

Question	Evidence	Achievement	Merit	Excellence
ONE (a) (i) & (ii)	Surface area. When the marble chips are crushed there is a greater surface area. This means there are now more particles for collisions to occur between the acid and the calcium carbonate. Because more collisions can now occur in a shorter amount of time (more frequently) the reaction is faster.	• Surface area • There is a greater surface area when powder is used. • Collisions occur more frequently when powder is used.	• Links surface area correctly to particle collision theory.	
(b)	In Experiment 2, the only change is an increase in temperature. An increase in temperature means a faster rate of reaction. For a chemical reaction to occur, the reactants must collide effectively. This means they must collide with enough energy to overcome the activation energy of the reaction. The activation energy is the energy that is required to start a reaction. When the temperature is higher, the particles have more kinetic energy; the particles are moving faster. Because the particles are moving faster, there will be more frequent collisions. Also because the particles are moving with more kinetic energy, it will be more likely that when collisions occur they are more likely to be effective, i.e. collide with enough energy to overcome the activation energy. Therefore the rate of reaction is faster, as more effective collisions are occurring more frequently. In Experiment Three, a catalyst is used (the copper ions). Use of a catalyst speeds up the rate of chemical reaction. For a chemical reaction to occur, the reactants must collide effectively. This means they must collide with enough energy to overcome the activation energy of the reaction. The activation energy is the energy that is required to start a reaction. When a catalyst is used, the activation energy is lowered. This is because the catalyst provides an alternative pathway for the reaction to occur in which the activation energy is lowered. Now that the activation energy has been lowered, more reactant particles will collide with sufficient energy to overcome this lowered activation energy. Therefore, the rate of reaction is faster as more effective collisions are occurring more frequently.	• For a chemical reaction to occur, particles must collide effectively. • An increase in temperature means particles move faster OR have more kinetic energy. • Collisions occur more frequently when there is an increase in temperature. • The activation energy is the energy that must be provided to start a chemical reaction. • A catalyst speeds up the rate of reaction by lowering the activation energy OR providing an alternative pathway.	• Links temperature correctly to particle collision theory. • Links catalyst correctly to activation energy.	• Elaborates on why Experiment 2 reaction is faster than Experiment 1 reaction. • Elaborates on why Experiment 3 reaction is faster than Experiment 1 reaction.

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response or no relevant evidence.	2a	3a	4a	5a	2m	3m	e	2e

Question	Evidence	Achievement	Merit	Excellence
TWO (a) (b) (c)	$K_c = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3}$ $2\text{SO}_2 + \text{O}_2 \rightleftharpoons 2\text{SO}_3$ When a change is made to a system that is at equilibrium, the system responds to reduce the effect of that change. If there is an increase in pressure, the system responds by decreasing the pressure. This occurs by favouring the reaction that produces fewer gas particles. Because there are now fewer particles hitting the sides of the container, there is less pressure. In Reaction One there are two moles of gas particles on each side of the equation. Because there are the same numbers of gas particles on both sides of the reaction, then a change in pressure will have no effect as neither reaction will be favoured. In Reaction Two however, there are four moles of gas particles on the reactant side of the equation and two moles of gas particles on the product side of the equation. Therefore, when there is an increase in pressure, the system would shift and favour the forward reaction meaning there are now fewer gas particles overall and hence fewer gas particles hitting the sides of the container and therefore less pressure overall.	• Correct K_c expression. AND writes a correct equation. • If there is an increase in pressure, the system responds by decreasing the pressure. • Increase in pressure favours the side with fewer moles of gas. • For Reaction One reactant moles = product moles. AND For Reaction Two reactant side has more moles than product side.	• When a change is made to a system that is at equilibrium the system responds to reduce the effect of that change. If there is an increase in pressure the system responds by decreasing the pressure. • In Reaction One there are the same number of gas particles on both sides of the equation and therefore neither reaction will be favoured. AND In Reaction Two there are less gas particles on the product side than on the reactant side. Therefore the forward reaction would be favoured. • As K_c decreases, this means there is less of the product, as the K_c equals the concentration of the product divided by the reactants. For the K_c to be smaller the number on top must be smaller, i.e. there will be less of the product and more of the reactants. OR When temperature increases the system responds and decreases the temperature. To do this, the reaction that is endothermic will be favoured. • Calculation correct.	• Comprehensively compares and contrasts the two reactions in (c). • Elaborates on the effect of the temperature on K_c and links it to the formation of NH_3 being exothermic.
(d)	As the temperature increases, K_c decreases. The decreasing value of K_c indicates that the reaction is reactant-favoured (i.e. more reactants than products). When temperature increases, the system responds and decreases the temperature by shifting in the endothermic direction. Since the increasing temperature favours the reactants, this must mean that the reverse reaction is endothermic and the forward reaction (formation of NH_3) is exothermic.	• As the temperature increases, the K_c decreases. • When the temperature is increased, the system responds by reducing the temperature. • A smaller value of K_c indicates there are more reactants than products. • One step in calculation correct.		

(e)	$\frac{[\text{HI}(\text{g})]^2}{[\text{H}_2(\text{g})][\text{I}_2(\text{g})]} = 46.8$ $\frac{[\text{HI}(\text{g})]^2}{[0.0190][0.210]} = 46.8$ $\frac{[\text{HI}(\text{g})]^2}{3.99 \times 10^{-3}} = 46.8$ $[\text{HI}(\text{g})]^2 = 0.187$ $[\text{HI}(\text{g})] = 0.432 \text{ mol L}^{-1}$							
NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response or no relevant evidence.	1a	2a	4a	5a	2m	3m	e	2e

Question	Evidence	Achievement	Merit	Excellence
THREE (a)	An acid and its conjugate base differ by a hydrogen ion. An acid has an extra hydrogen ion. HCl has an extra hydrogen ion than its conjugate base Cl^- and HSO_4^- has an extra hydrogen ion than its conjugate base SO_4^{2-} .	Describes an acid and its conjugate base as differing by one hydrogen ion.	Explains the difference between an acid and its conjugate base using an example from the table.	Comprehensively compares and contrasts the reactivity of TWO of the acids with Mg in terms of $[\text{H}_3\text{O}^+]$, strength of acid and collision frequency.
(b)	$[\text{OH}^-] = \frac{1.00 \times 10^{-14}}{0.0125} = 8.00 \times 10^{-13} \text{ mol L}^{-1}$ $\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log 0.0125 = 1.90$	One calculation correct from (b).		
(c)(i)	$\text{CH}_3\text{COOH} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}_3\text{O}^+$	Equation correct	Explains that the solution is acidic because the concentration of hydronium ions is greater than $1 \times 10^{-7} \text{ mol L}^{-1}$	
(ii)	This solution is acidic, as ethanoic acid reacts with water to produce hydronium ions. $[\text{H}_3\text{O}^+] > [\text{OH}^-]$ making the solution acidic.	ethanoic acid reacts with water to produce hydronium ions.		
(d)(i)	$2\text{HA} + \text{Mg} \rightarrow \text{MgA}_2 + \text{H}_2$ OR $2\text{H}^+ + \text{Mg} \rightarrow \text{Mg}^{2+} + \text{H}_2$	Correct equation with magnesium.	OR$[\text{H}_3\text{O}^+] > [\text{OH}^-]$.	
(ii)	A strong acid is an acid that dissociates completely, meaning that all the acid molecules donate H^+ ions. A weak acid partially dissociates, meaning that only a small proportion of acid molecules donate H^+ ions.	- Strong acid dissociates completely. - OR - Weak acid partially dissociates.		
(iii)	$\text{HA} [\text{H}_3\text{O}^+] = 10^{-3.4} = 3.98 \times 10^{-4} \text{ mol L}^{-1}$ $\text{HB} [\text{H}_3\text{O}^+] = 10^{-2} = 0.0100 \text{ mol L}^{-1}$ $\text{HC} [\text{H}_3\text{O}^+] = 10^{-5} = 1.00 \times 10^{-5} \text{ mol L}^{-1}$ The concentration of hydronium ions is the same as the concentration of the acid for HB and HC, which means they are strong acids, since they both completely dissociate when they react with water. The concentration of hydronium ions in HA is less than the concentration of the acid HA, therefore it is a weaker acid, since it only partially dissociates in water. HB will react faster with the Mg, as it has the greatest concentration of hydronium ions since it has the lowest pH. Because the concentration of hydronium ions is greater in HB, there are more hydronium ion particles in the same volume to collide with the Mg. Therefore, there will be more frequent collisions, and hence a faster rate of reaction. Even though HA has a higher concentration than HB, it is a weaker acid, so it only partially dissociates and not all of the HA particles donate hydrogen ions. Therefore the concentration of hydronium ions is low, so there are fewer hydronium ion particles	- One correct calculation of hydronium ions. - States the strength of TWO of the acids.	Explains the reactivity of the TWO of the acids with Mg in terms of $[\text{H}_3\text{O}^+]$. OR explains the strength of TWO of the acids in terms of [acid] and $[\text{H}_3\text{O}^+]$.	

	in the same volume to collide with the Mg. Therefore, there will be less frequent collisions, and hence a slower rate of reaction compared to HB. The concentration of HC is very low, and even though it is a stronger acid than HA and completely dissociates in water, there will still be the lowest number of hydronium ion particles in the same volume to collide with Mg. Therefore there will be even less frequent collisions, and hence the slowest rate of reaction compared to HB and HA.							
NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response or no relevant evidence.	1a	2a	3a	4a	2m	3m	e (minor error / omission / extra information present)	e

Judgement Statement

	Not Achieved	Achievement	Achievement with Merit	Achievement with Excellence
Score range	0 – 6	7 – 13	14 – 18	19 – 24