

Mark Scheme

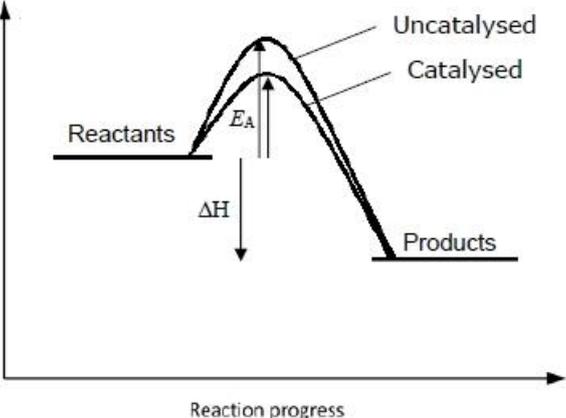
Q1.

Question Number	Answer	Mark
(i)	<p>The only correct answer is A (The minimum energy required for a reaction to take place when reactant molecules collide)</p> <p><i>B is not correct because very little energy is required for molecules to collide, but they just bounce off one another</i></p> <p><i>C is not correct because not all collisions result in a reaction under most conditions, the particles bounce off one another</i></p> <p><i>D is not correct because particles can collide with the appropriate orientation with very little energy so will bounce off one another unless there is enough energy in the collision</i></p>	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> • (at higher temperature) the peak shifts to the right and is lower (1) • because at higher temperatures there are more particles with higher energy (1) 	<p>Allow reverse arguments for lower temperatures</p> <p>Allow at higher temperatures the particles are distributed over a wider range (of energies)</p> <p>Allow fewer particles are present at the modal / average temperature</p> <p>If no other mark is scored allow at higher temperature / T_2 (on average) the particles have greater (kinetic) energy</p> <p>Ignore comments about the area under the curves</p> <p>Ignore comments about the area under the curves</p> <p>Ignore comparisons of activation energy or particles which have the activation energy</p> <p>Ignore discussion of collisions and/or rate of reaction</p>	(2)

Question Number	Answer	Mark
(iii)	<p>The only correct answer is D (there are more collisions, all of which are successful, at a higher temperature)</p> <p><i>A is not correct because the number of particles under the curve are those which can react in a collision and there are more at a higher temperature</i></p> <p><i>B is not correct because on average particles have more energy so a larger percentage of collisions are successful at a higher temperature</i></p> <p><i>C is not correct because more collisions result in more successful collisions giving a faster rate of reaction</i></p>	(1)

Q2.

Question Number	Answer	Additional Guidance	Mark
(i)	<ul style="list-style-type: none"> • position of reactants and products with labels (1) • two curves with at least one correctly labelled as catalysed or uncatalysed (1) • approximately vertical arrow from approximately the reactant line to nearly the height of the top of one or both of the curves labelled E_a / activation energy (1) • approximately vertical arrow from reactant line to products line labelled energy change / enthalpy change / ΔH (1) 	 <p>Allow any suitable equivalent labels Ignore any transition states, labelled or not Do not award straight lines for curves Penalise double headed arrow once only Do not award the arrow in the wrong direction Do not award $-\Delta H$ instead of ΔH For an endothermic reaction do not award M1</p>	(4)

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: <ul style="list-style-type: none"> a catalyst lowers the activation energy (for the reaction without being used up by it) 	Ignore just 'provides an alternative pathway' Do not award lowers the activation energy without taking part in the reaction	(1)

Q3.

Question Number	Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following points: <ul style="list-style-type: none"> Step 1 is the rate determining step (1) as it involves (1 mol of) both propanone and hydrogen ions (which matches the rate equation) (1) 	Stand alone Allow RDS / slow step Conditional on M1 Allow it does not involve I ₂ (which is zero order) Allow it involves both species in the rate equation Allow I ₂ is not involved in the RDS so RDS must be before Step 2	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: (The statement is not valid because) <ul style="list-style-type: none"> one hydrogen ion is regenerated / reformed (so is acting as a catalyst) (1) the other hydrogen ion is lost from the propanone (when replaced by iodine) / is a (by-)product of the reaction / is used to form HI (1) 	Ignore reference to specific steps. Do not award M1 if candidate states that it is valid Ignore it is an autocatalyst	(2)

Q4.

Question Number	Acceptable Answer	Additional Guidance	Mark
	<p>An explanation which makes reference to the following points:</p> <ul style="list-style-type: none">• a catalyst increases the rate at which the reaction moves towards equilibrium / decreases the time a reaction takes to arrive at a particular yield of product / (provides a reaction pathway with) a lower activation energy (1)• allows milder conditions to be used (lowering cost) (1)	<p>Allow a catalyst increases the rate of attainment of equilibrium / decreases the time a reaction takes to arrive at equilibrium Do not award just 'a catalyst increases the rate of reaction'</p> <p>Allow lower temperature and/or lower pressure and/or lower energy conditions Allow more product for the same energy Do not award just 'decreases the cost'</p>	(2)

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark																				
*	<p>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content.</p> <table border="1"> <thead> <tr> <th>Number of indicative marking points seen in answer</th> <th>Number of marks awarded for indicative marking points</th> </tr> </thead> <tbody> <tr> <td>6</td> <td>4</td> </tr> <tr> <td>5-4</td> <td>3</td> </tr> <tr> <td>3-2</td> <td>2</td> </tr> <tr> <td>1</td> <td>1</td> </tr> <tr> <td>0</td> <td>0</td> </tr> </tbody> </table> <p>The following table shows how the marks should be awarded for structure and lines of reasoning.</p> <table border="1"> <thead> <tr> <th></th> <th>Number of marks awarded for structure and sustained lines of reasoning</th> </tr> </thead> <tbody> <tr> <td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td> <td>2</td> </tr> <tr> <td>Answer is partially structured with some linkages and lines of reasoning.</td> <td>1</td> </tr> <tr> <td>Answer has no linkages between points and is unstructured.</td> <td>0</td> </tr> </tbody> </table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0		Number of marks awarded for structure and sustained lines of reasoning	Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2	Answer is partially structured with some linkages and lines of reasoning.	1	Answer has no linkages between points and is unstructured.	0	<p>Guidance on how the mark scheme should be applied:</p> <p>The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning, scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).</p> <p>If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</p> <p>In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.</p> <p>If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s). Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning.</p>	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points																						
6	4																						
5-4	3																						
3-2	2																						
1	1																						
0	0																						
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	<p>Indicative content:</p> <ul style="list-style-type: none"> • IP1 increase in temperature will increase rate • IP2 (but) increase in temperature will decrease yield/move the equilibrium to the LHS/ produce less SO₃ because it is an exothermic reaction (in the forward direction) • IP3 increase in temperature increases energy costs • IP4 increase in pressure has no effect on rate (because all the active sites are already occupied on a heterogeneous catalyst). OR increase in pressure will increase rate (of reaction) • IP5 increase in pressure will move position of eqm to RHS/increase yield because there are less moles/molecules (of gas) on the RHS • IP6 but increased pressure increases (construction and running) costs/reduces economic viability 	<p>Decreased yield with no reference to exothermic reaction does not get IP2.</p> <p>Allow increases yield of reactants/SO₂ and O₂ (with reference to exothermic reaction)</p> <p>Increased yield with no reference to number of moles does not get IP5.</p> <p>Award one mark for IP2 and IP5 if correct references to yield in both but reasons not given</p> <p>Allow IP3 and IP6 if increased costs of higher temperature and pressure are mentioned together provided that the temperature costs are linked to energy costs. Otherwise only IP6 can be awarded.</p> <p>Ignore any reference to catalyst</p>	
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Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> (the initial rate of reaction is slow) because both reacting species are negatively charged / repel each other or the reaction has a high activation energy / few particles have energy greater than (or equal to) the activation energy (1) (the rate of reaction increases) because Mn²⁺ ions (are formed) and they act as a catalyst / are autocatalytic / provide an alternative route with a lower activation energy (1) (the rate decreases) because the concentrations / amounts of the reactants decrease / the reactants are used up (1) 	<p>Allow because there is no catalyst / no Mn²⁺ ions present at the start</p> <p>Allow a description of how the Mn²⁺ ions are acting as a catalyst e.g. the idea of Mn²⁺ ions reacting and being regenerated</p> <p>Do not award 'enzyme'</p> <p>Allow example of one of the reagents used up / becoming a limiting factor</p> <p>Do not award 'the Mn²⁺ ions are used up'</p>	(3)

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	<p>Reagent</p> <ul style="list-style-type: none"> (concentrated) NaOH/KOH (1) <p>Conditions</p> <ul style="list-style-type: none"> ethanol (solvent) <u>and</u> heat/warm (1) 	<p>do not award OH⁻ or just 'hydroxide'</p> <p>do not award M1 if 'acidified'</p> <p>allow reflux</p> <p>M2 is dependent on M1 except for a near miss e.g. OH⁻</p>	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	<ul style="list-style-type: none"> Reagent: KCN/NaCN /potassium cyanide / sodium cyanide (1) Reason: increases the number of carbon atoms in the carbon chain/ length of carbon chain (1) 	ignore any mention of the solvent (aq ethanol) and conditions (reflux) do not award just CN ⁻ /cyanide/HCN	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	An explanation that makes reference to the following: <ul style="list-style-type: none"> heating increases rate (of reaction) (1) no sealed tube would result in loss of ammonia (gas)/ reactants / gas (1) 	ignore reference to activation energy/ starting the reaction/ reaction is endothermic ignore toxicity of reactants	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
(iv)	$\text{CH}_3 - \text{CH}_2 - \text{CH}_2 - \text{OH}$	allow displayed/structural/skeletal formula ignore name do not award just C ₃ H ₇ OH	(1)

Q8.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	$K_c = \frac{[\text{HI}(\text{g})]^2}{[\text{H}_2(\text{g})][\text{I}_2(\text{g})]}$	Ignore missing state symbols or units Do not award round brackets	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	$K_c = \frac{4y^2}{(a-y)^2}$ <ul style="list-style-type: none"> Numerator term correct (1) Denominator term correct (1) 	Allow square brackets Allow (2y) ² Allow (a ² - 2ay+y ²) or (a-y)(a-y)	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	<ul style="list-style-type: none"> both values correct to 2 DP 	1.13 2.93	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	<ul style="list-style-type: none"> All 7 points plotted correctly (1) Appropriate straight line of best fit, drawn through the origin (1) 	Allow TE for incorrect values from 9(b)(i) Do not allow all points above or below the line of best fit Allow line of best fit to intersect one square either side of the origin	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iii)	<ul style="list-style-type: none"> co-ordinates correctly read off the line on graph (1) <ul style="list-style-type: none"> gradient correctly calculated (1) 	At least 1 line must be shown on the graph to indicate selection of co-ordinates <u>Example of calculation</u> $\frac{3.40 - 0.00}{4.50 - 0.00} = \text{gradient of graph}$ $\text{Gradient} = 0.76$ Ignore SF except 1SF Do not allow units for the gradient Allow a value from 0.71 to 0.81 inclusive	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iv)	<ul style="list-style-type: none"> $\frac{\sqrt{K_c}}{2 + \sqrt{K_c}} = \text{gradient} / \frac{y}{a}$ (1) re-arrangement of expression and calculation of K_c (1) 	<u>Example of calculation</u> $\frac{\sqrt{K_c}}{2 + \sqrt{K_c}} = 0.76$ $K_c = 40.1 / 40 \text{ (no units)}$ Allow TE on gradient from part (iii) $K_c = [(2 \times \text{grad}) / (1 - \text{grad})]^2$ Correct answer with no working scores (2)	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	<ul style="list-style-type: none"> hydrogen is flammable / explosive 	Allow iodine vapour damages eyes /toxic Allow hydrogen iodide is corrosive / acidic / irritant (if qualified) / lachrymator Ignore references to high pressure Ignore references to safety precautions	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)	<ul style="list-style-type: none"> Faster rate of reaction / increased rate (1) K_c unchanged (1) 	Ignore references to shifting position of equilibrium	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)(i)	An explanation that makes reference to the following points: <ul style="list-style-type: none"> $(K_c \text{ is})$ smaller / decreases / gets less (1) (forward) reaction is exothermic (1) 	Allow reverse/backwards reaction is endothermic MP2 dependent on MP1	(2)

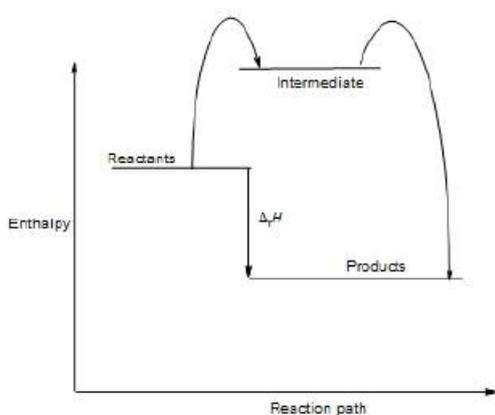
Question Number	Acceptable Answers	Additional Guidance	Mark
(e)(ii)	<ul style="list-style-type: none"> straight line drawn on the graph with a less steep gradient (and goes through the origin) 	Do not allow if lines cross	(1)

Q9.

Question Number	Answer	Additional Guidance	Mark
	<ul style="list-style-type: none"> tangent drawn on graph at 50 s (1) calculation of rate (1) units (1) 	<p><u>Example of calculation</u> vertical axis 0.055 mol dm⁻³ horizontal axis 110 s rate = 0.055 ÷ 110 = (-)5.0 x 10⁻⁴ Allow answers in the range (-)4.0 – (-)6.0 x 10⁻⁴ Ignore missing negative sign</p> <p>mol dm⁻³ s⁻¹ mol dm⁻³ /s mol dm⁻³ per s</p>	(3)

Q10.

Question Number	Answer	Additional Guidance	Mark
(i)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> provide / overcome the activation energy or (is slow at room temperature but) accelerates as temperature rises <p>(1)</p> <ul style="list-style-type: none"> (sufficiently / very) exothermic enough to melt the copper / break bonds in copper <p>(1)</p>	<p>Do not allow 'to lower the activation energy'</p> <p>Allow answers that link rise in temperature to rising rate</p>	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	 <ul style="list-style-type: none"> intermediate energy level/transition state (1) product line below level of reactant line and $\Delta_r H / \Delta H$ shown on down/ vertical arrow (1) 	<p>Allow transition state for intermediate</p> <p>Ignore type of arrows to and from intermediate Allow any diagram with a hump shown, with / without intermediate / transition state label</p> <p>Do not penalise missing 'Products' label Allow use of $\Delta_r H / - 905.2 \text{ (kJ mol}^{-1}\text{)}$</p>	(2)

Question Number	Answer	Additional Guidance	Mark
(iii)	<p>An answer that makes reference to any three of the following points:</p> <ul style="list-style-type: none"> reactants adsorb onto catalyst/surface (1) (there are) active sites on catalyst (surface) (1) bonds in reactants weakened / broken <p>or</p> <p>reaction takes place (1)</p> <ul style="list-style-type: none"> products desorb from the catalyst/active site (1) 	Do not allow absorb	(3)

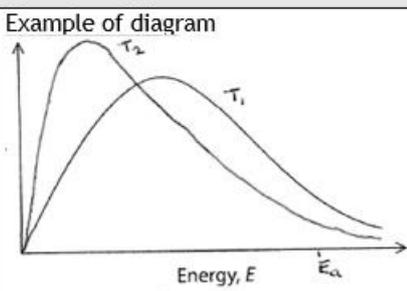
Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	<ul style="list-style-type: none"> five points plotted correctly Comment Ignore a sixth additional point (1) smooth curve passing through all the points (to within 1 square) excluding any anomalous incorrectly plotted points (1) 		(2)

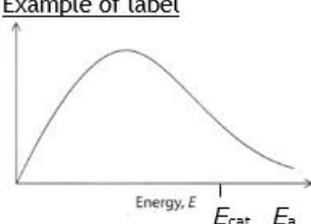
Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	<p>A description which refers to the following points:</p> <ul style="list-style-type: none"> take a tangent to the curve (1) (tangent taken at) time = 0 (for the initial rate) / at the start (1) (tangent taken at) at the steepest part of the curve (for the maximum rate) (1) find the gradient (of the tangent by change in concentration over change in time) (1) 	<p>Marks may be scored by tangents on the graph</p> <p>Allow assume that the very first part of the graph is a straight line and extrapolate / extend (up to 25 s)</p> <p>Allow where the slope is closest to vertical / at about 100 s / 0.050 mol dm⁻³ Ignore just 'highest'</p> <p>Allow description of finding the gradient e.g. finding dy/dx / dy/dt Ignore just mol dm⁻³ / s</p>	(4)

Q12.

Question Number	Answer	Additional Guidance	Mark
(i)	<ul style="list-style-type: none"> fraction / proportion / number of molecules / particles with energy, E 	Allow fraction / proportion / number of molecules / particles Allow label written on y axis on diagram	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	<ul style="list-style-type: none"> peak for T_2 to the left of T_1 (1) peak for T_2 higher than T_1 and asymptote lower than T_1 line and not touching the x axis (1) 	Example of diagram  Ignore missing label from added line Do not award M2 if added line curves upwards at the end	(2)

Question Number	Answer	Additional Guidance	Mark
(iii)	An explanation that makes reference to the following points: <ul style="list-style-type: none"> (at a lower temperature the) molecules / particles / collisions have lower (kinetic) energy (1) so fewer molecules / particles / collisions have energy greater than (or equal to) the activation energy / E_a (1) 	Ignore molecules / particles move more slowly Allow fewer molecules / particles have (enough energy to overcome) the activation energy Allow this shown as labelled shading on the diagram Ignore just 'fewer successful collisions'	(2)

Question Number	Answer	Additional Guidance	Mark
(iv)	<ul style="list-style-type: none"> E_{cat} labelled anywhere between the energy corresponding to the highest point of the peak and to the left of E_a 	Example of label  Allow other clear labels for E_{cat}	(1)

Q13.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> yield (of NO) decreases (1) increase in pressure shifts equilibrium (position) to the side of fewer moles (of gas molecules) (1) 	<p>if M1 and M2 are contradictory then do not award any marks</p> <p>allow 9 mol on LHS and 10 mol on RHS, may be shown above the equation</p> <p>allow more moles of product</p> <p>allow fewer moles of reactant</p> <p>allow marking points in either order</p>	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	<p>An answer that makes reference to the following points: (on increasing the pressure)</p> <ul style="list-style-type: none"> Rate increases because there are more molecules per unit volume (1) <p>so increase in frequency of collisions (between reacting molecules) (1)</p>	<p>allow increase in concentration of (gas) molecules</p> <p>allow any implication of more particles in a given volume, e.g. particles are closer together</p> <p>allow more collisions per unit time</p> <p>ignore just 'more collisions'/'more successful collisions' with no reference to time</p> <p>allow answers based on a solid catalyst</p>	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	<p>An answer that makes reference to:</p> <ul style="list-style-type: none"> heterogeneous: (the catalyst is in) a different phase/state to the reactants (1) increases the rate of the forward and backward / reverse reactions (1) 	ignore reference to products	(2)

Q14.

Question Number	Acceptable Answer	Additional guidance	Mark
	<p>An explanation that makes reference to the following:</p> <ul style="list-style-type: none"> increase surface (area) / more active sites (1) (honeycomb structure) allows gases to flow through (the exhaust) (1) 	<p>Do not award absorption Ignore reference to rate of reaction / remove pollutants</p> <p>Do not award if comments are made that refer to the structure acting like a filter for the particulates or other substances</p>	(2)

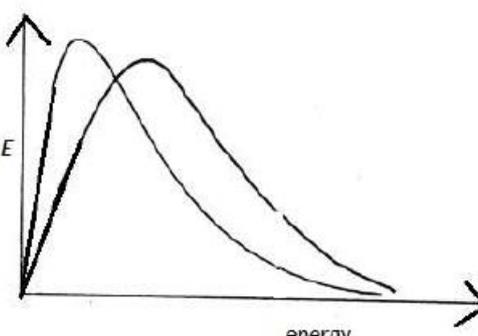
Q15.

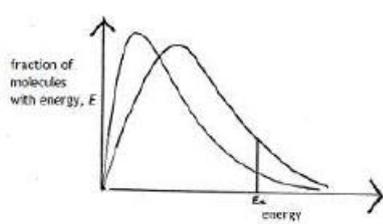
Question Number	Answer	Additional Guidance	Mark
	<p>A description that makes reference to the following points:</p> <ul style="list-style-type: none"> filter the solid from the solution after the experiment (1) (rinse with solvent / water and) dry (1) reweigh the solid (it should weigh 0.25 g) (1) repeat the experiment to see if identical results occur / to check catalyst still works (1) 	Do not award measure the volume of catalyst	(4)

Q16.

Question Number	Acceptable Answer	Additional Guidance	Mark
	<p>An explanation which makes reference to the following points:</p> <ul style="list-style-type: none"> (the reaction is catalysed by hydrogen ions and the concentration of hydrogen ions is initially very low (1) hydrogen ions are formed by the reaction so the concentration of catalyst increases / rate of reaction increases (1) 	<p>Allow concentration of hydrogen ions is zero Allow initially the reaction is not catalysed (due to lack of hydrogen ions)</p> <p>Allow the reaction is autocatalytic</p> <p>Allow the reaction is exothermic so it heats up after the start (and so gets faster) for 1 mark</p> <p>If M1 and M2 are not scored allow a comment that hydrogen ions catalyse the reaction for 1 mark</p>	(2)

Q17.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	<ul style="list-style-type: none"> additional curve added with peak to the right <u>and</u> lower 	 <p>fraction of molecules with energy, E</p> <p>energy</p> <p>Allow curve at start of line</p> <p>Do not allow the additional line to touch or cross the original curve more than once</p>	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> (higher temperature gives) molecules / particles more (kinetic) energy (and there is a higher collision frequency) <p>(1)</p> <ul style="list-style-type: none"> a single activation energy marked on graph <p>or</p> <ul style="list-style-type: none"> more molecules / particles / collisions have energy greater than / equal to the activation energy <p>or</p> <ul style="list-style-type: none"> more molecules / particles / collisions have the activation energy <p>(1)</p>	<p>Allow reverse argument for a decrease in temperature</p> <p>Allow collisions have more energy</p> <p>Ignore molecules/particles move faster</p> <p>Do not allow just 'gases/reactants/atoms' once only</p>  <p>fraction of molecules with energy, E</p> <p>energy</p> <p>Allow more molecules have enough energy to overcome the activation energy</p> <p>Do not allow any indication that the activation energy changes</p> <p>Do not allow any mention that the total area under the curve increases</p>	(3)

	<ul style="list-style-type: none"> so a greater proportion of the collisions result in a reaction <p style="text-align: right;">(1)</p>	<p>Allow so more collisions are successful</p> <p>Ignore just 'more frequent collisions'</p>	
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Q18.

Question Number	Answer	Additional Guidance	Mark
(i)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> (increasing the pressure) decreases the yield as the right hand side / products contain more moles of gas (increasing the pressure) increases the rate of reaction as collisions occur at an increased frequency 	<p>Award 4 moles of product formed from 2 moles of reactant</p> <p>Allow more particles in a given volume / particles are more likely to collide</p> <p>Ignore more collisions are of the correct orientation</p>	(4)

Question Number	Answer	Additional Guidance	Mark
(ii)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> at higher temperatures the yield of product would be less (as forward reaction is exothermic) at lower temperatures the reaction would be slower (500 K is a compromise) giving a reasonable yield at a reasonable rate / between yield and rate 		(3)

Q19.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	0.816 / 8.16×10^{-1} (g)		(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	<ul style="list-style-type: none"> calculation of moles of CO₂ 	<p><u>Example of calculation:</u></p> <p>(moles CO₂ = $\frac{225}{24000}$ =) 0.009375</p> <p>Allow 9.375×10^{-3} / 9.38×10^{-3} / 9.4×10^{-3}</p> <p>Ignore SF except 1SF</p>	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	<ul style="list-style-type: none"> moles of MCO₃ (1) method for calculation of molar mass of MCO₃ (1) molar mass final answer to 1, 2 or 3 SF (1) consequential identification of Group 2 metal by name or formula (1) <p>NOTE Alternative method can score 3 MAX</p> <p>Calculation of moles of CO₃²⁻ (1)</p> <p>(Calculation of mass of CO₃²⁻) Deduction of mass of M by subtraction (1)</p> <p>Calculation of Ar of M to 1, 2 or 3 SF AND Identification of group 2 metal (1)</p>	<p><u>Example of calculation:</u></p> <p>Moles of MCO₃ = moles CO₂ = 0.009375 (mol)</p> <p>Molar mass of MCO₃ = $\frac{0.816}{0.009375}$ (= 87.04 (g mol⁻¹)) M2 subsumes mark for M1</p> <p>= 87.0 / 87 / 90 (g mol⁻¹) NOTE M3 mark subsumes mark for M2 and M1</p> <p>(87.0 – 60) = 27 AND Mg / Magnesium / MgCO₃</p> <p>Allow TE on answers to parts (a) and (b), with Metal consequential on calculated molar mass but M must be a Group 2 element</p> <p>Moles CO₃²⁻ = 0.009375</p> <p>(Mass of CO₃²⁻ = 0.009375 x 60 = 0.5625 g) Mass of M = 0.2535 g</p> <p>Ar = 0.2535/0.009375 = 27.0 / 27 / 30 (g mol⁻¹) AND Mg / Magnesium / MgCO₃</p>	(4)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(i)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> the bung was not replaced quickly enough (1) (So) CO₂ / gas lost (to the surroundings) (1) 	<p>Allow bung not fitting tightly resulting in leaks Ignore references to CO₂ dissolving Ignore references to other types of gas leak</p> <p>Allow 'smaller volume of gas collected' / lower reading of gas volume Mark points M1 and M2 independently</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(ii)	<p>An answer that makes reference to the following point: The acid was (already) in excess (and more acid won't affect this)</p>	<p>Allow The carbonate is the limiting reactant / the acid is not the limiting reactant</p>	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(iii)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> rate of reaction is faster and powder has greater surface area (1) no effect on (final) volume of gas and moles of (metal) carbonate are unchanged or because the rate is faster more gas will be lost before the bung is replaced so the (final) volume will be less <p>(1)</p>	<p>Mark points M1 and M2 independently</p> <p>Both parts of statement needed</p> <p>Both parts of statement needed Allow mass / amount for moles Allow reactant for metal carbonate</p>	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)(i)	<ul style="list-style-type: none"> balanced equation with state symbols 	<p>Example of equation: MCO₃(s) → MO(s) + CO₂(g)</p> <p>Allow a correct equation for the decomposition of any Group 2 carbonate</p>	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)(ii)	<ul style="list-style-type: none"> subtractions to obtain masses (1) calculation of moles of CO₂ (1) calculation of molar mass of MCO₃ (1) 	<p><u>Example of calculation:</u> (mass of CO₂ = 20.447 - 20.205) = 0.242 AND (mass of MCO₃ = 20.447 - 19.996) = 0.451</p> <p>moles of CO₂ = $\frac{0.242}{44}$ = 0.0055(0) (mol) / 5.5(0) x 10⁻³ (mol) ALLOW TE from M2 to M3</p> <p>Mr of MCO₃ = $\frac{0.451}{0.0055(0)}$ = 82 (g mol⁻¹) Correct answer with or without working scores 3 Ignore SF except 1 Ignore attempts to identify the metal</p>	(3)

Question Number	Acceptable Answers	Additional Guidance	Mark
(f)	<p>An answer that makes reference to the following point:</p> <p>Student 3 used a smaller mass / less (and the uncertainty of the balance was the same) or Student 1 used a larger mass / more (and the uncertainty of the balance was the same)</p>	<p>Allow calculations comparing the two percentage errors: e.g. Student 1:- (0.001/0.816) x 100% = 0.12% and Student 3:- 0.001/0.451 x 100% = 0.22%</p>	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(g)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> more CO₂ (would appear to be) given off (1) (So) calculated molar mass is smaller (1) <p>OR</p> <ul style="list-style-type: none"> Less MO would appear to have been formed (1) Calculated molar mass would be greater (1) 	<p>M2 dependent on M1</p> <p>M2 dependent on M1</p>	(2)

Q20.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(i)	correct equation	Example of equation: $2\text{NaN}_3 \rightarrow 2\text{Na} + 3\text{N}_2$ Allow multiples Ignore state symbols even if incorrect	(1)

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(ii)	<ul style="list-style-type: none"> conversion of volume and temperature to correct units (1) rearrangement of ideal gas equation so $n = pV \div RT$ and calculation of $n(\text{N}_2)$ in moles (1) evaluation of $n(\text{NaN}_3)$ (1) answer converted into mass to 2/3 SF (1) <p>Allow TE at each stage</p>	<p>Example of calculation:</p> <p>$67 \text{ dm}^3 = 0.067 \text{ m}^3$, $300^\circ\text{C} = 573 \text{ K}$</p> <p>$n(\text{N}_2) = \frac{140\,000 \times 0.067}{8.31 \times 573} = 1.9699\dots(\text{mol})$</p> <p>$n(\text{NaN}_3) = (2/3 \times 1.9699\dots) = 1.313\dots(\text{mol})$</p> <p>$m = (1.313 \dots \times 65 = 85.3629\dots) = 85.4 / 85 \text{ (g)}$</p> <p>Correct answer without working scores (4)</p>	(4)

Question Number	Acceptable Answer	Additional guidance	Mark
(b)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> Nitrogen (is reduced) from +5 to 0 (1) Sodium (is oxidised) from 0 to +1 (1) Balanced equation (1) 	<p>Look for oxidation numbers annotated on the equation</p> <p>Do not award potassium oxidised</p> <p>Penalise omission of "+" sign, once only</p> <p>Example of balanced equation: $10\text{Na} + 2\text{KNO}_3 \rightarrow \text{K}_2\text{O} + 5\text{Na}_2\text{O} + \text{N}_2$ Allow multiples</p>	(3)

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	An answer that makes reference to the following points: <ul style="list-style-type: none">• Neutralisation reaction / acid base reaction (1)• Sodium and/or potassium oxides are caustic / corrosive (1)• Salts (silicates) formed are inert / unreactive (1)	Allow salt formation Allow "metal oxides" Ignore "harmful" / "alkaline" Allow "not harmful"/ "not caustic" Ignore "neutral"	(3)

Question Number	Acceptable Answer	Mark
(d)	The only correct answer is A <i>B is incorrect because the peak would shift to the left and be higher</i> <i>C is incorrect because the peak would shift to the left not to the right</i> <i>D is incorrect because the peak would be shift to the left not to the right</i>	(1)

Q21.

Question Number	Answer	Additional Guidance	Mark
	<ul style="list-style-type: none"> tangent drawn to curve when time = 0 tangent must touch curve for at least first 3 small squares on x axis and extend to at least 120 s calculation of gradient units 	<p><u>Example of tangent</u></p> <p>gradient = $\frac{1.0}{300} = 3.33 \times 10^{-3}$ Allow 3.13×10^{-3} to 3.53×10^{-3}</p> <p>TE on tangent drawn or measurements from line on graph with no tangent Ignore SF including 1SF</p> <p>g s^{-1} or g/s stand alone mark</p>	(3)

Q22.

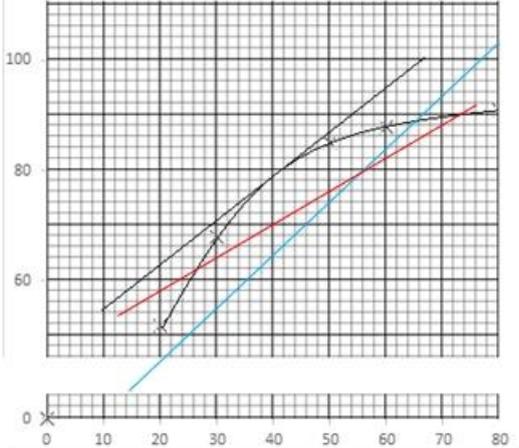
Question Number	Answer	Additional Guidance	Mark
	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> provides a surface for the reaction 	<p>Ignore References to lowering the activation energy Providing alternative route Details of adsorption, weakening of the bonds and desorption Easy to separate after the reaction</p>	(1)

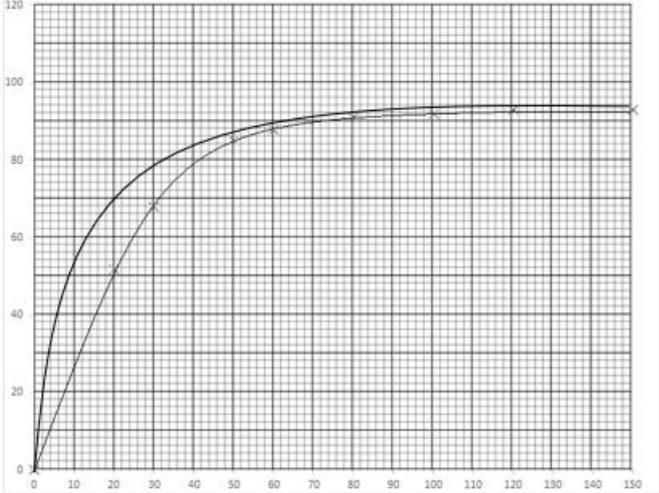
Q23.

Question Number	Acceptable Answer	Additional Guidance	Mark
	<p>An answer which makes reference to the following point:</p> <ul style="list-style-type: none"> it is very difficult to judge where the tangent should be drawn for the initial rate compared to other points on the line 	<p>Allow comments about the tangent being difficult to measure initially or easier at the maximum rate</p>	(1)

Q24.

Question Number	Answer	Additional Guidance	Mark
(i)	<ul style="list-style-type: none"> calculation of the rate of reaction and units 	<p><u>Example of calculation</u></p> $= \frac{51}{20}$ $= 2.55 \text{ cm}^3 \text{ s}^{-1} / 2.55 \text{ cm}^3/\text{s}$ <p>Do not award $\text{cm}^3/\text{s}^{-1}$</p> <p>Allow $= \frac{50}{20} = 2.5 \text{ cm}^3 \text{ s}^{-1}$</p> <p>Ignore SF except 1SF</p>	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	<ul style="list-style-type: none"> draw suitable tangent (1) calculation of gradient (1) 	 <p>Example of calculation</p> $= \frac{100 - 54}{66 - 10} = 0.82143 \text{ (cm}^3 \text{ s}^{-1}\text{)}$ <p>Ignore units even if incorrect Ignore SF</p> <p>Correctly calculated values in a range 0.950 – 0.600 score (2) (approx. blue line – red line) Values outside this range max (1).</p>	(2)

Question Number	Answer	Additional Guidance	Mark
(iii)	<ul style="list-style-type: none">• line rising more steeply than original line of best fit, always above / to the left (1) • finishing at a volume slightly above the original but less than 100. (1)	 <p data-bbox="593 824 1129 855">Do not award if the volume exceeds 100 cm³</p>	(2)

Question Number	Answer	Additional Guidance	Mark
(iv)	<p>An explanation that makes reference to the following points:</p> <p>EITHER</p> <ul style="list-style-type: none"> • the rate of reaction is faster (at a higher temperature) / more gas is produced at a given time • because there is a greater proportion of collisions with energy greater than the activation energy (for the reaction) <p>OR</p> <ul style="list-style-type: none"> • the volume is higher than before because of the increased temperature • the volume of gases increases with temperature 	<p>Allow the gradient / line is steeper</p> <p>(1) Allow just particles have more energy Award converse arguments for lower temperature Ignore just more collisions</p> <p>(1)</p> <p>Do not award just 'more gas is produced'</p> <p>(1)</p> <p>(1)</p>	(2)