13. Photosynthesis

13.2 Investigation of Limiting Factors

Paper 4

Marking Scheme

Q1.

7(a)(i)	1 rate of oxygen produced / rate of photosynthesis, is low / stays constant **or** small decrease in, rate of oxygen produced / rate of photosynthesis ; 2 light intensity was the limiting factor / AW ; 3 (so) less / little, light energy absorbed / photolysis (of water) / photoactivation (of chlorophyll)/ light-dependent reactions / photophosphorylation ; **R** no light energy absorbed	**3**

7(a)(ii)	*any **three** from:* 1 rate of oxygen produced / rate of photosynthesis, decreased ; 2 two paired data quotes with units ; 3 because, enzyme / ATP synthase / NADP reductase / oxygen evolving complex, denatured ; **A** rubisco 4 change in active site / fewer ESCs ;	**3**

temperature / °C	rate of oxygen production / $mm^3\ h^{-1}$
30	4 / 4.00
40	2.55
50	0.65 (**A** 0.62-0.65)

Q2.

5(b)(i)	*any **three** from:* **D1** rate of energy transfer, higher / highest, for tropical **or** rate of energy transfer, lower / lowest, for snow forest ; **D2** paired data quote with units (at least once) ; **S3** tropical forest has, high(er/est) temperature / hot(ter) ; **S4** tropical forest has high(er/est) light, intensity / duration ; **S5** temperature / light intensity, is a limiting factor (on photosynthesis) ;	**3**

5(b)(ii)	*any **three** from:* **1** more, transpiration / water loss (from leaves) ; **2** stomata shut reducing, carbon dioxide (entry) / gas exchange ; **3** (so) carbon dioxide (concentration) is a limiting factor ; **4** (grassland / desert) fewer plants / less plant cover / smaller plants ; **5** (so smaller surface area) less light absorbed ; **6** AVP ;	**3**

Q3.

4(b)	*any **two** from:* **1** less / decreased, surface area (of leaf exposed) ; **2** less light absorbed by, chloroplasts / thylakoid membranes / grana / pigments / chlorophyll / light harvesting complexes / photosystems ; **3** fewer stomata, exposed / available (to air) ; **4** less carbon dioxide, enters / absorbed ;	**2**

Q4.

8(a)(i)	*any **two** from:* 1 higher rate of activity (of rubisco) in GM rice (throughout) ; 2 (low CO_2 concentrations) rate of activity for both increases ; 3 comparative figures – GM and non-GM at one CO_2 concentration ;	**3**

atmospheric CO_2 concentration / mg dm^{-3} ±5	rate of activity of rubisco / arbitrary units	
	non-GM rice ±0.05	GM-rice ±0.05
0	0.7	0.80
100	1.8	2.70
200	2.4	3.95
280	2.6	4.15
300	2.6	4.15
400	2.6	4.30
500	2.6	4.45
600	2.6	4.55

8(a)(i)	*plus* *levels off because:* 4 carbon dioxide <u>concentration</u> no longer limiting **or** light <u>intensity</u> limiting **or** temperature limiting **or** rubisco active sites saturated (with carbon dioxide) **or** less RuBP available ;	

Q5.

8(c)(i)	$\frac{3.10-1.55}{15}$ **or** $\frac{3.10-1.50}{15}$; 0.10 / 0.11 ;	**2**
8(c)(ii)	*any **three** from:* 1 temperature now not limiting **or** carbon dioxide concentration now limiting ; 2 closure of stomata ; 3 lack of water / **AW** ; 4 denaturation of enzymes **or** active site no longer complementary to substrate / no ESCs form ; 5 AVP ; e.g. *ref. to* optimum temperature / photorespiration occurs	**3**

8(c)(iii)	similar shape but below high intensity curve ;	**1**

Q6.

8(a)	letter **X** on rising slope to the left of the angle where line plateaus ;	**1**

8(b)(iii)	*any **three** from:* 1 in high light intensity plant can photosynthesise more ; 2 so they need (more) / upregulate / increase / make (more) (named) enzymes / proteins, for photosynthesis ; 3 (plus) named, enzyme / protein (for photosynthesis) ; 4 (named) pigments to protect cells from excess light ; 5 enzymes to make, sucrose / starch / amino acids ; 6 proteins for, sucrose / amino acid, transport ; 7/8 AVP ;; e.g. DELLA breaks down releasing, phytochrome interacting factors / PIF	**3**

Q7.

2(c)	*any **three** from:* 1 ref. (named) <u>enzymes</u> ; 2 high(er) temperature increases rate ; 3 (temperature affects) photophosphorylation / light-dependent / Calvin cycle / light-independent / ESC formation ; **ora** 4 enzymes denature at, too high a temperature / very high temperature / above optimum temperature ; 5 AVP ;	**3**

Q8.

2(a)(i)	*any **two** from:* 1 *ref. to* light energy / photons ; 2 for, light-dependent stage / photophosphorylation / photolysis / photoexcitation / photoactivation ; 3 to make, reduced NADP / ATP ; 4 to open stomata (for CO_2 to enter) ;	**2**

Q9.

5(b)	100 ;	**1**
5(c)(i)	**1** 0 – 400 ; **A** up to 400 **I** units *any **two** from:* **2** temperature / concentration of carbon dioxide, becomes the limiting factor ; **3** (at a lower than optimum temperature) less kinetic energy so fewer collisions between rubisco and CO_2 **or** a lower temp will limit the rate of (named) enzyme-controlled reactions ; **4** (with a lower than optimum CO_2 concentration) less fixation of CO_2 / AW ; **5** all, enzymes / processes, in photosynthesis, already at, highest rate / optimum **or** maximum amount of light is being absorbed (by the pigments) ;	**3**
5(c)(ii)	*any **three** from:* **1** different wavelengths of light absorbed by different pigments ; **2** red light is absorbed the most ; **3** green light is, absorbed less / reflected ; **4** shorter the wavelength the greater the energy / red light has more energy (than blue light) ; **ora** **5** the more, light / energy, absorbed the more, light dependent reaction / photophosphorylation, occurs ; **ora**	**3**

Q10.

1(b)(i)	**1** (from 0.25) to 1.00 (mol dm^{-3}), concentration / CO_2, is limiting factor **or** at / >, 1.00 (mol dm^{-3}), concentration / CO_2, no longer limiting factor ; **2** at / >, 1.00 (mol dm^{-3}), light intensity / temperature, is limiting factor ; **3** CO_2, needed / used, for Calvin cycle / for light independent stage **or** CO_2, reacts with / fixed by, RuBP ;	**3**
1(b)(ii)	little / no, photosynthesis ; (aerobic) respiration uses oxygen ;	**2**
1(b)(iii)	*any **three** from:* **1** to control a variable / to ensure a fair test / so CO_2 is the only variable ; **2** low, temperature / kinetic energy, decreases, rate / reaction / photosynthesis / O_2 production / O_2 increase ; **3** low, temperature / kinetic energy, decreases, (named) enzyme-substrate, collisions / complexes ; **4** low(er) temperature, is a limiting factor / may limit rate ; **5** high, temperature / kinetic energy, decreases, rate / reaction / photosynthesis / O_2 production / O_2 increase ; **6** high, temperature / kinetic energy, denatures (named) enzyme(s) ; **7** high / increased, temperature, causes / increases, photorespiration ;	**3**

Q11.

2(a)(i)	*any **four** from:* *differences* 1 cotton (enzyme / rubisco activase) has a higher, optimum temperature / temperature at which activity is highest ; **ora** 2 maximum / highest / peak, activity higher in flax (enzyme / rubisco activase) (than in cotton) ; **ora** 3 cotton (enzyme / rubisco activase) can work at higher temperature (than flax) ; 4 (at stated temp) <30 °C flax (enzyme) has higher activity than cotton ; **ora** 5 (at stated temp) >30 °C cotton (enzyme) has higher activity than flax ; **ora** *similarities* 6 (activity of) both increases then decreases as temperature increases ; 7 (enzyme / rubisco activase) activity, same / 0.104 (au), at 30 °C ;	**4**
2(a)(ii)	*any **three** from:* 1 cotton, is adapted to / lives in areas with, high(er) temperatures ; **ora** 2 *ref. to* different, genes / alleles (in cotton vs. flax) ; 3 *ref. to* different primary structure of rubisco activase (in cotton vs. flax) ; 4 *ref. to* different tertiary structure of rubisco activase (in cotton vs. flax) ; 5 AVP ;	**3**

Q12.

1(c)(i)	**1** oxygen, combines / reacts, with, rubisco / RuBP ; **2** less / no, carbon dioxide, combines / reacts, with, rubisco / RuBP ; **A** less or no carbon fixation **3** *ref. to* photorespiration ; *ignore refs to denaturation*	**2**

1(c)(ii)	*any **three** from:* **1** photosynthesis (by C3 plants) is occurring ; **2** decrease in (atmospheric) carbon dioxide **or** increase in (atmospheric) oxygen **or** increase in / high, oxygen to carbon dioxide ratio ; **3** rubisco favours reaction with oxygen / AW ; **4** C4 plants have a selective advantage / description ; **5** oxygen acts as a selection pressure ; **6** AVP ; e.g. *ref. to* mutation in C3 plants	**3**

Q13.

1(c)(i)	*any **four** from:* **1** as temperature increases rate increases, up to 25 °C / at low temperatures, for both ; **2** as temperature increases rate decreases, above 35 °C / at high temperatures, for both ; **3** C3 rate higher, at low temperatures / < 22 °C ; **4** C3 rate lower, at high temperatures / > 22 °C ; **5** C3, peak rate / maximum rate / optimum T °C, at 25 °C **and** C4, peak rate / maximum rate / optimum T °C, at 30–35 °C ; **6** C3 has lower, maximum rate / peak ; **7** C3, maximum rate / peak, is at lower temperature **or** C3 has a lower optimum temperature ; **8** comparative data quote ;	**4**
1(c)(ii)	*comparison* rate, higher / faster, high CO_2 conditions ; (at 30–35 °C) rate is maximum for both ; *explanation (max 1)* carbon dioxide, limits rate / is limiting factor, in low CO_2 conditions ; AVP ;	**2**

Q14.

5(b)(i)	more carbon dioxide react with RuBP / more CO_2 fixation / more carbon dioxide available to bind to rubisco ; **ora** more, Calvin cycle / light independent reaction / detail ; **ora**	**2**
5(b)(ii)	*any **three** from:* 1 as day length increases rate (of photosynthesis) increases / positive correlation ; 2 data quote: two day lengths in hours **and**, two carbon dioxide concentrations / difference between two carbon dioxide concentrations ; 3 more light is absorbed by, photosystems / pigments / named pigment ; 4 *ref. to* more, photophosphorylation / light dependent reaction / photolysis ; 5 more, oxygen / reduced NADP / ATP / glucose / starch, produced ;	**3**

5(c)(i)	(pH 8.4) optimum pH of, rubisco / enzymes ; fewer, H^+ / protons, result in higher rate of, photosynthesis / activity of enzymes ;	**2**
5(c)(ii)	*idea of* less carbon dioxide, absorbed / fixed (so ocean acidification not reduced) ;	**1**

Q15.

7(c)	*any 3 of:* *describe* 1 (enzyme in) *Amaranthus* / C4, peaks, at higher temperature **or** (enzyme in) *Amaranthus* / C4, has higher optimum temperature **or** (enzyme in) *Pisum* / C3, has higher activity at low(er) temperatures ; **ora** 2 data quote ; e.g. C4 – 45 °C **and** C3 – 30 °C at 100% **or** C4 – 70% **and** C3 – 25% at 50 °C ; *explain* 3 enzyme in, *Pisum* / C3, less thermostable / denatures at lower temperature ; **ora** 4 AVP ; e.g. *Amaranthus* adapted to a hot climate / **ora** e.g. enzyme in *Amaranthus* has more S-S bonds	**3**