InkBiology

ANSWER BOOK

The Calvin cycle: three steps, and the arithmetic behind them

Photosynthesis and primary productivity · Unit B13

AQA 3.5.1 · OCR A 5.2.1 · Edexcel A Topic 5.5 · CAIE 13.1

6 questions · 21 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 **B1** the enzyme is rubisco, also called RuBP carboxylase. **B1** one turn produces two molecules of GP. [2]

SECTION B · Standard, 3 to 5 marks

B1 **M1** each turn fixes one carbon dioxide and a hexose holds six carbons, so six turns are needed per hexose and 6 × 2 = 12 turns in all. **M1** each turn makes two GP and each GP is reduced to one triose phosphate, so 2 × 12 = 24 molecules of triose phosphate. **A1** reducing 24 molecules of GP uses 24 ATP and 24 reduced NADP, one of each per molecule. **M1** regenerating RuBP costs one further ATP per turn, so 12 more ATP. **A1** 36 molecules of ATP and 24 molecules of reduced NADP in total, which is eighteen ATP per hexose. [5]

B2 **B1** fixation: rubisco joins one molecule of carbon dioxide to the five-carbon RuBP, and the six-carbon product is so unstable that it splits immediately into two molecules of GP. **B1** reduction: GP is reduced to triose phosphate, with reduced NADP supplying the hydrogen and ATP supplying the energy for the reaction. **B1** the oxidised NADP and the ADP go straight back to the thylakoid membranes to be used again. **B1** regeneration: most of the triose phosphate is rearranged, at a further cost in ATP, back into RuBP, while the rest leaves the cycle to be built into hexose sugars, lipids or amino acids. [4]

B3 **B1** ATP and reduced NADP are made only in the light and are not stored in quantity, so within seconds the blocked step is the reduction of GP to triose phosphate. **B1** GP rises, because it lies immediately before the block: rubisco carries on fixing carbon dioxide onto the RuBP still present, so GP is still being made and is no longer being used. **B1** triose phosphate falls, because it lies immediately after the block: it is still being used and is no longer being made. **B1** RuBP falls as well, because it is still being consumed by fixation but is regenerated from triose phosphate, and there is no longer any triose phosphate to regenerate it from. [4]

B4 **B1** the ten that remain hold thirty carbons, which is exactly the number needed to rebuild the six molecules of RuBP the six turns started from. **B1** RuBP is not supplied from outside the chloroplast, so the only source of it is the regeneration of triose phosphate. **B1** if all twelve left, there would be no acceptor for the next carbon dioxide and the cycle would stop after a single round, so no further carbon could be fixed. [3]

B5 **B1** the stomata close to conserve water, so carbon dioxide entering the leaf falls while the oxygen made by photosynthesis builds up inside it. **B1** the active site of rubisco accepts oxygen as well as carbon dioxide, so with the ratio of the two gases shifted the enzyme takes up oxygen more often. **B1** when it does, the products are one GP and a two-carbon compound the plant has to spend energy recovering, so less carbon is fixed into the cycle and productivity drops. [3]