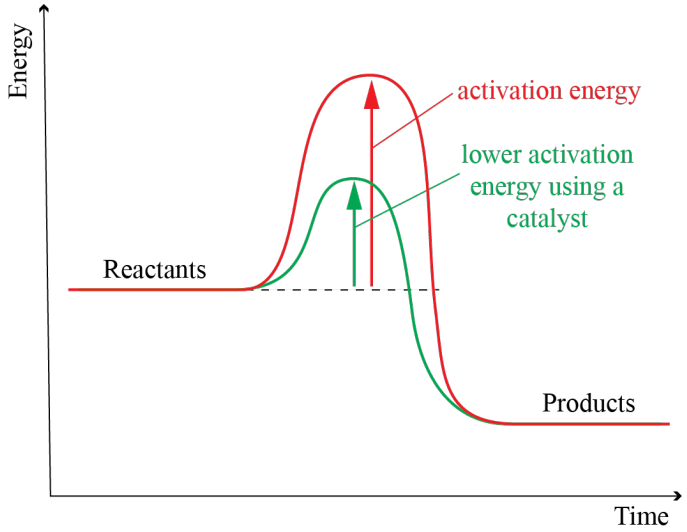
Assessment Schedule – 2024

Chemistry: Demonstrate understanding of chemical reactivity (91166)

Evidence

Q	Evidence	Achievement	Merit	Excellence
ONE (a)(i)	Added line should have a steeper gradient, and begin and end at the same mass of Al_2O_3 as the original line (ending at 0 g, touching the *x*-axis).	• Correct second line.		
(ii)	• The added line shows a steeper decline in mass of Al_2O_3 due to the higher concentration of NaOH, which means there will be more particles of NaOH per unit volume available to react with Al_2O_3. • Collision theory states that reactant particles need to collide with enough energy and in the correct orientation to react. The higher the concentration, the more particles there are available to collide per unit volume, and the rate of reaction will increase as collisions will occur more frequently; therefore successful collisions will occur more frequently. The mass declines over time in both reactions as the reactants are used up forming products. As this happens, the rate of both reactions reduce, as can be seen in Section B. • The added line starts and ends at the same mass of Al_2O_3 as the original line, because all of the Al_2O_3 has successfully reacted into products at the end of both reactions. However, as the added higher concentration line indicates, the end point is reached sooner due to the increased rate of reaction.	• States that the same mass of Al_2O_3 is used (starts or ends) • Correctly identifies higher concentration increases rate of reaction. OR Identifies that higher concentration means more reactant particles (does not need to explicitly link to volume for A).	• Correctly links increased concentration to the increase in frequency of successful collisions. • A correct comparison of sections A and B. OR Correctly identifies that the end point is reached sooner.	• Full comparison including a correct comparison of sections A and B linked to the gradient of one line, which links the increase in concentration to the increase in frequency of successful collisions and an increase in the rate of reaction.
(b)(i)	$[H_3O^+] = \frac{1\times10^{-14}}{0.5}$ $[H_3O^+] = 2 \times 10^{-14}$ mol L^{-1}	• Correctly calculates $[H_3O^+]$ (can accept e^{-14})		
(ii)	pH = –log (2×10^{-14}) pH = 13.7 (3 sf) Accept use of pH = 14-pOH.	OR Incorrectly calculates pH using $[OH^-]$.	• Correct pH (sig figs are not required).	

(c)	A catalyst increases the rate of a reaction by providing an alternative pathway for the reaction that has a lower activation energy compared to the original reaction. Activation energy is the minimum energy required of a collision in order for it to be successful and have the reactants convert to products. • By lowering the activation energy requirement (using a catalyst that provides an alternative pathway), more of the collisions occurring will now have sufficient energy to overcome activation and react. There is a greater proportion of successful collisions per second, increasing the rate of reaction.  	• Basic definition of a catalyst (catalyst lowers the activation energy OR provides an alternative pathway)	• Links the higher rate of reaction to the lower activation energy requirement and the catalyst providing an alternative pathway.	• Explanation including reference to activation energy pathway with relevant sketch / diagram.

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response; no relevant evidence.	1a	2a	3a	4a	3m	4m	2e minor error	2e

Q	Evidence	Achievement	Merit	Excellence
TWO (a)(i)	$O_2(g) + 2SO_2(g) \rightleftharpoons 2SO_3(g)$	• Correct without states.		
(ii)	$K_c = 32.7 = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$ $[O_2] = \frac{[SO_3]^2}{K_c \times [SO_2]^2}$ $[O_2] = 0.265 \text{ mol l}^{-1}$ (3sf)	• First step correct, but incorrect answer.	• Correct answer.	
(b)(i)	$= \frac{0.62^2}{0.53^2 \times 0.71}$ $= 1.93$ (3 sf) This value is lower than the K_c value, so the reaction is not at equilibrium.	• Correct substitution OR Identifies calculated value is not the same as Kc value (based on incorrect calculation)	• Correct value (sig figs are not required) • States the correct calculated value is not the same as Kc and therefore not in equilibrium. OR Identifies the reaction proceeds forwards (with reason).	• Correct value including full justification.
(ii)	To establish equilibrium, the forward reaction must proceed at a greater rate than the reverse, as the value is smaller than K_c. This indicates the reaction mixture currently has a higher concentration of reactants (K_c is small so product concentration is too low), so the forward reaction must be favoured to lower reactants and increase products, increasing value until it matches K_c.	• Correct direction based on answer from (b)(i)		

(c)(i)	Forward is favoured. Water vapour is a reactant. Increasing the concentration of reactant will result in a shift to use up this extra reactant by converting it to products, hence the forward reaction is favoured to re-establish the relative concentration of reactants to products at equilibrium, K_c. Forward is favoured. Sodium hydroxide reacts with the H_2SO_4 product in a neutralisation reaction, reducing the concentration of H_2SO_4 present. Reducing the concentration of a product will result in a shift to make more products by driving the reaction in a forward direction to re-establish the relative concentration of reactants to products at equilibrium, K_c	• One correct answer.	• Either correct answer linked to a reason for the shift and the outcome.	• Justification of increase favouring forward reaction and products for either (c) (i) OR (c) (ii).
(ii)	Le Chatalier's principle states that increasing the pressure will favour the reaction that produces the fewer moles of gas particles. In this reaction, that is the products side as the left has 2 moles of gas and right has 1. This means an increase in pressure will favour the forward reaction, and the production of the desired H_2SO_4. Because the products are favoured, the reaction will give more product if performed at higher pressure, as equilibrium shifts towards products.	• Identifies it will favour products with no explanation.	• Explains increase favours side with fewer gas moles which favours the forward direction.	

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response; no relevant evidence.	1a	2a	3a	4a	3m	4m	2e minor error	2e

Q	Evidence	Achievement	Merit	Excellence
THREE (a)(i)	Acid: HSO_4^- Conjugate base: SO_4^{2-} Base: CO_3^{2-} Conjugate acid: HCO_3^-	• One pair correct.		
(ii)	$K_c = \frac{[SO_4^{2-}][HCO_3^-]}{[HSO_4^-][CO_3^{2-}]}$	• Correct K_c.		
(iii)	Increasing the K_c value shows that the changes to the reaction has favoured the forward reaction. This is because K_c is the product concentration / reactants concentration, so more products (and / or smaller value for reactants) will give a larger K_c value. Therefore, the forward reaction is favoured. Increasing the temperature favours the endothermic reaction, as this reaction can consume the excess energy (or equivalent explanation). This means that the increased temperature favoured the endothermic reaction, and the forward reaction; therefore the forward reaction must be endothermic, and the reverse is exothermic.	• Recognises that the forwards reaction is endothermic OR Identifies that Kc increase shows products favoured.	• Explains that the K_c increase shows products were favoured when temperature is increased. • Explains that increasing the temperature favours the endothermic reaction to minimise the change	• Endothermic nature of the forwards reaction is justified linked to the increase in Kc due to temperature.

(b)(i)	HNO_3 is a strong acid, so will have a pH of 1–2, as it completely dissociates in water, donating a proton to form H_3O^+, resulting in the highest H_3O^+ concentration. NH_3 is a weak base that accepts a proton from water but only partially dissociates so only some OH^- is produced. The pH will be 9–10, as it has the lowest H_3O^+ concentration. Ammonium chloride is an acidic salt, so after complete separation into its ions (Cl^- and NH_4^+), the ammonium produced is a weak acid. This means it will react with water to form some of its conjugate weak base and some free H_3O^+, with an intermediate concentration of H_3O^+ ions compared to the other two solutions. As this only occurs in small amounts the pH will be 4–5. $HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$ $NH_4Cl \rightarrow NH_4^+ + Cl^-$, $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$ $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$	• Identifies 2 correct pH • Any 2 correctly balanced equations	• Explains the pH of 2 solutions using correct equations.	• Full justification including correct equations for ammonium chloride.
(ii)	To conduct, a substance needs to contain freely moving charged particles, such as electrons or ions. The greater the concentration of freely moving charged particles present in a solution, the more conductive it will be. HNO_3 and NH_4Cl will have similar / identical conductivities, and both will be greater than NH_3. This is because both HNO_3 and NH_4Cl dissociate fully when in water, giving two ions per molecule, as per previous equations. $HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$ $NH_4Cl \rightarrow NH_4^+ + Cl^-$, $(NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+)$ This means they will have a relatively high concentration of freely moving charged particles, and will conduct electricity well. NH_3 is a weak base, so does not fully dissociate in water, existing in equilibrium, as per previous equation, $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ This means there will be a lower concentration of ions present than for HNO_3 and NH_4Cl, so it will be less conductive Note: if candidate references further reaction of ammonium chloride with water may change conductivity slightly do not penalise them.	• Correct statement about the conductivity of two species. • Defines conductivity correctly.	• Correct statement relative concentration of species linked to the conductivity of two species. • Connects conductivity to the extent of dissociation of two species	• Full justification of all three species (does not need to include the numbers of ions but should include a relative difference).

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response; no relevant evidence.	1a	2a	3a	4a	3m	4m	2e	3e minor error

Cut Scores

Not Achieved	Achievement	Achievement with Merit	Achievement with Excellence
0 – 07	08 – 13	14– 18	19 – 24