

1.1	value from graph used to show volume increase	values must be approximately correct must include a time or volume value	1	AO2 5.6.1.1 5.10.2.11
	values from graph used to show the volume increases less rapidly	must include time interval or volume increment	1	
	volume or time stated when graph line levels off	allow levels off at 60 (cm ³) or 28 to 30 s allow descriptions in terms of rate of reaction	1	

1.2	draw tangent at <u>15 s</u>	allow draw a straight line on the curve at <u>15 s</u>	1	AO2 5.6.1.1 5.10.2.11
	calculate gradient	allow correct description of gradient calculation ignore calculations if given	1	

1.3	centimetres cubed per second	allow cm^3/s or $\text{cm}^3 \text{s}^{-1}$ (all lower case) allow mixture of abbreviations and words, eg centimetres cubed/s do not accept non-SI abbreviations (eg sec for s)	1	AO1 5.6.1.1 5.10.2.11
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1.4	(rate) increases as chips get smaller	allow converse	1	AO3 5.6.1.1 5.6.1.2
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1.5	small(er) chips have large(r) surface area (for the same volume)	allow converse	1	AO3 5.6.1.2 5.6.1.3
	so more frequent collisions	allow more chance of collisions allow more likely to collide do not accept reference to speed of particles or energy of collisions ignore more collisions ignore more successful collisions	1	AO1 5.6.1.2 5.6.1.3

1.6	(sloping part is less steep because) reaction is slower due to less frequent collisions fewer acid particles (in same volume) or (sloping part is less steep because) reaction is slower (1) there are fewer acid particles (in same volume) (1) (graph levels off lower) so less gas is produced (1)	allow converse for more concentrated acid do not accept reference to speed of particles or energy of collisions ignore fewer collisions ignore weaker acid	1 1 1	AO2 5.6.1.2 5.6.1.3 10.2.11
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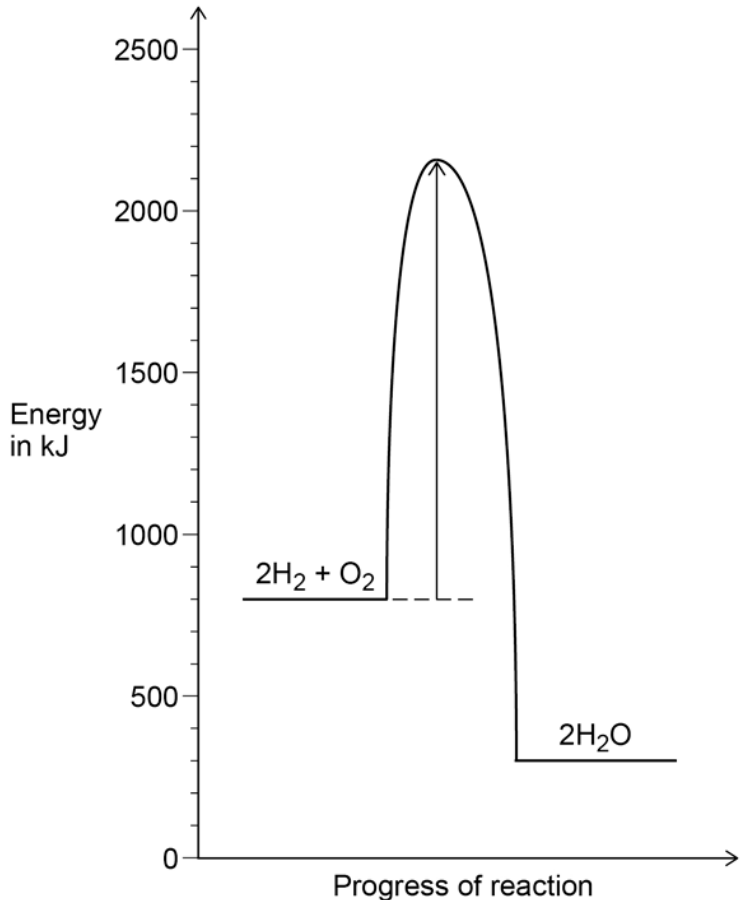
2.1	Level 3: The method would lead to the production of a valid outcome. All key steps are identified and logically sequenced.	5–6	AO1 4.6.1.2
	Level 2: The method would not necessarily lead to a valid outcome. Most steps are identified, but the method is not fully logically sequenced.	3–4	
	Level 1: The method would not lead to a valid outcome. Some relevant steps are identified, but links are not made clear.	1–2	
	No relevant content	0	
	Indicative content method • measure (indicated) volume of sodium thiosulfate • place sodium thiosulfate in (conical) flask • measure (indicated) volume of hydrochloric acid • place on cross or between light sensor or - connect to a gas syringe or - other suitable method for timing a change • add hydrochloric acid to (conical) flask • swirl • start stopclock / stopwatch • measure time for cross to become no longer visible or - log light transmission over time or - measure time for fixed volume of gas to be produced • repeat and find mean • repeat for different concentrations of sodium thiosulfate or change ratio of sodium thiosulfate volume : water volume control variables • concentration of hydrochloric acid • volume of hydrochloric acid • (total) volume of sodium thiosulfate solution		

3.1	all eight points plotted correctly	allow a tolerance of $\pm$ half a small square.	2	AO2 4.6.1.1
	line of best fit	allow six or seven points plotted correctly for 1 mark	1	

3.2	correctly drawn tangent at 0.95 g correct value for x step and y step from tangent (rate =) $\frac{\text{value for y step}}{\text{value for x step}}$ correctly evaluated and rounded to 2 sig figs	an incorrect answer for one step does not prevent allocation of marks for subsequent steps allow evidence of use of two points on tangent either on the graph or in the text allow (rate =) $\frac{\text{value for x step}}{\text{value for y step}}$ (ie inverted division) correctly evaluated and rounded to 2 sig figs	1 1 1 1	AO2 4.6.1.1
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4.1	enzyme		1	AO2 4.6.1.4
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4.2	provides different reaction pathway (which has a) lower activation energy	allow provides a different mechanism / route	1	AO1 4.6.1.4
		ignore references to collisions	1	

5.1	line from reactants to top of curve (i.e. from 800 to 2160)  Energy in kJ 2500 2000 1500 1000 500 0 2H₂ + O₂ 2H₂O Progress of reaction ignore arrowheads	1	AO1 5.5.1.2
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6.1	both reaction profiles start at the same energy level and end at the same energy level.		1	AO3 5.6.1.4
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7.1	all points correctly plotted	allow a tolerance of $\pm \frac{1}{2}$ a small square allow 1 mark for at least 4 points correctly plotted	2	AO2 5.6.1.1
	line of best fit		1	

7.2	(rate) decreases	allow (rate is) fastest at the beginning	1	AO3 5.6.1.1
	(rate decrease) more slowly as time increases (in rate)		1	AO3 5.6.1.1
	(rate) becomes zero at time read from graph	allow reaction stops at time read from graph	1	AO3 5.6.1.1

7.3	(rate decreases because) fewer particles (of acid / magnesium) as reaction progresses	Incorrect reference to energy scores max. 1 allow (rate decreases because) concentration of acid decreases as reaction progresses	1	AO2 5.6.1.3
	(so) less frequent collisions	allow collisions less likely ignore less / fewer collisions	1	AO1 5.6.1.3
	reaction stops due to limiting factor / reagent	allow reaction stops because a reactant is used up	1	AO2 5.6.1.3 7.1 .2.4

8.1	(gas) syringe	allow measuring cylinder (and water trough) allow balance	1	AO1 4.6.1.1
	stopclock / stopwatch	allow timer / clock / watch	1	

8.2	all points plotted correctly	allow a tolerance of $\pm \frac{1}{2}$ a small square allow at least 3 points plotted correctly for 1 mark.	2	AO2 4.6.1.1
	line of best fit	allow correctly drawn line of best fit for incorrectly plotted points	1	

8.3	(rate) decreases	allow slows down	1	AO3 4.6.1.1
	(rate decreases) more slowly as time increases	allow (rate decreases) at a non-linear rate	1	
	(rate) becomes zero at 60 s	allow the reaction stops at 60 s allow ecf from question 8.2	1	

8.4	more bubbles were produced in the first 10 seconds		1	AO2
	the magnesium was used up more quickly		1	4.6.1.2

9.1	11 (cm³) and 120 (seconds) (mean rate of reaction = $\frac{11}{120}$) = 0.09167 = 0.092 (cm³/s)	an answer of 0.092 (cm³/s) scores 3 marks allow an answer of 0.091666 (cm³/s) correctly rounded to at least 2 significant figures for 2 marks allow an answer of 0.033 (cm³/s) for 2 marks allow an answer of 0.033333 (cm³/s) for 1 mark allow a correct calculation using incorrectly determined value(s) for difference in volume and / or time allow a correctly calculated answer given to 2 significant figures from an incorrect attempt at the rate equation	1 1 1	AO2 4.6.1.1
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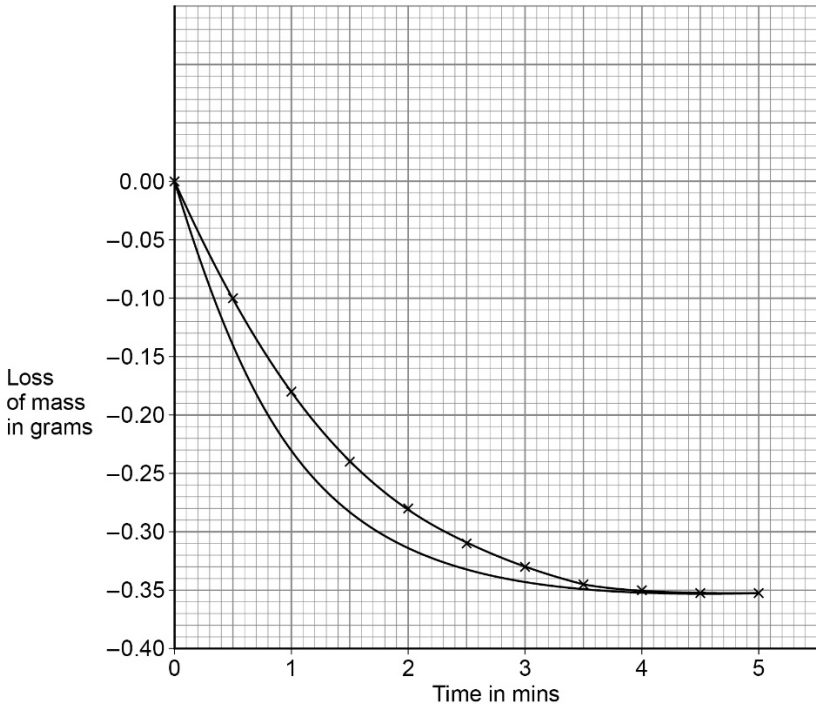
9.2	line starts at origin and less steep than solid line		1	AO2
	line levelling off at 40 (cm ³)	allow a tolerance of $\pm \frac{1}{2}$ a small square	1	AO3 4.6.1.2

9.3	(because) surface area (of fine manganese dioxide powder) greater	allow converse for coarse lumps	1	AO2 4.6.1.2 4.6.1.3
	(so) more collisions (with hydrogen peroxide molecules / particles) per unit time	do not accept references to changes in kinetic energy or speed (of molecules / particles) ignore references to activation energy.	1	

10.1	any one from: • warm / heat the mixture • increase the concentration of the (hydrochloric) acid	ignore add a catalyst ignore stir ignore powder ignore add more zinc oxide do not accept volume / amount of (hydrochloric) acid do not accept increase the surface area	1	AO1 5.10.12 5.10.13 RPA8
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11.1	Level 3: The method would lead to the production of a valid outcome. All key steps are identified and logically sequenced.	5–6	AO3 5.6.1.2
	Level 2: The method would not necessarily lead to a valid outcome. Most steps are identified, but the plan is not fully logically sequenced.	3–4	
	Level 1: The method would not lead to a valid outcome. Some relevant steps are identified, but links are not made clear.	1–2	
	No relevant content	0	
	Indicative content: • use a measuring cylinder / pipette / burette to measure 50 cm³ of sodium thiosulfate • use a different measuring cylinder / pipette / burette to measure 10 cm³ of hydrochloric acid • start the timer when the acid is added • record the temperature of the solution after the acid is added • stop the timer when the cross is no longer visible • record the temperature of the solution at the end of the reaction • calculate the mean temperature of the reaction • repeat the experiment at different temperatures • use the same concentration of sodium thiosulfate and same concentration of hydrochloric acid • use the same volume of sodium thiosulfate and the same volume of hydrochloric acid • describe how to heat the thiosulfate / acid solutions		

11.2	(change in mass of gas =) 0.15 and (time =) 2 (rate of reaction =) $\frac{0.15}{2}$ 0.075 (g/min)	ignore signs allow correct use of incorrectly determined values for mass and / or time	1 1 1	AO2 5.6.1.1 5.6.1.4
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11.3	curve starts at same point, to the left and steeper line levels at -0.35 g the curve below can be awarded 2 marks  <table><caption>Data points from the graph</caption><tr><th>Time in mins</th><th>Loss of mass in grams</th></tr><tr><td>0</td><td>0.00</td></tr><tr><td>0.5</td><td>-0.10</td></tr><tr><td>1.0</td><td>-0.18</td></tr><tr><td>1.5</td><td>-0.24</td></tr><tr><td>2.0</td><td>-0.28</td></tr><tr><td>2.5</td><td>-0.31</td></tr><tr><td>3.0</td><td>-0.33</td></tr><tr><td>3.5</td><td>-0.34</td></tr><tr><td>4.0</td><td>-0.35</td></tr><tr><td>4.5</td><td>-0.35</td></tr><tr><td>5.0</td><td>-0.35</td></tr></table>	Time in mins	Loss of mass in grams	0	0.00	0.5	-0.10	1.0	-0.18	1.5	-0.24	2.0	-0.28	2.5	-0.31	3.0	-0.33	3.5	-0.34	4.0	-0.35	4.5	-0.35	5.0	-0.35	1 1	AO2 5.6.1.1 5.6.1.2 5.6.1.4
Time in mins	Loss of mass in grams																										
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3.5	-0.34																										
4.0	-0.35																										
4.5	-0.35																										
5.0	-0.35																										

12.1	the (minimum) energy needed for particles to react or the (minimum) energy needed for a reaction to occur	allow the (minimum) energy needed to start a reaction	1	AO1 4.5.1.2
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13.1	(0.01 mol/dm ³) methanoic acid has a lower pH (so 0.01 mol/dm ³) methanoic acid has a higher concentration of hydrogen ions (therefore) more collisions per unit time	allow converse argument for ethanoic acid		AO2
		allow (0.01 mol/dm ³) methanoic acid is a stronger acid	1	AO2
			1	AO3
			1	4.6.1.2 4.6.1.3 4.7.2.4

14.1	all seven points plotted correctly	allow a tolerance of $\pm\frac{1}{2}$ small square allow 1 mark for five or six points plotted correctly	2	AO2 4.6.1.1
	line of best fit		1	

14.2	0.0038 and 0.0014 $\frac{0.0038 - 0.0014}{105 - 20}$ = 0.000028 or = 2.8×10^{-5} mol/s	allow correct use of incorrectly determined mole value(s) allow moles per second	1 1 1 1	AO2 4.6.1.1
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[illegible]

15.1	particles collide (but at room temperature) particles have insufficient energy or (but) have energy less than the activation energy (so collisions are not successful)		1 1	AO3 5.5.1.2
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16.1	all points correctly plotted	allow a tolerance of $\pm \frac{1}{2}$ a small square allow 1 mark for 4 or 5 points correctly plotted	2	AO2 5.6.1 RPA11
	line of best fit	must include 0,0	1	

16.2	the rate decreases		1	AO3 5.6.1 RPA11
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16.3	the magnesium reacted more quickly		1	AO3 5.6.16.1
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16.4	rate increases	allow reaction happens faster	1	AO1 5.6.16.1 5.6.16.2
	(because) particles have more energy	allow (because) particles move faster allow (because) more particles have energy greater than the activation energy	1	
	(so) more frequent collisions		1	

17.1	provides an alternative pathway (which has) a lower activation energy		1 1	AO1 5.6.1.4
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18.1	reaction has stopped	allow no more gas produced	1	AO2 4.6.1.1 RPA5
	(because a) reactant is used up	allow named reactants	1	

18.2	any one from: - the line (for 0.05 mol/dm^3 sulfuric acid) is less steep $(0.05 \text{ mol/dm}^3 \text{ sulfuric acid})$ produces less gas in a fixed time - the reaction (using 0.05 mol/dm^3 sulfuric acid) takes longer to finish	allow converse statements about 0.10 mol/dm^3 sulfuric acid ignore produces less gas do not accept produces less gas in total	1	AO1 4.6.1.1 RPA5
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18.3	tangent drawn at 80 s on 0.05 mol/dm ³ curve		1	AO2 4.6.1.1 RPA5
	(from tangent) value for x-step and value for y-step	allow a tolerance of $\pm \frac{1}{2}$ a small square	1	
	(rate =) $\frac{\text{value for y-step}}{\text{value for x-step}}$	allow correct use of incorrectly determined values from tangent for x-step and/or y-step	1	
	calculation of rate	allow an answer correctly calculated to 2 significant figures	1	
	answer to 2 significant figures	from an incorrect calculation of rate	1	

19.1	fizzing / effervescence or magnesium disappears		1	AO3 5.4.2.5
	at a greater rate with a strong acid	allow converse with weak acid allow for 2 marks strong acid has a greater temperature increase	1	

20.1	all points correctly plotted	allow 1 mark for 3, 4 or 5 points correctly plotted allow a tolerance of $\pm \frac{1}{2}$ a small square	2	AO2
	line of best fit		1	AO3 5.6.1.1

20.2	correct values for x step and y step from tangent		1	AO2 5.6.1.1 RPA11
	(rate =) $\frac{\text{value for y step}}{\text{value for x step}}$	allow correct use of an incorrectly determined value from tangent for x step and/or y step	1	
	correct calculation of rate		1	
	s dm ³ /mol		1	

20.3	(as reaction proceeds) fewer (sodium thiosulfate) particles per unit volume (so) frequency of (particle) collisions decreases	allow (as reaction proceeds) concentration (of sodium thiosulfate) decreases allow (so) probability of collision decreases	1 1	AO2 5.6.1.2 5.6.1.3 RPA11
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21.1	enzyme		1	AO1 5.21.14
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21.2	provides a different reaction pathway (which) has a lower activation energy		1 1	AO1 5.21.14
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22.1 View with Figure 7	correctly drawn tangent at 30 s		1	AO2 4.6.1.1 RPA5
	correct values for x step and y step from tangent	allow correct use of an incorrectly drawn tangent allow a tolerance of $\pm \frac{1}{2}$ a small square for each coordinate	1	
	(ratio =) $\frac{\text{value for y step}}{\text{value for x step}}$	allow correct use of incorrectly determined values from tangent for x step and/or y step	1	
	correct calculation of ratio		1	
	(conversion rate = ratio $\times 7.1 \times 10^{-5}$) correct evaluation of rate (mol/s)	allow correct use of an incorrectly calculated ratio	1	

22.2	rate decreases	allow the collision frequency decreases	1	AO2 4.6.1.1 4.6.1.2 RPA5
	(because) concentration of reactants decreases alternative approach: greatest rate at start (1) (because) greatest concentration of reactants at start (1)	allow the collision frequency is highest at the start	1	

22.3	(hydrochloric) acid is used up	allow (hydrochloric) acid is the limiting reactant ignore reactants used up	1	AO3 4.3.2.4 4.6.1.2 RPA5
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22.4 View with Figure 8	decreasing curve starting at (0,95) and steeper initially than curve for 0.10 mol/dm³ sodium thiosulfate solution levelling at 24%		1 1	AO2 4.6.1.2 RPA5
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23.1	all points plotted correctly	allow a tolerance of $\pm \frac{1}{2}$ a small square allow at least 4 points plotted correctly for 1 mark	2	AO2
	line of best fit		1	AO3 5.6.1.4

23.2	manganese dioxide (because manganese dioxide) has the steepest gradient	allow ecf from question 23.1 allow (because manganese dioxide) produces the most gas per unit time	1 1	AO3 5.6.1.4
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23.3	same number of particles per unit volume (so) same frequency of collisions (with catalyst)	allow same concentration (of hydrogen peroxide solution)	1 1	AO3 5.6.1.4
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23.4	tangent drawn at 20 s		1	AO2 5.6.1.1
	value for x step and y step from tangent	allow evidence of use of two points on tangent either on the graph or in the text	1	
	(rate =) $\frac{\text{value for y step}}{\text{value for x step}}$	allow correct use of incorrectly determined value(s) for x step and/or y step from a drawn tangent	1	
	correctly calculated		1	
	to 3 significant figures	allow a correctly calculated answer to 3 significant figures from an incorrect calculation which uses values determined from the graph	1	

24.1	(mean rate =) $\frac{0.78 + 0.81 + 0.81}{3}$ 0.80 (cm³/s) $0.80 = \frac{20}{\text{mean time taken}}$ (mean time taken =) $\frac{20}{0.80}$ = 25 (s) alternative approach: $0.78 = \frac{20}{\text{time}}$ or $0.81 = \frac{20}{\text{time}} \text{ (1)}$ (trial 1 time = $\frac{20}{0.78}$ =) 25.6 (1) (trial 2 and 4 time = $\frac{20}{0.81}$ =) 24.7 (1)	allow $\frac{0.78 + 0.81 + 0.68 + 0.81}{4}$ = 0.77 (cm³/s) for 1 mark allow correct use of incorrectly determined mean rate	1 1 1 1	AO3 AO2 AO2 AO2 4.6.1.1 RPA5
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24.2	use a lower temperature use sulfuric acid of a lower concentration		1 1	AO1 4.6.24.1 RPA5
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25.1	(a catalyst) provides a different pathway for the reaction (which has a) lower activation energy		1 1	AO1 4.6.1.3 4.6.1.4
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25.2	correct value for x step and y step from tangent		1	AO2 4.6.1.1
	(rate =) $\frac{\text{value for y step}}{\text{value for x step}}$	allow correct use of incorrectly determined x and/or y step	1	
	correct calculation of rate		1	
	answer to 2 significant figures	allow an answer correctly rounded to 2 significant figures from an incorrect calculation which uses values determined from the graph.	1	

25.3	line starting at 0,0 which is less steep than existing line which becomes level at 0.80 g	allow a tolerance of $\pm \frac{1}{2}$ a small square	1 1	AO2 4.3.4 4.6.1.2
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