Question 42   **(26 marks)**

Acid rain is a significant issue in many industrialised areas of the world; particularly around power stations using fossil fuels. Legislation has been developed in Australia to minimise the formation of sulfur dioxide, $SO_2(g)$, such as from the use of low-sulfur fuels in automobiles, which can cause acid rain. Normal rain has a pH of about 5.6; it is slightly acidic because carbon dioxide, $CO_2(g)$ dissolves into it, forming weak carbonic acid. Rain with a pH less than 4.4 is usually classified as acid rain.

Testing was carried out on a rainwater sample taken near a coal-fired power station by titration, using sodium hydroxide solution, $NaOH(aq)$. Standardisation of the sodium hydroxide solution was carried out before it was used in the titration. An anhydrous sodium carbonate, $Na_2CO_3(s)$, primary standard was used to standardise a hydrochloric acid solution, $HCl(aq)$ and subsequently used to standardise the $NaOH(aq)$ solution.

Sodium carbonate, $Na_2CO_3(s)$ was heated at 110 °C in a drying oven for 1 hour before 6.08×10^{-4} g was dissolved in distilled water to make 2.00 L of the primary standard. Three 25.0 mL aliquots of $HCl(aq)$ were titrated and an average titre of 16.4 mL was required for neutralisation.

(a) Demonstrate, by means of calculation, that the concentration of HCℓ(aq) solution is 3.76 x 10⁻⁶ mol L⁻¹. (5 marks)

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(b) Outline **two** reasons why sodium hydroxide, NaOH(s) is **not** a suitable primary standard for this titration. (2 marks)

One: _____

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Two: _____

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An average titre of 21.3 mL of the standardised (3.76×10^{-6} mol L^{-1}) HCℓ(aq) solution was required to neutralise 25.0 mL aliquots of NaOH(aq) solution.

(c)　　Calculate the concentration of the NaOH(aq) solution.　　　　　　　　　(3 marks)

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The standardised NaOH(aq) solution was then used for the titration of a rainwater sample. A 100.0 mL sample of rain water was collected near a coal-fired power station and diluted to 250.0 mL with distilled water in a volumetric flask. 25.0 mL aliquots of the diluted rainwater were used in the titration.

(d)　　Complete the table below to state with what the following pieces of glassware should be rinsed for this titration.　　　　　　　　　(3 marks)

Glassware	Final rinse
Burette	
Conical flask	
Pipette	

The titre values obtained for the rainwater sample are shown in the table below:

Titre volume of NaOH (mL)				Average titre volume (mL)
Trial 1	Trial 2	Trial 3	Trial 4	
21.81	19.64	19.67	19.66	

(e)   Calculate the average titre volume and record it in the table above.   (1 mark)

(f) Calculate the pH of the undiluted rainwater sample. Determine if it would be classified as acid rain or not. (6 marks)
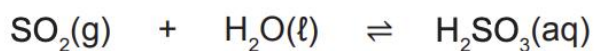
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(g) If carbon dioxide, $CO_2(g)$ alone accounts for rain with a pH of 5.60, then calculate the volume of sulfur dioxide, $SO_2(g)$ at 16.0 °C and 97.2 kPa, that would also need to be dissolved to produce 0.100 L of an acid rain sample with a pH of 4.0. Use the equation below.

$$SO_2(g) + H_2O(\ell) \rightleftharpoons H_2SO_3(aq)$$

For this calculation, assume the complete ionisation of $H_2SO_3(aq)$.　　　　(6 marks)