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NZQA | Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 2 Chemistry 2024

91166 Demonstrate understanding of chemical reactivity

Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of chemical reactivity.	Demonstrate in-depth understanding of chemical reactivity.	Demonstrate comprehensive understanding of chemical reactivity.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

A periodic table and other reference material are provided in the Resource Booklet L2–CHEMR.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–16 in the correct order and that none of these pages is blank.

Do not write in any cross-hatched area (⁄⁄⁄). This area will be cut off when the booklet is marked.

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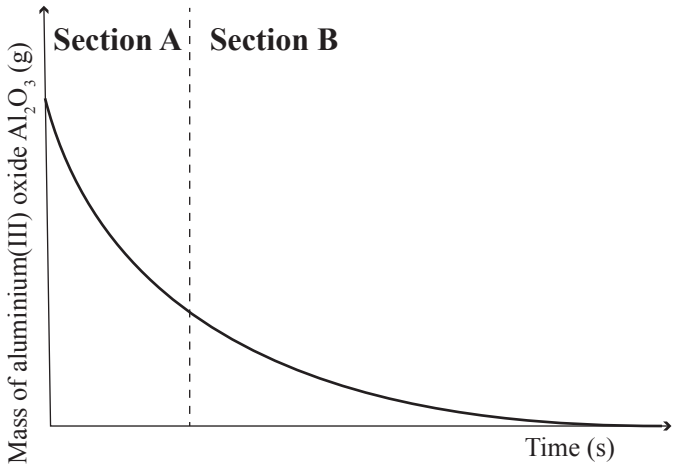
QUESTION ONE

Tiwai Point in the South Island of New Zealand extracts large amounts of aluminium sourced from an ore called bauxite, which contains the mineral aluminium(III) oxide, Al_2O_3. One step of the main extraction process is as follows:

$$Al_2O_3(s) + 2NaOH(aq) \rightarrow 2NaAlO_2(aq) + H_2O(\ell)$$

The graph below shows the mass of aluminium(III) oxide, Al_2O_3, as it reacts with 0.5 mol L^{-1} NaOH.



If you need to redraw your response, use the graph on page 11.

(a) (i) Add a second line to the graph to predict the rate of decline in mass of aluminium(III) oxide if 2 mol L^{-1} NaOH were used in the reaction instead.

Assume both reactions started with the same mass of ore.

(ii) With reference to the line you have drawn, explain the effect that this change in concentration of NaOH from 0.5 mol L^{-1} to 2 mol L^{-1} would have on the rate of this reaction.

In your answer you should include reference to:

- mass of Al_2O_3
- each section of the line
- collision theory.

(b) For the 0.5 mol L^{-1} NaOH solution, calculate:

(i) the hydronium ion, H_3O^+, concentration

(ii) the pH.

(c) Using the principles of collision and particle theories, explain why using a catalyst would help to increase the rate of production of sodium aluminium salt ($NaAlO_2$).

You should include an energy profile diagram to support your answer.

Space for diagram

QUESTION TWO

Superphosphate fertiliser is manufactured in New Zealand using phosphorite rocks and sulfuric acid. The sulfuric acid is often produced on site, and includes a reaction involving oxygen, $O_2(g)$, sulfur dioxide, $SO_2(g)$, and sulfur trioxide, $SO_3(g)$, which is represented by the equilibrium constant expression below:

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]} \qquad K_c = 32.7 \text{ at } 25\,^\circ\text{C}$$

(a) (i) Give the equation for this reaction.

(ii) The reaction is set up and allowed to reach equilibrium.

Calculate the concentration of oxygen, O_2, at equilibrium if the concentration of sulfur dioxide, SO_2, is 0.17 mol L^{-1} and sulfur trioxide, SO_3, is 0.50 mol L^{-1}.

(b) The reaction is set up differently, with concentrations of each component as indicated below.

$[SO_2] = 0.530$ mol L^{-1}

$[O_2] = 0.710$ mol L^{-1}

$[SO_3] = 0.620$ mol L^{-1}

(i) Using a calculation, explain why this reaction is not at equilibrium.

(ii) Explain what must occur for equilibrium to be established.

(c) Sulfuric acid, H_2SO_4, can be manufactured using the following reaction:

$SO_3(g) + H_2O(g) \rightleftharpoons H_2SO_4(g)$

(i) Using equilibrium principles, identify, then describe, the effect on the position of the equilibrium when:

- water vapour, $H_2O(g)$, is added to the reaction mixture

  Circle your choice:

  Forward is favoured **No Change** **Reverse is favoured**

- sodium hydroxide, NaOH(*aq*), is added to the reaction mixture.

  Circle your choice:

  Forward is favoured **No Change** **Reverse is favoured**

(ii) This reaction can be performed under high pressure.

Explain why this is beneficial to the manufacturing process.

QUESTION THREE

(a) A reaction of HSO_4^- is shown below:

$HSO_4^-(aq) + CO_3^{2-}(aq) \rightleftharpoons SO_4^{2-}(aq) + HCO_3^-(aq)$

(i) Identify the species acting as an acid and the species acting as a base in the above equation, and their conjugate pairs:

Acid:	Conjugate base:
Base:	Conjugate acid:

(ii) Write the equilibrium constant expression, K_c for this process:

(iii) This reaction was initially performed at 25 °C to determine the K_c value. When the reaction temperature was increased to 50 °C, the K_c value increased.

Explain whether the forward reaction is exothermic or endothermic.

(b) Solutions of 0.1 mol L^{-1} concentration were made of each of the following three substances:

NH_3 HNO_3 NH_4Cl

(i) Explain the pH of each of these solutions.

Include:

- a choice of pH value for each substance from the options below
- a classification for each substance
- any equations to explain the pH value.

pH options: 1–2 4–5 7 9–10 13–14

NH_3:

HNO_3:

NH_4Cl:

Question Three continues on the next page.

(ii) Discuss the conductivity of the solutions:

NH_3 HNO_3 NH_4Cl

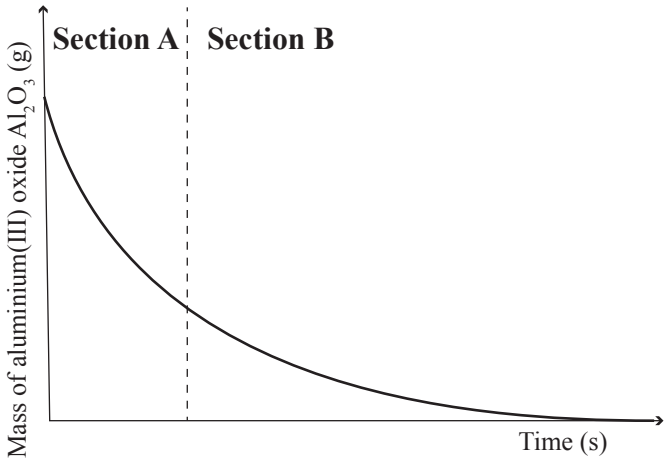
Note they are all equal in concentration.

In your answer you should:

- explain the requirements for a solution to conduct electricity
- compare the extent of conductivity of each substance
- reference the relevant equations from your previous answer to part (b)(i).

SPARE DIAGRAMS

If you need to redraw your response to Question One (a)(i), use the graph below. Make sure it is clear which answer you want marked.



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