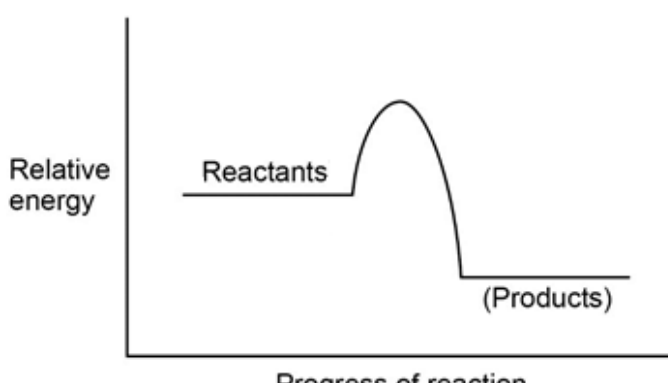
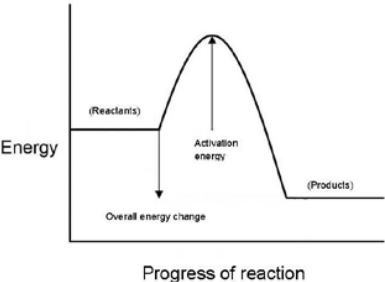


1.1	 ignore labels any curve / line going up and then down products <u>line</u> below reactants allow curve to start / finish anywhere along reactant / product lines	1 1	AO1 5.5.1.2
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2.1	temperature increases or temperature does not decrease	ignore because it is exothermic ignore references to copper allow (because) energy / 'heat' is transferred to the surroundings allow energy / 'heat' is given out allow energy / 'heat' is not taken in (from the surroundings) allow the energy of the products is less than the energy of the reactants	1	AO3 4.5.1.1
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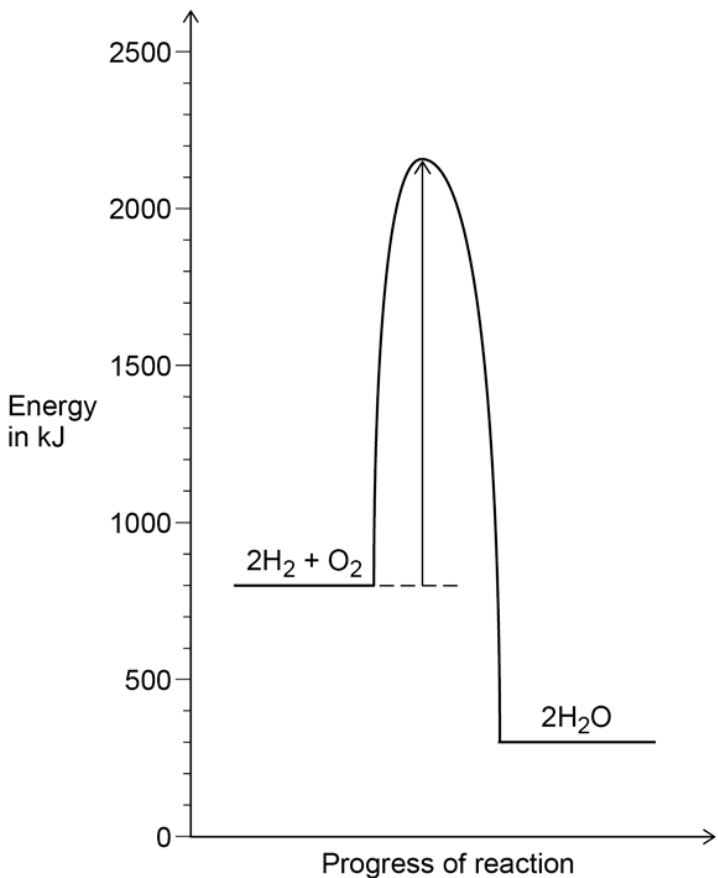
2.2	suitable method described the observations / measurements required to place in order an indication of how results would be used to place the unknown metal in the reactivity series a control variable to give a valid result approaches that could be used approach 1: add the unknown metal to copper sulfate solution (1) measure temperature change (1) place the metals in order of temperature change (1) any one from (1): • same volume of solution • same concentration of solution • same mass / moles of metal • same state of division of metal approach 2: add the metal to salt solutions of the other metals or heat the metal with oxides of the other metals (1) measure temperature change (only if salt solutions used) or observe whether a chemical change occurs (1) place the metals in order of temperature change or compare whether there is a reaction to place in correct order (1) any one from (1): • same volume of salt solutions • same concentration of salt solutions • same (initial) temperature of salt solutions • same mass / moles of metal or metal oxide • same state of division of metal or metal oxide	dependent on a suitable method	1 1 1 1	AO3 4.4.1.2 4.5.1.1
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2.2 cont.	approach 3: add all of the metals to an acid (1) measure temperature change or means of comparing rate of reaction (1) place the metals in order of temperature change or rate of reaction (1) any one from (1): • same volume of acid • same concentration of acid • same (initial) temperature of acid • same mass / moles of metal • same state of division of metal approach 4: set up electrochemical cells with the unknown metal as one electrode and each of the other metals as the other electrode (1) measure the voltage of the cell (1) place the metals in order of voltage (1) any one from (1): • same electrolyte • same concentration of electrolyte • same temperature of electrolyte		
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2.3	correct shape for exothermic reaction labelled activation energy labelled (overall) energy change	an answer of:  scores 3 marks the reactant and product lines needed not be labelled do not accept incorrectly labelled reactant and product lines ignore arrow heads	1 1 1	AO1 4.5.1.2
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3.1	(bonds broken = $4(412) + 193$ $\Rightarrow 1841$) (bonds formed = $3(412) + 366 + X$ $\Rightarrow 1602 + X$) $-51 = 1841 - (1602 + X)$ (X =) 290 (kJ/mol) OR alternative method ignoring the 3 unchanged C–H bonds $(412 + 193 \Rightarrow) 605$ (1) $366 + X$ (1) $-51 = 605 - (366 + X)$ (1) (X =) 290 (kJ/mol) (1)	an answer of 290 (kJ/mol) scores 4 marks an answer of 188 (kJ/mol) scores 3 marks an incorrect answer for one step does not prevent allocation of marks for subsequent steps allow use of incorrectly calculated values of bonds broken and / or bonds formed from steps 1 and 2 for steps 3 and 4 allow a correctly calculated answer from use of $-51 = \text{bonds}$ formed – bonds broken	1 1 1 1	AO2 4.5.1.3
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4.1	Level 3: The design/plan would lead to the production of a valid outcome. All key steps are identified and logically sequenced.	5–6	AO3 AO2
	Level 2: The design/plan would not necessarily lead to a valid outcome. Most steps are identified, but the plan is not fully logically sequenced.	3–4	5.5.1.1
	Level 1: The design/plan 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 Steps • use a suitable container eg test tube • use insulation • add water • measure the initial water temperature (with a thermometer) • add stated mass eg 1g or 1 spatula • stir (to dissolve the solid) • measure the final (allow lowest or highest) temperature of the solution • calculate the temperature difference or determine graphically • repeat with different masses • repeat with the same volume of water to access level 3 there must be an indication of how the temperature change is determined using different masses dissolved in the same quantity of water		

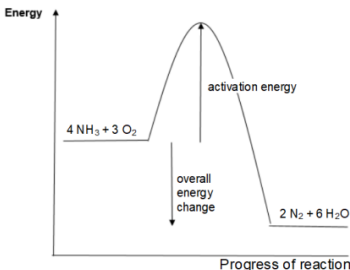
5.1	line from reactants to top of curve (i.e. from 800 to 2160)  Energy in kJ 2500 2000 1500 1000 500 0 2H₂ + O₂ 2H₂O Progress of reaction ignore arrowheads	1	AO1 5.5.1.2
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5.2	reads levels of reactants (800 kJ) and products (300 kJ) (800 – 300) = 500 (kJ)	an answer of (–) 500 (kJ) scores 2 marks ignore sign	1	AO2 AO3 5.5.1.2
		allow correct subtraction of one incorrect value determined for the energy change	1	

5.3	(bonds broken) $((4 \times 463) + (2 \times 138) =)$ 2128 (bonds made) $((4 \times 463) + (496) =)$ 2348 (energy change = bonds broken – bonds made) $(2128 - 2348 =)$ (–) 220 (kJ) alternative approach: (bonds broken) $(2 \times (\text{O}=\text{O}) = (2 \times 138) =)$ 276 (1) (bonds made) $(1 \times (\text{O}=\text{O}) =)$ 496 (1) (energy change = bonds broken – bonds made) $(276 - 496 =)$ (–) 220 (kJ) (1)	an answer of (–) 220 (kJ) scores 3 marks an incorrect answer for one step does not prevent allocation of marks for subsequent steps ignore energy change sign allow correct calculation using incorrect values from step 1 and/or step 2	1 1 1	AO2 5.1.1.1 5.5.1.1 5.5.1.3
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6.1	(for bonds broken) $((12 \times 391) + (3 \times 498) =)$ 6186	an answer of (-)1272 (kJ) scores 3 marks	1	AO2 4.5.1.3
	(for bonds made) $((2 \times 945) + (12 \times 464) =)$ 7458		1	
	(overall energy change = 6186- 7458 =) (-)1272 (kJ)	allow correct calculation using incorrectly calculated values from step 1 and/or step 2	1	

6.2	7458 (kJ) (released in making bonds) is greater than 6186 (kJ) (used in breaking bonds) or the products have 1272 (kJ) less energy than the reactants (so) energy is released (to the surroundings)	allow ecf from question 6.1	1	AO2 4.5.1.3
		allow the (overall) energy change is -1272 (kJ) dependent on MP1 being awarded allow (so) heat is released (to the surroundings) if no values given, allow 1 mark for more energy released in making bonds than used in breaking bonds	1	

6.3	activation energy labelled (overall) energy change labelled	 scores 2 marks allow discontinuous lines ignore arrow heads	1 1	AO1 4.5.1.2
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7.1	polystyrene is a better (thermal) insulator	allow polystyrene is a poorer (thermal) conductor	1	AO3 4.5.1.1
	(so) reduces energy exchange (with the surroundings)	allow (so) reduces energy / heat loss (to the surroundings)	1	

7.2	all six points plotted correctly	allow a tolerance of $\pm \frac{1}{2}$ a small square allow 1 mark for at least 3 points plotted correctly	2	AO2 4.5.1.1
	line of best fit through points plotted from Table 6		1	
	both lines of best fit extrapolated correctly until they cross		1	

7.3	$(27.5 - 18.9) = 8.6 (^{\circ}\text{C})$	allow ecf from question 7.2 allow answers in the range 8.5 to 8.7 ($^{\circ}\text{C}$) allow a tolerance of $\pm \frac{1}{2}$ a small square	1	AO2 4.5.1.1
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8.1	to reach a constant temperature	allow to reach room temperature	1	AO3 5.4.1.2 5.5.1.1 RPA 10
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8.2	line of best fit after 7 minutes extends line back to 4 minutes	ignore extension of line beyond 4 minutes	1 1	AO2 5.4.1.2 5.5.1.1 RPA 10
	the diagram below scores 2 marks			

Temperature in °C

Time in mins

Time (mins)	Temperature (°C)
0	18
1	17.5
2	17.5
3	17.5
4	17.5
5	23.2
6	25.2
7	25.8
8	25.5
9	25.3
10	25.1
11	24.9
12	24.7
13	24.5
14	24.3

8.3	(maximum and minimum values at 4 minutes) 26.3 (°C) and 17.5 (°C) (temperature change at 4 minutes) = 8.8 (°C)	allow ecf from 8.2	1 1	AO3 5.4.1.2 5.5.1.1 RPA 10
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8.4	the reaction finished / stopped	allow maximum temperature has been reached	1	AO3 5.4.1.2 5.5.1.1 RPA 10
	(so) energy is lost to surroundings / atmosphere or (so the) solution cools (back to room temperature)	allow heat for energy	1	

8.5	aluminium / zinc / iron / beryllium	allow Al / Zn / Fe / Be do not accept copper, silver MP2 dependent on a correct answer to MP1	1	AO3
	metal Q is less reactive (than magnesium) or metal Q is lower in reactivity series	allow converse	1	AO2 5.4.1.2 5.5.1.1 RPA 10

9.1	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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10.1	the activation energy should be from the reactants (line to the peak)	ignore description of where the activation energy is on the diagram	1	AO3 4.5.1.2
	the products (line) should be below the reactants (line) or the products should have less energy than the reactants	allow the product (line) is above the reactants (line) allow the products have more energy than the reactants allow the profile shows an endothermic reaction ignore the arrow for the overall energy change should point downwards	1	

11.1	the temperature decreases (initially) because energy is taken in (by the reaction from the solution)	allow temperature decreases (initially) because the reaction is endothermic	1	AO2 AO3 4.5.1.1 RPA 4
	when 1.5 g (of citric acid) is added the sodium hydrogencarbonate has all reacted	allow when the temperature reaches 11.6 °C the sodium hydrogencarbonate has all reacted	1	
	or from 1.5 g the citric acid is in excess	allow after the temperature reaches 11.6 °C the citric acid is in excess		
	or when 1.5 g (of citric acid) is added the reaction is complete	allow when the temperature reaches 11.6 °C the reaction is complete		
	(so) the temperature increases as energy is transferred from the room to the solution	allow (so) the temperature increases as energy is transferred from the excess citric acid to the solution	1	

11.2	less steep line starting at 16.8 °C and reaching 1.00 g (of citric acid)	ignore any part of the line drawn beyond 1.00 g	1	AO3 4.2.2.8 4.5.1.1 RPA 4
	(as) metal is a better conductor	allow (as) polystyrene is a better insulator	1	
	(so) more energy is absorbed (from the surroundings)	allow (so) more heat is absorbed (from the surroundings)	1	

12.1	any three from: • insulate the beaker or use polystyrene cup • add a lid • stir more (times) • repeat the experiment and calculate the mean (ignoring anomalous results) • use smaller volume (of water) • use larger mass of ammonium nitrate • more accurate balance • use digital thermometer or use a more accurate thermometer		3	AO3 5.5.1.1
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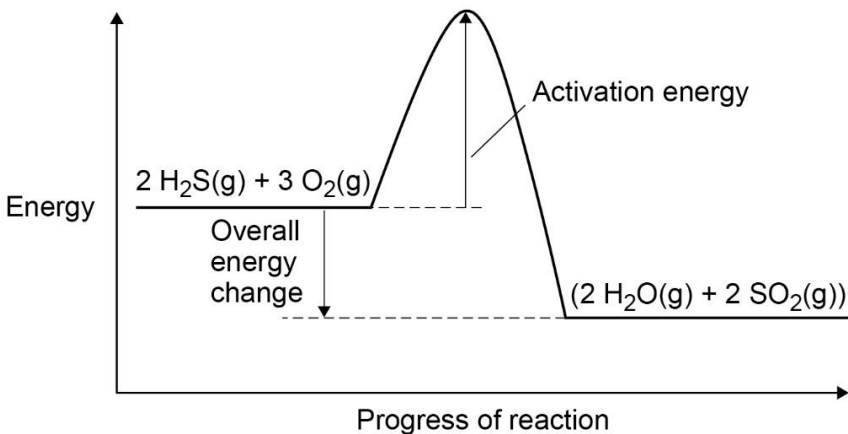
12.2	(from 0 to 1.5 minutes the) temperature decreases	allow the temperature decreases (from 21.4 °C to 15.4 °C)	1	AO3 5.5.1.1
	(because) ammonium nitrate dissolving is endothermic		1	
	(then) after 1.5 minutes the temperature increases	(then) after 15.4 °C the temperature increases	1	
	(because) energy transfers to the solution from the surroundings		1	

12.3	labelled horizontal lines for reactants and products, with the product line below the level of the reactant line		1	AO1 5.5.1.2
	reaction pathway	allow curve to start / finish anywhere along reactant / product lines	1	
	line from reactants to maximum labelled activation energy		1	
	line from reactants to products labelled overall energy change		1	
	the diagram below scores 4 marks			

13.1	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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13.2	(bonds broken = $(8 \times 410) + 2 \mathbf{X} + (5 \times 500)$ $= 5780 + 2 \mathbf{X}$	allow C–C for $\mathbf{X}$ allow (bonds broken = $(8 \times 410) + (5 \times 500)$ $= 5780$	1	AO2 5.5.1.3
	(bonds formed = $(6 \times 740) + (8 \times 460)$ $= 8120$		1	
	(bonds broken – bonds formed = energy released) $(5780 + 2 \mathbf{X}) - 8120 = -1640$	allow correct use of incorrect values from step 1 and/or step 2	1	
	$(2 \mathbf{X} =) 700$	allow correct use of incorrect value from step 3	1	
	$(\mathbf{X} =) 350 \text{ (kJ/mol)}$		1	

14.1	measure temperature change	allow measure the temperature before and after the reaction	1	AO1
	when each metal is added to silver nitrate solution		1	AO1
	same concentration / volume of solution or same mass / moles of metal	allow same initial temperature (of silver nitrate solution)	1	AO2
	the greater the temperature change the more reactive		1	AO3
				4.4.1.2 4.5.1.1 RPA4

15.1	product level below reactants activation energy drawn and labelled overall energy change drawn and labelled	ignore labelling of products if endothermic profile drawn allow corresponding overall energy change 	1 1 1	AO1 4.5.1.2
scores 3 marks				

15.2	(bonds broken = $4(364) + 3(498)$ =) 2950		1	AO2 4.5.1.3
	(bonds formed = $2950 + 1034$ =) 3984	allow correct use of incorrectly calculated values of bonds broken	1	
	$4X + 4(464) = 3984$	allow correct use of incorrectly calculated values of bonds formed	1	
	$4X = (3984 - 1856)$ =) 2128		1	
	$X = 532$ (kJ/mol)		1	
	alternative approach: (bonds broken = $4(364) + 3(498)$ =) 2950 (1)			
	(bonds formed = $4(464) + 4X$ =) $1856 + 4X$ (1)			
	$(1856 + 4X) - 2950 = 1034$ (1)	allow correct use of incorrectly calculated values of bonds broken and/or bonds formed		
	$4X = (1034 + 2950 - 1856)$ =) 2128 (1)			
	$X = 532$ (kJ/mol) (1)			

16.1	(bonds broken = (4 × 413) + C=C + 431 =) 2083 + C=C		1	AO2 5.5.1.3
	(bonds made = (346 + 339 + (5 × 413) =) 2750		1	
	(energy released = bonds made – bonds broken =) 56 = 2750 – [2083 + C=C]	allow correct use of incorrect value(s) from step 1 and / or step 2	1	
	(C=C) = 611 (kJ/mol)		1	

17.1	Level 3: The method would lead to the production of a valid outcome. The key steps are identified and logically sequenced.	5–6	AO1 4.5.1.1 RPA 4
	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 • measure volume of (hydrochloric) acid • with a measuring cylinder • pour (hydrochloric) acid into a suitable container eg polystyrene cup • measure the initial temperature (of hydrochloric acid) • with a thermometer • add a known mass of sodium carbonate • measured with a balance • stir • measure the highest temperature reached • repeat with different masses of sodium carbonate or add successive masses of sodium carbonate to the same mixture • repeat the whole investigation • use the same starting temperature • use the same volume of (hydrochloric) acid each time • use the same concentration of (hydrochloric) acid each time		

17.2	C		1	AO3 4.5.1.1 RPA 4
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17.3	(X) energy		1	AO1 4.5.1.2
	(Y) (overall) energy change		1	

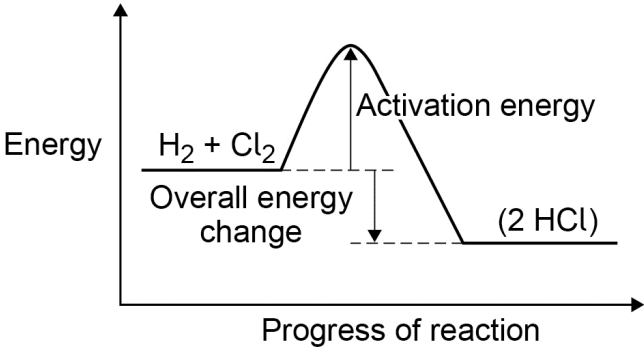
17.4	(level of) products is below (level of) reactants	allow the energy decreases (overall) allow energy is transferred to the surroundings ignore references to bond making / breaking	1	AO1 4.5.1.2
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18.1	endothermic (reaction)	allow reversible (reaction) allow (thermal) decomposition (reaction)	1	AO1 4.6.2.2
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19.1	temperature decreased	ignore correct references to energy transfer	1	AO1 4.5.1.1 RPA4
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20.1	$436 + 346 - (2 \times 432) \text{ kJ/mol}$		1	AO2 4.5.1.3
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Source: AQA 2023 Chemistry Paper 1 mark scheme, original question 04.2

20.3	profile completed with product energy below reactant energy activation energy labelled from reactant energy to top of curve overall energy change labelled from reactant energy to product energy an answer of  scores 3 marks	ignore arrow heads	1	AO1
			1	AO1
			1	AO2
				4.5.1.2