

4.1 Photosynthesis

Name: _____ Class: _____ Date: _____

Total: 20 marks**KEY WORDS** photosynthesis • limiting factor • endothermic

Objective

Write the photosynthesis equations, interpret limiting-factor graphs, (HT) use the inverse-square law for light, and describe RP6 with pondweed. Original questions for spec statements 4.4.1.1–4.4.1.2, with glucose-use links to 4.4.1.3.

1 Key knowledge and worked examples

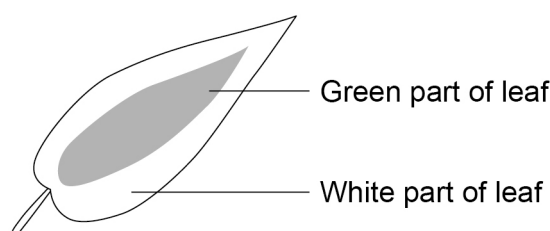
Photosynthesis is endothermic: energy is transferred **from the environment to the chloroplasts by light**.

Word equation: **carbon dioxide + water $\xrightarrow{\text{light}}$ glucose + oxygen**.

Symbol equation: **$6 \text{ CO}_2 + 6 \text{ H}_2\text{O} \xrightarrow{\text{light}} \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2$** .

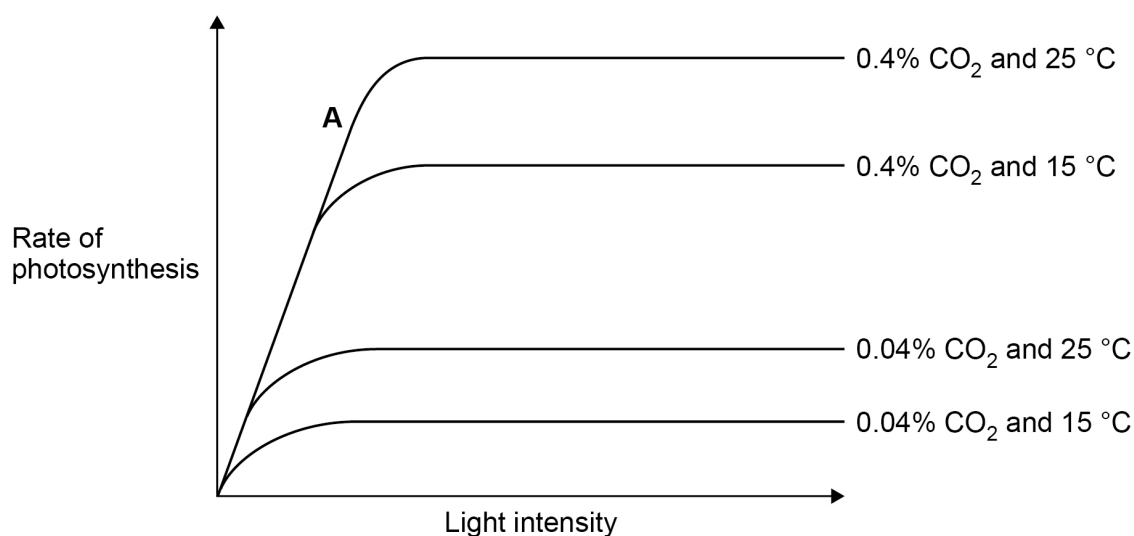
Chlorophyll absorbs light in chloroplasts. Carbon dioxide/water are reactants; glucose/oxygen are products. Glucose can be used in respiration, stored as insoluble starch or fat/oil, or used to make cellulose and amino acids/proteins (also requiring nitrate ions).

Figure 6



Starch evidence: green tissue has chlorophyll, absorbs light and makes glucose that can form starch; white tissue lacks chlorophyll. Black paper blocks light; sealed transparent plastic prevents CO_2 entry. Starch is not the direct product of photosynthesis.

Rate factors: light intensity supplies energy; CO_2 is a reactant; chlorophyll absorbs light; temperature affects enzymes. A light/ CO_2 plateau means another factor limits. Temperature rises towards an optimum, then falls as enzymes denature; there is no universal optimum temperature.

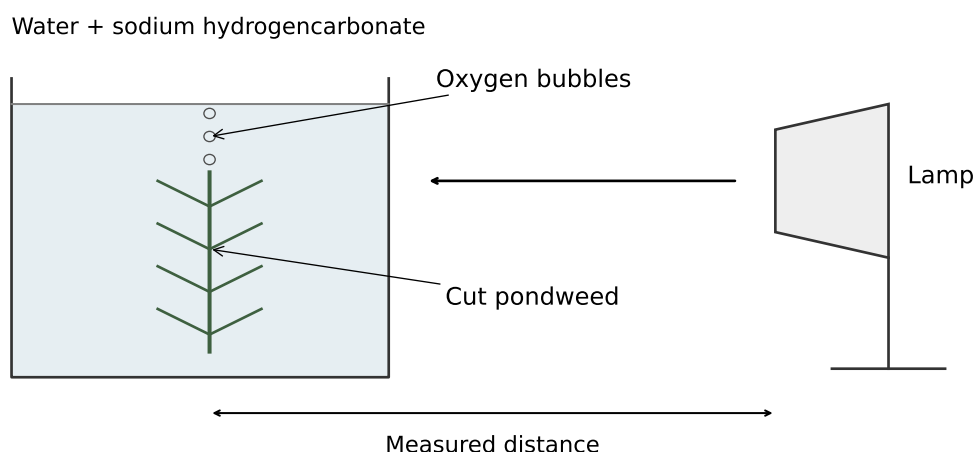


(HT) Graph reading: compare curves at the same light intensity. At fixed CO_2 , $15 \rightarrow 25^\circ\text{C}$ increases rate through faster enzyme-controlled reactions; at fixed temperature, $0.04 \rightarrow 0.4\%$ CO_2 supplies more reactant. At high-light plateaus another factor limits. On the original 2023 graph, the straight 0–5 000 lux section follows $y = mx + c$; the axis reads thousands of lux.

(HT) Inverse square: $I_2/I_1 = (d_1/d_2)^2$ for the same lamp. At $10 \rightarrow 20$ cm, intensity quarters. A rate prediction (40 $\rightarrow$ 10 bubbles/min) also assumes light limits in an approximately proportional region and temperature/ CO_2 are unchanged. At $15 \rightarrow 45$ cm: distance factor = $45/15 = 3$; $I_2/I_1 = (15/45)^2 = 1/9$, so intensity decreases to one ninth. This law predicts intensity, not automatically photosynthesis rate.

(HT) Greenhouses: change a factor that currently limits; explain the mechanism, then compare extra crop revenue with lighting/heating/ CO_2 cost. Heating towards the optimum helps enzyme reactions, not unlimited heating; heating alone does not necessarily add CO_2 .

RP6: pondweed in sodium hydrogencarbonate solution; vary measured lamp distance, allow adjustment, measure oxygen output in a fixed time; repeat and mean. Maintain temperature with a water bath/check with a thermometer; keep CO_2 constant; keep pondweed size/timing consistent. Rate = bubble count/time or oxygen volume/time. To improve volume accuracy, collect oxygen in a gas syringe or inverted measuring cylinder: bubble sizes vary. Repeats address random variation, not that size limitation.



Worked rate (2025 Q04.2): ten bubbles take 43 s at 20°C. Rate = count/time; rate = 10 bubbles / 43 s = 0.232558... bubbles/s; **rate = 0.233 bubbles/s** (3 sf). For ten bubbles at 10, 20, 30, 40 and 50°C, original times are 84, 43, 27, 25 and 33 s. Independent variable: temperature. Dependent variable: measured time. At 40°C versus 10°C rate is higher: greater kinetic energy → more frequent collisions. Shorter time for fixed output means higher rate.

Leaf discs (2023 application): vary colour with coloured LEDs or filters; time ten discs reaching the surface. Remove initial air so discs sink; hydrogencarbonate supplies CO₂; photosynthesis produces oxygen trapped in/around discs, making them rise. Blue 115 s / green 831 s / red 397 s: blue is fastest. The supplied spectrum shows about 80% absorption near 490 nm (blue 450–499 nm), but very little in green 500–570 nm. Explain colour → absorption → photosynthesis/oxygen → rise time. Two chlorophyll types broaden usable wavelengths, not all wavelengths.

2 Practice

2.1 Write the word equation for photosynthesis.

[1]

2.2 Photosynthesis is endothermic. State the source of the energy and where in the cell the reaction happens.

[2]

2.3 Sketch the graph of rate of photosynthesis against temperature, labelling the optimum.

[2]

3 Exam-style questions

3.1 A student grows pepper plants in a greenhouse. Explain two ways the student could increase the rate of photosynthesis, and one economic problem of each. [6]

3.2 (*HT*) A lamp is 15 cm from pondweed. The lamp is moved to 45 cm. Explain, with a calculation factor, how the light intensity changes. [3]

3.3 Describe how a student could investigate the effect of light intensity on the rate of photosynthesis using pondweed, including how the rate is calculated and two control variables. [6]

Solutions

2.1 Carbon dioxide + water → glucose + oxygen, with light energy.

2.2 Light (energy transferred from the environment); in the chloroplasts.

2.3 Curve rising to a peak then falling; optimum labelled at the peak.

3.1 Teacher rubric: two distinct changes, 3 marks each (max 6). For each: name the change (1), explain why it raises the rate under the stated limiting conditions (1), give its economic problem (1). Example: add lighting (1), supplying more light energy if light is limiting (1), but electricity cost may exceed extra crop revenue (1). Alternative: add CO₂ (1), supplying more reactant if CO₂ is limiting (1), but CO₂ supply costs may exceed the extra revenue (1). Alternative: heat towards the optimum (1), increasing enzyme-controlled reaction rate if temperature limits (1), but heating costs may outweigh extra revenue (1). Heating alone does not necessarily add CO₂; do not conflate the two.

3.2 Distance factor = $45 \div 15 = 3$ (1); using inverse-square dependence, new/old intensity = $(15/45)^2 = 1/9$ (1); intensity becomes one ninth of the original, a decrease (1). This predicts light intensity, not automatically the photosynthesis rate.

3.3 Pondweed in water with sodium hydrogencarbonate; use bubble counts or collect oxygen volume in a gas syringe/inverted measuring cylinder; lamp at measured distances, e.g. 10, 20, 30 cm, left to adjust for a few minutes each time; count bubbles per minute, repeat and take a mean; rate = bubbles ÷ time (or volume of gas per minute); controls: same temperature – water bath maintains it, thermometer monitors it; same CO₂ concentration and same pondweed length/water volume.