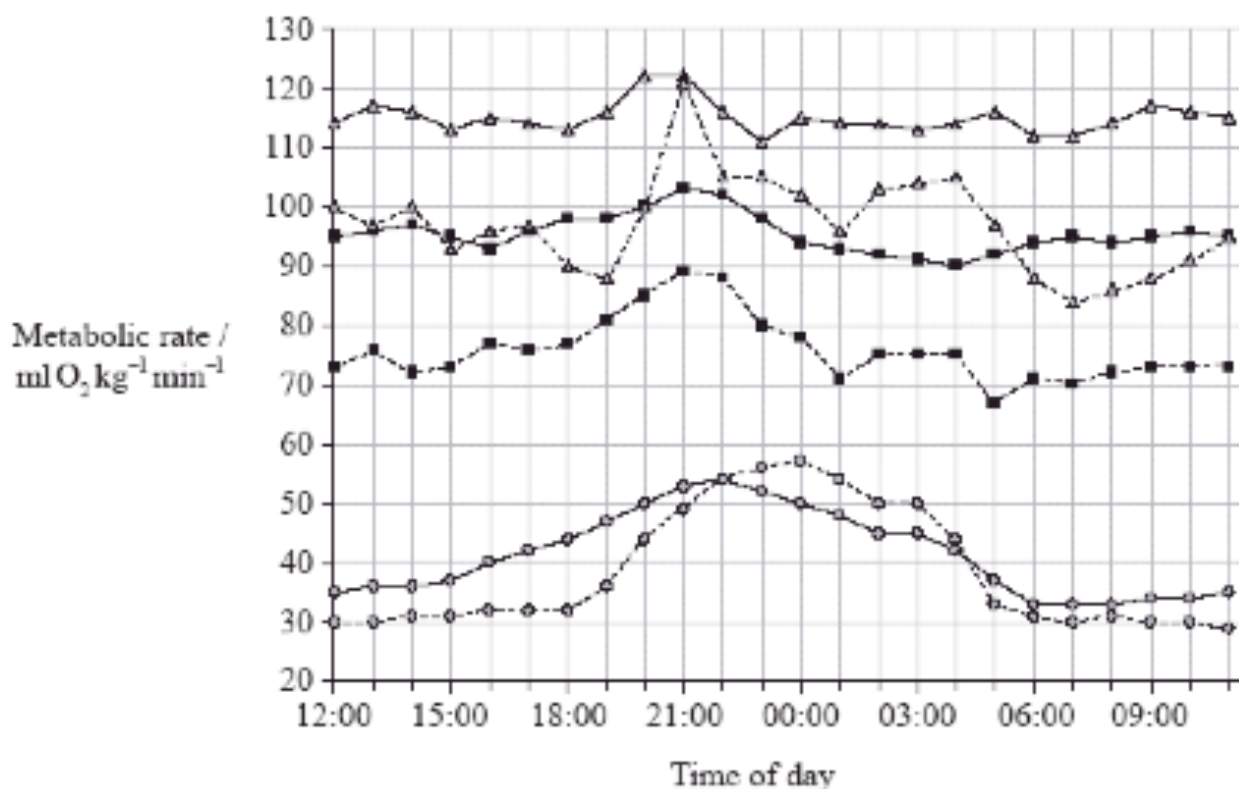
.....

c. Animals that are active at night are nocturnal. Suggest **one** advantage for mice being nocturnal. (1 mark)

.....

.....

The investigators also found that the metabolic rate of the mice changed at different times of the day. Mice were kept at one of the three constant temperatures for 24 hours and their oxygen consumption was measured. The graph below shows the results for single mice and the mean values for group mice.



d. State the relationship between temperature and metabolic rate. (1 mark)

.....

.....

e. Compare the results for the single mice at 15 °C with those for the group mice at 15 °C. (2 marks)

.....

.....

.....

.....

.....

f. Suggest **one** reason why the results differ for single mice and group mice. (1 mark)

.....

.....

g. Explain why oxygen consumption is used as a measure of metabolic rate. (2 marks)

.....

.....

.....

.....

.....

h. Using the data from both graphs, evaluate the hypothesis that increased activity causes an increase in metabolic rate in mice. (2 marks)

.....

.....

.....

.....

.....

Answers

1a (2 marks)

- a. 27 (± 1)
- b. 90 (± 1)

1b (2 marks)

- a. as the concentration of Mg increases the rate increases
- b. most rapid increase between 1 and 2 mmol dm⁻³
- c. peaks at 4 mmol dm⁻³
- d. until it plateaus (at 5 mmol dm⁻³) / no more increase / drops slightly

1c (1 mark)

1:4

1d (1 mark)

- a. membrane bound is 10 times more efficient (12000 to 1200)
- b. difference is (12618-1215) 11403 arbitrary units greater in membrane bound
- c. about 1000% greater / 938.5% greater

1e (1 mark)

- a. purification could have affected structure of protein
- b. bound to membrane allows interactions / other molecules in membrane may help it / be acting as coenzymes

2a (1 mark)

210 ml kg⁻¹ min⁻¹ (± 2) (units required)

2b (1 mark)

Accept 86 (± 2) or 46 (± 2)

2c (3 marks)

- a. oxygen delivery is similar to healthy
- b. oxygen use is lower / half
- c. insufficient energy / ATP produced by aerobic respiration
- d. forced to respire anaerobically
- e. lactic acid builds up

3a (2 marks)

- a. rate of photosynthesis increases (rapidly) / directly proportional
- b. rate of photosynthesis levels off / increases slightly after 10000 lumen m⁻²

3b (3 marks)

- a. maximum photosynthetic rate is highest with highest CO₂ concentration
- b. at low light levels, higher CO₂ slightly increases the photosynthetic rate
- c. at low CO₂ / 280 ppm, the photosynthetic rate reaches its maximum at low light levels / constant over most light intensity / at 280 ppm CO₂ concentration limits photosynthesis
- d. at 500 and 1300 ppm CO₂ the curve is the same shape but with different maximum rates / each higher light intensity requires a higher CO₂ concentration to reach maximum rate
- e. maximum rate of photosynthesis from 280 to 500 ppm / increases 5 to 6 times while 500 to 1300 ppm increases 1.5 times

3c (2 marks)

- a. the rate of photosynthesis will increase (over the rate at 370 ppm)
- b. the photosynthetic rate will at least double (but less than 5–6 times)
- c. not linear **OR** bigger plants / more growth / more grain / greater yield

3d (1 mark)

13.2%

3e (2 marks)

- shade leaves receive less light than sun leaves
- to capture sunlight, shade leaves produce more chlorophyll
- to capture sunlight, shade leaves have greater leaf area

4a (1 mark)

06:00 / 19:30 to 19:45. (Accept 6 am / 7:30 pm to 7:45 pm)

4b (1 mark)

23 mg CO₂ h⁻¹ (±0.1) (units required)

4c (3 marks)

- more uptake at 15°C than 30°C during the hours of daylight
- both are high during the hours of daylight / reverse argument
- greater uptake at 30°C than 15°C during the hours of darkness
- at only 15°C uptake become negative

4d (1 mark)

respiration rate greater than photosynthesis (during the hours of darkness)

5a (1 mark)

90 (minutes)

5b (1 mark)

as temperature increases activity increases/positive correlation

5c (1 mark)

avoid predators / less competition for food

5d (1 mark)

as temperature increases metabolic rate decreases/negative correlation (accept converse)

5e (2 marks)

- metabolic rate of group mice is always less than single mice (accept converse)
- both follow similar pattern of increases/decreases/fluctuations at same time of day
- fluctuations greater in group mice
- both most active/higher metabolic rate during evening/21:00 (accept any reference to times between 18:00 and 00:00)

5f (1 mark)

single mice have more heat loss because more surface exposed to air / group mice huddle to reduce air exposure

5g (2 marks)

- oxygen is required for (aerobic) respiration
- respiration produces ATP/releases energy/heat in the mice
- metabolic rate is a measure of total energy released/consumed in the body / oxygen consumption is proportional to energy released / consumed in body / proportional to metabolic rate

5h (2 marks)

- metabolic activity high when mice more active supports the hypothesis
- activity is normally correlated with energy consumption
- but another factor may be causing both to increase at the same time / correlation does not always establish cause and effect
- grouping/environmental temperature also affect metabolic rate