# 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

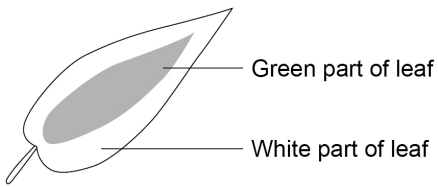
**Photosynthesis** is **endothermic**: energy is transferred **from the environment to the chloroplasts by light**.

Word equation: **carbon dioxide + water –light→ glucose + oxygen**.

Symbol equation: $\mathbf{6\ CO_2 + 6\ H_2O \xrightarrow{light} C_6H_{12}O_6 + 6\ O_2}$.

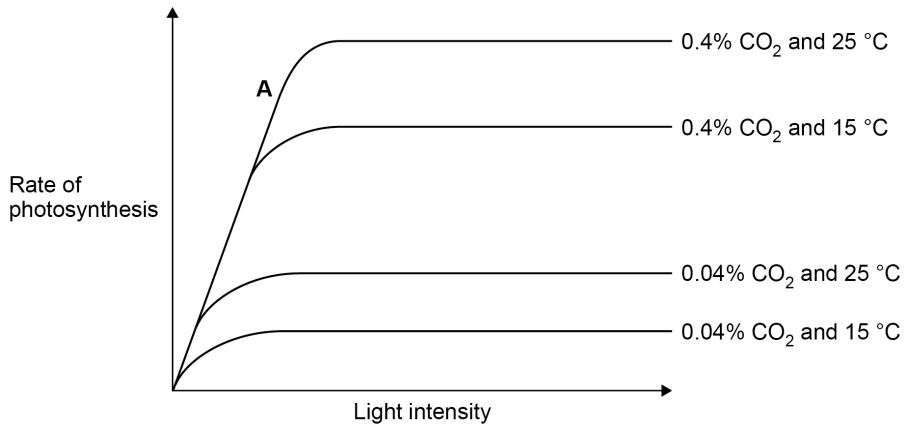
Chlorophyll absorbs light in chloroplasts. Carbon dioxide/water are reactants; glucose/oxygen are products. Glucose can be used in respiration, stored as insoluble starch or fat/oil, or used to make cellulose and amino acids/proteins (also requiring nitrate ions).

**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.

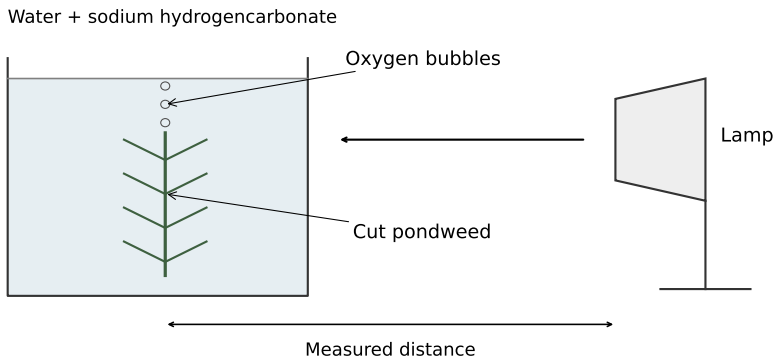



**(HT) Graph reading:** compare curves at the same light intensity. At fixed $CO_2$, 15→25°C increases rate through faster enzyme-controlled reactions; at fixed temperature, 0.04→0.4% $CO_2$ supplies more reactant. At high-light plateaus another factor limits. On the original 2023 graph, the straight 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→20 cm, intensity quarters. A rate prediction (40→10 bubbles/min) also assumes light limits in an approximately proportional region and temperature/$CO_2$ are unchanged. At 15→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 $CO_2$; 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 $CO_2$ (1), supplying more reactant if $CO_2$ is limiting (1), but $CO_2$ 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 $CO_2$; 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 $CO_2$ concentration and same pondweed length/water volume.