Mark scheme - Photosynthesis

Question			Answer/Indicative content	Marks	Guidance
1			C	1	
			Total	**1**	
2			B	1	
			Total	**1**	
3			D ✓	1	
			Total	**1**	
4			C ✓	**1**	**Examiner's Comments** Despite the novel approach, few were significantly challenged by this question which was answered correctly by a high proportion of candidates. However, some candidates were caught out by the presence of NAD in options **A** and **B** as opposed to NADP needed for the correct response, option **C**.
			Total	**1**	
5			C ✓	**1**	**Examiner's Comments** Candidates did have to process some information from a graph in this question and choose appropriate values to perform a percentage change calculation. Whilst candidates often struggle with such calculations in the question styles of section **B**, this posed little problem for nearly 80% of candidates who identified option **C** as the correct response.
			Total	**1**	
6			A ✓	**1**	**Examiner's Comments** There were many correct responses for the reason why *V.minimum* did not need chloroplasts with candidates demonstrating the ability to make deductions from information provided.
			Total	**1**	
7			D ✓	1	**Examiner's Comments**

					Option **A** provided a distractor and common incorrect response to the correct option, **C** in this question as statement 1, whilst correct, was irrelevant to the question being asked about ecdysone. Option B provided a distractor and common incorrect response to the correct option, D, in this question. This is possibly due to misconceptions surrounding the synthesis of ATP by different methods of phosphorylation.
			Total	**1**	
8			D ✓	1 (AO2.7)	**Examiner's Comments** Candidates that understood the principles of light absorption by pigments chose D as the correct option. However, the question proved challenging for some candidates and there was confusion as to which wavelengths of light (blue or red) were absorbed or reflected by the blue pigments in the Cyanobacteria.
			Total	**1**	
9	a	i	9.7×10^{-3} **OR** 0.0097 ✓✓✓	3	**IGNORE** + or - **ALLOW two marks** if answer is correct but not to two S.F. **ALLOW two marks** if answer is incorrect for correct calculation e.g. $\frac{0.05^2 \times \pi \times 3.7}{3}$ **OR** $\frac{0.029}{3}$ **ALLOW one mark** for $0.05^2 \times \pi \times 3.7$ **OR** 0.029 **Examiner's Comments** Mathematical skills were being assessed in this part of the question. To achieve all three marks a great deal of processing was required. Candidates had to choose the

					correct figure from Table 22.1, calculate the radius using the figure given for diameter, substitute their figures into the equation provided and then divide by three to obtain a response in mm^3 per hour. Many candidates were credited with all three marks. Many others gained two marks for a correct calculation because they had not written their response to two significant figures. Some candidates appeared to forget to divide by three and gained one mark, others used the diameter instead of the radius in their calculation which was not credited.
		ii	140 (two s.f.) /142 / 141.7 / 141.67 / 141.6· ✓✓	2	**ALLOW** one mark if answer is correct but 'decrease' has been calculated so response given as 'minus' number If answer is incorrect **ALLOW one mark** for $\frac{2.9-1.2}{1.2} \times 100$ **OR** $\frac{1.7}{1.2}$ x 100
		iii	removing CO_2 would prevent photosynthesis ✓ CO_2 would be a limiting factor for photosynthesis ✓	1 max	**ALLOW** Calvin cycle / light independent stage for photosynthesis throughout **ALLOW** e.g. so they could still photosynthesise e.g. CO_2 needed for photosynthesis
	b		at 1510 (lux) the distance moved by the fluid (in respirometer) is , zero / 0 ✓ at 1510 (lux) rate of photosynthesis is equal to rate of respiration ✓ at 1510 (lux) there is no <u>net</u> change in volume in the respirometer ✓	2 max	'at 1510 (lux)' only needs to be mentioned **once** throughout **ALLOW** at 1510 (lux) compensation point has been reached **<u>Examiner's Comments</u>** Many candidates demonstrated the ability to use the data in Table 22.1 to describe the results for 1500 lux and conclude from this that the rates of respiration and photosynthesis were equal, thereby gaining both marks.
			Total	**8**	
10				2 max	**IGNORE** reference to external membrane **ALLOW** plants (chloroplasts) have more

			Chromista (chloroplast) has <u>fewer</u> thylakoids ✓ *Chromista* (chloroplast) has no , inter-granal lamellae / lamellae between thylakoids ✓ plants (chloroplasts) have thylakoids in groups of more than three ✓ plants (chloroplasts) have starch grains / *Chromista* (chloroplast) does not have starch grains ✓		thylakoids **ALLOW** plant (chloroplasts) have lamellae between thylakoids **ALLOW** thylakoids in plant (chloroplasts) form grana **IGNORE** *Chromista* (chloroplast) has thylakoids in groups of three **<u>Examiner's Comments</u>** This part of the question was generally well-answered with a good demonstration of knowledge across the ability range regarding the presence of grana, inter-granal lamellae and a greater number of thylakoids in the chloroplasts of flowering plants compared to Chromista. It was important for candidates to specify which chloroplast was being discussed to achieve full marks.
			Total	**2**	
11		i	*idea of* little (visible) light available / plants absorb most light available / only certain wavelengths of light available underwater ✓ *idea of* it absorbs light, at different wavelengths, compared to aquatic plant species ✓ *idea of* absorbs wider range of wavelengths (compared to chlorophyll A alone) ✓	1 (AO3.2)	e.g. 'longer wavelengths of light available in their aquatic environment' e.g. 'able to use, far red / longer, wavelengths compared to aquatic plants' e.g. 'able to absorb wavelengths of light that Chlorophyll A does not'
		ii	Z✓	1 (AO2.8)	
			Total	**2**	
12		i	pigment A contains 2, components / molecules (1) pigments B and D contain 1, component / molecule (1) pigment C contains 3, components / molecules (1) *idea that* pigments A and C share	3	

			2, components / molecules (1) *idea that* pigments A and D **OR** pigments B and C **OR** pigments C and D share 1, component / molecule (1) all pigments are soluble (in liquid phase) (1)		
		ii	0.35 ± 0.01 (1)(1)	2	**ALLOW** 1 mark for evidence of 19 ÷ 55 1 mark maximum for incorrect s.f.
			Total	**5**	
13		i	(pigments) absorb , light / photons ✓ electrons , excited / raised to higher energy level ✓ accessory pigments pass energy to , reaction centres / primary pigments ✓ primary pigments , become oxidised / lose electrons / pass electrons to ETC ✓ for light dependent reaction / photophosphorylation ✓	4 max	**ALLOW** named accessory pigments e.g. chlorophyll b / xanthophyll / carotenoids **ALLOW** chlorophyll a for primary pigment **ALLOW** for making , ATP / reduced NADP **Examiner's Comments** AO1 was assessed in this part of the question. Many candidates were able to state that pigments absorbed light, excited electrons and were important in a named stage or process in photosynthesis. Mark points 3 and 4 were most often credited to higher ability candidates who were able to differentiate between primary and accessory pigments and their relevant roles.
		ii	*idea that* they have to absorb light of short (er) wavelengths ✓ *idea that* some wavelengths (of light) don't reach , depths / them ✓	1 max	**ALLOW** blue / blue-violet light **ALLOW** wavelengths between 400 and 500nm **ALLOW** high(er) frequency e.g. some wavelengths of light may not reach *Chromista* if they are in deep water **Examiner's Comments** There were few correct responses for this part of the question which was assessing AO2. Many candidates were able to appreciate that living in water was the reason

					behind the need for a different pigment but did not mention the fact that it was because only certain (shorter) wavelengths of light penetrated sufficiently to reach Chromista.
			Total	**5**	
14		i	silica (gel) ✓	**1**	**ACCEPT** aluminium oxide / alumina / cellulose / zirconium oxide / silicon dioxide **DO NOT ACCEPT** paper / silicon / aluminate **IGNORE** plastic / Perspex **Examiner's Comments** A relatively small number of candidates were able to state a material that could be used in the stationary phase of thin layer chromatography. Silica gel was the most frequent correct answer although other suitable alternatives, such as silicon dioxide or aluminium oxide, were occasionally seen. Many candidates erroneously suggested paper or named a solvent.
		ii	photosystems ✓ (in) thylakoid (membranes) ✓	**2**	**ACCEPT** antenna complex / reaction centre / light harvesting, clusters / systems **IGNORE** grana **ACCEPT** lamellae (membranes) **Examiner's Comments** Most candidates gained at least one mark for identifying the thylakoid membrane as the precise location of photosynthetic pigments in a chloroplast. Many then went on to state that pigments would be found in the photosystems or light harvesting clusters.
			Total	**3**	
15	a	i	*Rf* = 0.53 / 0.52 ✓ ✓ *pigment* = chlorophyll a ✓	3 (AO2.4) (AO3.2)	If incorrect: **ALLOW for 1 mark for** correct use of $R_f = \frac{(distance\ moved\ by\ spot)}{(distance\ moved\ by\ solvent)}$ **e.g.** $R_f = \frac{(46)}{(86)}$ **OR** inappropriate use of sig. figs e.g. 0.533 / 0.5

					ALLOW ECF if incorrect calculation **IGNORE** colour e.g. blue-green
		ii	grey ✓	1 (AO2.4)	**ALLOW ECF** from calculated Rf value in part (ii) (for ECF looking for a pigment next highest in value than calculated as spot 4 has travelled further from origin than spot 3) ECF list: 0.32-0.44 - prediction = green 0.49 - prediction= blue-green 0.65 -prediction = yellow-orange
		iii	spot 5 ✓ (because) is most soluble in , mobile phase / solvent ✓	2 (AO2.3) (AO2.4)	**ALLOW** is less attracted to stationary phase / TLC plate
	b	i	*hold TLC plate carefully* (so that) movement of spots not affected (by damage) **OR** *(so that) plates are not contaminated* (by fingerprints / oils from skin) ✓ *make sure plate doesn't touch sides of jar* (because) condensation / liquid / solvent , on walls of jar may affect movement of spots **OR** to avoid , solvent / spots , travelling in wrong direction ✓	2 (AO1.2)	**MUST be linked to appropriate precaution** **ALLOW** e.g. pigments for 'spots'
		ii	to , reduce / avoid / prevent , damage / degradation / contamination / AW , of the (photosynthetic) pigments ✓ to , reduce / avoid , evaporation of propanone / solvent ✓	1 max (AO1.2)	
			Total	**9**	
16		i	nicotinamide adenine dinucleotide phosphate / NADP ✓	1 (AO1.1)	**ALLOW** $NADP^+$ **DO NOT ALLOW** NADPH / reduced NADP
		ii	(final) electron acceptor ✓ replaces, NADP / the usual electron acceptor ✓	Max 2 (AO2.3)	**ALLOW** proton / hydrogen (ion) acceptor

			allows photolysis to continue ✓		
		iii	***Tube A:*** photosystems / components, are not in, stroma / supernatant / liquid ✓ ***Tube B****:* proteins / enzymes / (intact) membranes, are needed ✓ ***Tubes C & D****:* light is required (for electron transport / reduction of DCPIP) ✓ ***Tube E****:* DCPIP does not spontaneously, decolourise / reduce / AW ✓	4 (AO3.2)	**ALLOW** stage only takes place in chloroplasts / thylakoids / thylakoid membranes **ALLOW** stage does not take place in the stroma **ALLOW** photosystems are contained in, thylakoids / thylakoid membranes / pellet / sediment **ALLOW** ATP synthase needed **ALLOW** reactions stop when, enzymes denatured / membranes disrupted
		iv	(buffer) maintains optimum pH **OR** enzymes / proteins, have an optimum pH ✓ (no sucrose) no need to prevent damage to chloroplasts / AW **OR** damage to chloroplasts increases access of DCPIP to (reaction) components ✓	Max 2 (AO2.7 AO3.4)	**1 max for buffer and 1 max for sucrose** **ALLOW** if pH changes, proteins / enzymes, denature
		v	**I1** use ice-cold solutions ✓ **E1** prevents damage to components / reduces rate of enzyme reactions ✓ **I2** centrifuge at different speeds ✓ **E2** to obtain different fractions / AW **OR** to obtain a pellet containing mainly chloroplasts / AW ✓	max 4 (AO3.3)	**1 mark** for each improvement (**I**) and **1 mark** for correct explanation (**E**). *Explanation must correspond to improvement* **I1 ALLOW** keep, extract / AW, cold **E2 ALLOW** to remove, cell debris / nuclei / membranes

			I3 use, a heat shield / water bath ✓ **E3** so that temperature (of all tubes) is, not a variable / controlled / kept constant ✓ **I4** use same, light source / distance from light source, for illuminated tubes ✓ **E4** so that light, intensity / wavelength, is, not a variable / controlled / kept constant (for those tubes) ✓		
			Total	**13**	
17			(light-independent stage is) controlled by (named) enzymes ✓ *idea that* higher temperature will increase, kinetic energy of enzyme molecules / number of successful collisions /ESCs formed / ora ✓ enzymes may be denatured at high temperatures / described ✓	**2 max**	**IGNORE** no enzymes in light dependent stage **ALLOW** fewer enzymes in light dependent stage **ALLOW** Rubisco as named enzyme **Examiner's Comments** Many candidates recognised that enzymes control the light independent reactions and Rubisco was frequently quoted. References about the effect of temperature were often vague. The idea of increasing the kinetic energy of the enzyme molecules, number of successful collisions or number of ESCs was rarely addressed, and marks were frequently lost for not relating high temperatures to denaturation. A few candidates thought that the light independent stage required photons, or that temperature excited the enzymes.
			Total	**2**	
18		i	*for all crops* initial increase in assimilation with increasing temperature (1) at higher temperatures the assimilation decreases (1)	2	**DO NOT ALLOW** accounts that describe the curve for each crop individually.

		ii	*C3* 34.5 **and** *C4* 73.5 (1) CO_2 kg ha^{-1} h^{-1} (1)	2	**1 mark for both means calculated correctly.** **1 mark for correct units given for both.**
		iii	C3 plants assimilate less carbon dioxide than C4 plants **ora**	1	**ALLOW** a conclusion cannot be drawn because there is not enough data on each type of plant.
		iv	*Sugar cane* C4 crop 2 (1) *Barley* C3 crop 1 (1)	2	
			Total	**7**	
19		i	*synthesis of:* (named) carbohydrate (1) hexose sugars (1) amino acids (1) lipids (1)	2	**ALLOW** regeneration of RuBP
		ii	GP / glycerate-3-phosphate	1	
			Total	**3**	
20	a		**A** RuBP / ribulose bisphosphate ✓ **B** triose phosphate / TP ✓ **C** fatty acid(s) ✓ **D** amino acid(s) ✓	4(AO1.2)	**Mark first response on each line** **IGNORE** biphosphate **IGNORE** named fatty acids / triglycerides / fats **IGNORE** named amino acids **ALLOW** polypeptide / protein **Examiner's Comments** Many candidates appeared confident in their ability to identify the molecules here, often achieving all four marks. Abbreviations for ribulose bisphosphate and triose phosphate were allowed for A and B.
	b	i	*accurate because:* does not require , photons / light energy ✓ *inaccurate because:* needs , ATP / reduced NADP , produced in light-dependent stage ✓	2 (AO1.2)	**IGNORE** can occur in the dark **ALLOW** variations of reduced NADP e.g.NADPH **Examiner's Comments**

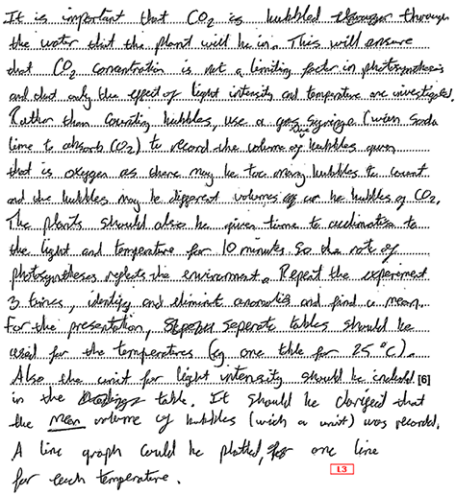
					There were good responses where candidates clearly understood that light energy wasn't required for the 'dark reaction' but that it was required to synthesise ATP and reduced NADP in the light-dependent reaction. Many candidates did not refer to light energy at all and some correctly pointed out that the products of the light-dependant stage were needed, but then did not name either of them to gain a mark. Unfortunately some candidates also confused NADP with NAD from cell respiration.
		ii	ribulose bisphosphate carboxylase / RuBisCO ✓	1 (AO1.2)	**ALLOW** RUBISCO / rubisco
			Total	**7**	
21	a	i	increased photosynthetic activity during daylight (1) as light intensity increases there is increased activity of the light dependent reaction (1)	2	No marks available for describing the shape of the curve.
		ii	daytime temperatures generally higher than night time (1) rate of respiration increases with increased temperature as its enzymes are temperature-dependent (1)	2	No marks available for describing the shape of the curve.
		iii	compensation point(s) / carbohydrate produced by photosynthesis equal to carbohydrate used in respiration (1)	1	
	b	i	deactivation of RuBisCO will reduce, carbon dioxide fixation / light independent reaction (1) the light dependent reaction will reduce when the supply of NADP is reduced (1) reduction in stomatal aperture will reduce carbon dioxide available for fixation (1)	3	
		ii	*four from* damage to chlorophyll / reduction in pigment (1) which will reduce the light dependent stage (1)	4	**Award 1 mark for the alteration of the ultrastructure (max 2) and 1 further mark for details of its effect on photosynthesis (max 2).**

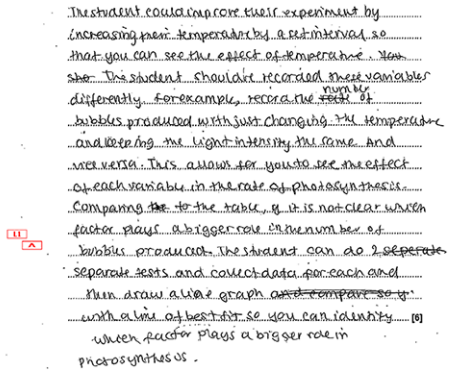
			damage to membranes in chloroplast / reduction in sites for light capture (1) which will reduce the light dependent stage (1) damage to membranes in chloroplast / reduction in reaction sites for electron transfer (1) which will reduce, photophosphorylation / ATP production in the light dependent stage (1) damage to membrane around chloroplast / release of enzymes (1) which will reduce, light independent stage / Calvin cycle (1)		
			Total	**12**	
22			*idea that* at low light levels, photosynthetic rate is greater when light is shone on the upper surface ✓ palisade cells are, nearer / AW, upper surface ✓ *idea that* chloroplasts also present in cells at lower surface ✓ (little difference because) leaf is thin ✓ *idea that* light can pass through the leaf from the lower surface to reach palisade cells ✓ no difference (in rate) at high(er) light intensity ✓ (at high light intensity) carbon dioxide (concentration) is limiting factor / number of stomata limit carbon dioxide uptake ✓ figures to support, with units ✓	4 max	

			Total	**4**	
23			the factor that will, determine / limit / AW, the rate ✓ when at, low(er) / sub-optimal / AW, level ✓	**2**	**Both marks can be gained from a correctly described example** e.g. when CO_2 (concentration) is in short supply, it prevents the rate of photosynthesis increasing **DO NOT ALLOW** inhibits / reduces **ALLOW** prevents rate from increasing / slows down rate of increase / stops rate from increasing / causes rate to plateau **ALLOW** when in short (est) supply **Examiner's Comments** **Q18(a)** was a challenge for many candidates because they failed to articulate clearly that rate is not reduced by the limiting factor, but simply capped. Stronger candidates were able to score two marks in a very brief answer but this was rarely seen by Examiners. Mark point one was most commonly awarded but a significant number of candidates referred to the rate being reduced or the reaction being stopped by the limiting factor which could not be credited. Few candidates used an example to express their answer, although many did relate limiting factors to photosynthesis but only in the form of a list of their effect on photosynthesis. A number of candidates failed to gain credit for the first marking point by referring to limiting factors *affecting* the rate without explaining what that effect might be. Mark point two was rarely awarded.
			Total	**2**	
24		i	(anomaly is) 28 / (light intensity of) 32 and (temperature of) 40.5 / row 6 ✓ repeat test ✓	**2**	**ALLOW** highlighted row or 28 in the table **IGNORE** plot points on a graph **Examiner's Comments** A number of candidates correctly identified the anomaly and often went onto say why they considered 28 bubbles an anomaly. Not all of the candidates went onto mention

					repeats being the way to confirm it as the anomaly. Some incorrectly mentioned drawing a graph and seeing whether the result did or did not fit the normal trend. Some candidates seemed to have difficulty in making it clear which result was anomalous, but this could have been achieved by circling the result in the table provided. A number of candidates wrongly identified the anomaly, but mentioned repeats and therefore got credited a mark for that.
		ii	**Level 3 (5-6 marks)** Provides **detailed** descriptions of improvements to both presentation **and** experimental method. *There is a well-developed line of reasoning, which is clear and logically-structured and uses scientific terminology at an appropriate level. All the information presented is relevant and forms a continuous narrative.* **Level 2 (3-4 marks)** Provides correct descriptions of improvements to both presentation **and** experimental method. *There is a line of reasoning presented with some structure and use of appropriate scientific language. The information presented is mostly relevant.* **Level 1 (1-2 marks)** Provides a correct description of an improvement to both the presentation **and** experimental method. *The information is communicated with only a little structure. Communication is hampered by the inappropriate use of technical terms.*	**6**	**Indicative scientific points may include:** *(examples of the detailed descriptions required for level 3 are shown in **bold**)* *Improvements to presentation* • Units for light intensity should be shown **(e.g. AU or lux, etc.)** • The table should be presented to make comparisons of light intensity easier **(example of improvement - e.g. separate tables for temperature and light intensity)**. • The heading of column three could be improved (**e.g. 'rate of photosynthesis - bubbles min^{-1}')** • present data as a graph **(e.g. light intensity / temperature vs, number of bubbles)** *Improvements to method* • A more precise method for measuring photosynthetic rate (**e.g.** a (calibrated) **oxygen sensor** (rather than counting bubbles) **use of a photosynthometer / gas syringe / burette / measuring cylinder** (to measure volume of gas).

			0 marks No response or no response worthy of credit.		• Control other variables in the experiment (**named control variables e.g. same, size/age, pondweed /** **same pH / change water surrounding pondweed for each measurement / time to acclimatise / same wavelength of light)** • Provide carbon dioxide source **(e.g. so carbon dioxide in excess / not limiting / add hydrogencarbonate)** • Smaller and more consistent intervals between light and temperature values should be used **(e.g. intervals of 50 light intensity units or 10°C)**. • repeats should be used. **(e.g. to calculate mean or identify anomalies)** **<u>Examiner's Comments</u>** This question was on the whole answered well, particularly with regard to descriptions of improvements to the method. Less able candidates were able to score marks on this question by giving correct descriptions of improvements to both method and presentation. Marks were lost by candidates for lack of detailed descriptions, in particular to do with the presentation. For example, with the improvement to the method, some stated correctly that counting bubbles was not a precise method of measuring the rate of photosynthesis but did not suggest a more precise method. A large number suggested that a potometer could be used to measure the rate of photosynthesis, or that the bubbles were carbon dioxide rather than oxygen. Many candidates suggested that a control should be set up or that other variables in the experiment needed to be controlled and gained credit for this, but did not to say what the control variables should be. Candidates also often mentioned that the

					light and temperature should be increased in regular intervals but did not state what these intervals should be. For improvements to presentation they stated that there should be units in the table for light intensity but did not give an example of a unit. They also did not often mention recording results in separate tables for temperature and light intensity to make comparisons of light intensity easier. It was seen that suggestions for improving presentation were sometimes missing from answers and as a consequence these candidates scored no marks, even if they had given or described a detailed improvement to the method, . This is because for Level 1 we needed an improvement to method and presentation. Other common loss of marks were for the use of the term average instead of mean, drawing a bar chart rather than a line graph and mentioning repeats to remove anomalies The overall impression though is that candidates are being taught well, to analyse practical methods and the presentation of data. **Exemplar 1**  It is important that CO_2 is bubbled through the water that the plant will be in. This will ensure that CO_2 concentration is not a limiting factor in photosynthesis and that only the effect of light intensity and temperature are investigated. Rather than counting bubbles, use a gas syringe (with soda lime to absorb CO_2) to record the volume of bubbles given off is oxygen as there may be too many bubbles to count and the bubbles may be different volumes eg or be bubbles of CO_2. The plants should also be given time to acclimatise to the light and temperature for 10 minutes, so the rate of photosynthesis reflects the environment. Repeat the experiment 3 times, identify and eliminate anomalies and find a mean. For the presentation, Several seperate tables should be used for the temperatures (eg one table for 25 °C). Also the unit for light intensity should be included [6] in the headings table. It should be clarified that the mean volume of bubbles (with a unit) was recorded. A line graph could be plotted for one line for each temperature. L3 In this answer, the candidate gave several correct detailed improvements to the method and two detailed improvements for the presentation (use of separate tables, and use of a line graph with separate lines for each

					temperature), with a well-structured answer gaining all 6 marks. In this answer, the candidate gave several correct detailed improvements to the method and two detailed improvements for the presentation (use of separate tables, and use of a line graph with separate lines for each temperature), with a well-structured answer gaining all 6 marks. **Exemplar 2**  The student could improve their experiment by increasing their temperature by a set interval so that you can see the effect of temperature. You She The student should recorded their variables differently, for example, record the num by rate of bubbles produced with just changing the temperature and keeping the light intensity the same and vice versa. This allows for you to see the effect of each variable in the rate of photosynthesis. Comparing the to the table, it is not clear which factor plays a bigger role in the number of bubbles produced. The student can do 2 seperate seperate tests and collect data for each and then draw a line graph and compare so it with a line of best fit so you can identify which factor plays a bigger role in photosynthesis. [6] In this answer, the candidate gave one correct improvement to the method (increasing temperature by set intervals) and a correct improvement to the presentation(draw a line graph), but neither improvement is detailed - so credited Level 1. The response contains a lot of irrelevant material and has little structure, so was not given the communication mark.
			Total	**8**	
25	a	i	*independent variable* temperature ✓ *dependent variable* concentration of oxygen ✓ *control variable* species / type of pondweed **OR** <u>mass</u> of pondweed **OR** light intensity / distance of light source from beaker **OR**	3 (AO3.3)	**NOTE: 1 max for control variable** **IGNORE quoted figures** **ALLOW** *P. pusillus* for pondweed **ALLOW** wavelength of light **<u>Examiner's Comments</u>**

			time in water bath / equilibration time / time intervals **OR** volume of (distilled) water **OR** mass of $NaHCO_3$ ✓		This part of the question was generally well-answered with many candidates correctly identifying all three variables thereby gaining three marks. The most common error was in reversing the independent and dependent variables.
		ii	pH ✓ concentration of CO_2 ✓ age of pondweed ✓ size / surface area / number , of leaves ✓	1 max (AO3.3)	**IGNORE** reference to equipment **ALLOW** *P. pusillus* for pondweed **Examiner's Comments** It is important when discussing variables that candidates avoid using vague terms such as 'amount' or 'same'. Good responses often identified concentration of carbon dioxide or surface area of leaves as variables that were not controlled in this method.
	b		***descriptions*** **D1** increasing temperature increases , O_2 concentration / rate of photosynthesis ✓ **D2** at each temperature rate of , oxygen production / photosynthesis , is constant ✓ ***explanations*** **E1** oxygen is a product of , photosynthesis / photolysis / light-dependent reactions ✓ **E2** temperature acts as a limiting factor ✓ **E3** no other (named) factor was limiting ✓ **E4** increasing temperature increases , kinetic energy of molecules / rate of enzyme reactions ✓	3 max (AO2.8)	**ALLOW** ORA for decreasing temperature ***2 max for explanations*** **ALLOW** e.g. light intensity / CO_2 concentration **ALLOW** e.g. increases , ESC / EPC , formation e.g. increases number of successful collisions **ALLOW** KE for kinetic energy **ALLOW** ORA for decreasing temperature **Examiner's Comments** There were some good comprehensive responses for this question although many

					did not gain full marks. This was often due to the fact that they gave figures from the graph to support their answer without describing while they explained the general trend. Some candidates did not describe the relationship between the two variables, instead they referred to 'optimum' temperature or used examples of temperatures and rates. Other responses were too descriptive and merely stated the oxygen production at different temperatures without making the connection between temperature and photosynthesis. Very few candidates described the rate of oxygen production/photosynthesis as being constant at each stage or discussed whether there were any limiting factors. Some candidates went into explanations of oxidative phosphorylation and respiration rather than photosynthesis.
			Total	**7**	
26			***GP*** **1** (concentration of) GP decreases ✓ **2** (GP decreases) because less CO2 available to react with RuBP to produce GP ✓ ***RuBP*** *(2 max)* **3** (concentration of) RuBP increases **AND** then decreases ✓ **4** RuBP increases because it is not converted to GP ✓ **5** RuBP increases as it is still being produced from TP ✓ **6** RuBP decreases because less GP available to , regenerate / AW , RuBP ✓	3 max (AO2.3)	**IGNORE** 6C intermediates **ALLOW** no / less , carbon (dioxide) fixation taking place **Max 2 from MPs 3,4, 5 and 6**
			Total	**3**	
27		i	***Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.***	6 (AO2.3) (AO2.4) (AO3.1)	**Indicative scientific points may include (but are not limited to):** *AO2.3 and 2.4 Apply knowledge and understanding of scientific ideas and*

			In summary: *Read through the whole answer. (Be prepared to recognise and credit unexpected approaches where they show relevance.)* *Using a 'best-fit' approach based on the science content of the answer, first decide which of the level descriptors,* ***Level 1****,* ***Level 2*** *or* ***Level 3****, best describes the overall quality of the answer.* *Then, award the higher or lower mark within the level, according to the Communication Statement (shown in italics):* ○ *award the higher mark where the Communication Statement has been met.* ○ *award the lower mark where aspects of the* ***Communication Statement*** *have been missed.* • *The science content determines the level.* • *The Communication Statement determines the mark within a level.* **Level 3 (5-6 marks)** Detailed description **and** linked explanation of results for **both** tables. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Describes results for **both** tables with some explanation of at least **one** table. *There is a line of reasoning with some structure. The information*		*techniques in a practical context when handling qualitative and quantitative data.* *Descriptions:* <u>Table 3.1</u>: • light increases length and mass of both roots and stems • group A has less growth than group B <u>Table 3.2</u>: • stems grow towards the light (with a few exceptions) • (almost) half the roots grow away from light • some appear unaffected by light or grow towards light *AO3.1 Analyse scientific information to make judgements and reach conclusions* *Explanations:* <u>Table 3.1</u>: • more carbohydrates produced during photosynthesis • light may trigger growth and germination (through phytochromes) <u>Table 3.2</u>: • details of phototropism (e.g. auxins produced in shoot tip moves to side away from light / auxins cause more cell elongation on side away from light) • light allows photosynthesis • positive phototropism in stems • geotropism more important than phototropism in roots • (some) negative phototropism in roots • other reasons for varied data, e.g. conditions not natural / measurement error / shading of

			presented is relevant and supported by some evidence. **Level 1 (1-2 marks)** Offers some description for both tables **or** describes and explains one table. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.		stems / stems heavier than roots so tips
		ii	(unpaired) t-test ✓	1 (AO2.8)	**ALLOW** unrelated t-test **DO NOT ALLOW** paired/related, t-test
		iii	*idea of* comparing two means ✓	1 (AO3.3)	
		iv	8.10 is greater than 5.99 (at 2 degrees of freedom) ✓ (therefore) significant (difference) at (p =) 0.05 ✓ not significant at (p =)0.01 ✓ (indicates greater than 95% probability that) difference is not due to chance ✓ null hypothesis can be rejected (at p = 0.05) ✓	3 max (AO3.2)	**ALLOW ECF for mp2 ,4 and 5 if 9.49 or 11.07 value used from table for max 2 marks** **ALLOW** 'students chi-squared value greater than critical value for 2 degrees of freedom' **ALLOW** 'there is a significant difference between the observed and expected results' **ALLOW** 'less than 5% probability that difference is due to chance'
			Total	**11**	
28	a		*D. antarctica habitat*: lower (maximum) light levels ✓ *idea of* reason for lower (maximum) light levels ✓	2 max (AO3.2)	**ORA** *Z. mays habitat* **ALLOW** less available light / darker habitat / more shaded e.g more cloud cover / shorter day length / taller / competing, plants (shade fern)

			idea that optimum rate of photosynthesis (in its habitat) is at a lower light intensity than that of *Z. mays* ✓		e.g. rate of photosynthesis is higher at lower light levels compared to *Z. mays*
	b	i	**FIRST CHECK ON ANSWER LINE** **If answer = 0.943 award 3 marks** $\Sigma d^2 = 2$ ✓ $n(n^2 -1) = 210$ ✓ $1 - (6 \times 2) / 210 = 0.943$ ✓	3 (AO2.4)	**ALLOW** calculator value (0.942857) or any correctly rounded value **ALLOW ECF** final answer if incorrect values used for Σd^2 and / or $n(n^2 -1)$ for mp3
		ii	significant positive correlation (at 0.05 confidence) ✓	1 (AO3.1)	**ALLOW ECF** correct conclusion based on incorrect calculated value from **c(i)**
		iii	no significant (positive) correlation ✓	1 (AO3.1)	
			Total	**7**	