Course 3 -Acid/Base Titrations

Question 1

1. A student determined the concentration of a hydrochloric acid solution by titration with 25.0 cm^3 portions of a 0.05 M primary standard solution of anhydrous sodium carbonate. The portions of sodium carbonate solution were measured into a conical flask using a 25 cm^3 pipette. The hydrochloric acid solution was added from a burette. The mean titre was 20.8 cm^3.

The balanced equation for the titration reaction was:

$$\mathbf{2HCl + Na_2CO_3 \longrightarrow 2NaCl + H_2O + CO_2}$$

(*a*) Explain the underlined term. (5)

(*b*) Describe how the student should have prepared 500 cm^3 of the 0.05 M primary standard solution from a known mass of pure anhydrous sodium carbonate, supplied on a clock glass. (12)

Calculate the exact mass of anhydrous sodium carbonate ($\mathbf{Na_2CO_3}$) required to prepare this solution. (6)

(*c*) (*i*) Describe how the liquid level in the burette was adjusted to the zero mark.

(*ii*) Why was a pipette filler used to fill the pipette with 25.0 cm^3 of the sodium carbonate solution? (6)

(*d*) Name a suitable indicator for this titration.

State the colour change observed at the end point. (9)

(*e*) Calculate, correct to two decimal places, the concentration of the hydrochloric acid solution in

(*i*) moles per litre,

(*ii*) grams per litre. (12)

Question 2

1. An experiment was carried out to determine the percentage water of crystallisation and the degree of water of crystallisation, **x**, in a sample of hydrated sodium carbonate crystals (**$Na_2CO_3.xH_2O$**). An 8.20 g sample of the crystals was weighed accurately on a clock glass and then made up to 500 cm^3 of solution in a volumetric flask. A pipette was used to transfer 25.0 cm^3 portions of this solution to a conical flask. A previously standardised 0.11 M hydrochloric acid (**HCl**) solution was used to titrate each sample. A number of accurate titrations were carried out. The average volume of hydrochloric acid solution required in these titrations was 26.05 cm^3.

The titration reaction is described by the equation:

$$\mathbf{Na_2CO_3 + 2HCl \longrightarrow 2NaCl + CO_2 + H_2O}$$

(*a*) Identify a primary standard reagent which could have been used to standardise the hydrochloric acid solution. (5)

(*b*) Name a suitable indicator for the titration and state the colour change observed in the conical flask at the end point. Explain why not more than 1 – 2 drops of indicator should be used. (12)

(*c*) (*i*) Describe the correct procedure for rinsing the burette before filling it with the solution it is to deliver.

(*ii*) Why is it important to fill the part below the tap of the burette? (12)

(*d*) From the titration figures, calculate the concentration of sodium carbonate (**Na_2CO_3**) in the solution in

(*i*) moles per litre,

(*ii*) grams per litre. (9)

(*e*) Calculate the percentage water of crystallisation present in the crystals and the value of **x**, the degree of hydration of the crystals. (12)

Question 3

Section A

Answer at least <u>two</u> questions from this section [see page 1 for full instructions].

1. A batch of washing soda crystals (hydrated sodium carbonate, $\mathbf{Na_2CO_3.}\boldsymbol{x}\mathbf{H_2O}$) had lost some of its water of crystallisation by a process called efflorescence. A chemist was required to determine the percentage water of crystallisation in the crystals and the value of $\boldsymbol{x}$, the average number of water molecules in the formula.

A sample of the crystals was accurately weighed and found to have a mass of 2.50 g. The sample was dissolved in deionised water and made up to 250 cm^3 of solution. A number of 25.0 cm^3 portions of this solution were titrated with a previously <u>standardised</u> 0.10 M hydrochloric acid (**HCl**) solution. The mean volume of the hydrochloric acid solution required to reach the end point was 21.6 cm^3.

The balanced equation for the titration reaction is:

$$\mathbf{2HCl} + \mathbf{Na_2CO_3} \rightarrow \mathbf{2NaCl} + \mathbf{H_2O} + \mathbf{CO_2}$$

(*a*) Explain the underlined term. (5)

(*b*) Describe in detail how the chemist should have dissolved the weighed sample of washing soda crystals and made the solution up to exactly 250 cm^3. (12)

(*c*) State **one** precaution that should have been taken as the end point of the titration was approached. Explain how this precaution would have contributed to the accuracy of the titration result. (6)

(*d*) Name a suitable indicator for this titration. State the colour change in the titration flask at the end point. (9)

(*e*) From the mean volume of the hydrochloric acid solution, calculate the concentration of sodium carbonate ($\mathbf{Na_2CO_3}$) in the original solution in (*i*) moles per litre, (*ii*) grams per litre. (9)

(*f*) Calculate the percentage water of crystallisation in the crystals and the value of $\boldsymbol{x}$, the average number of water molecules in the formula $\mathbf{Na_2CO_3.}\boldsymbol{x}\mathbf{H_2O}$. (9)

Question 4

1. Washing soda is a cheap, household chemical used for laundry, removing grease and softening water. Washing soda crystals are hydrated sodium carbonate (**$Na_2CO_3.xH_2O$**). The crystals effloresce (lose some water of crystallisation) in dry air becoming powdery in the process.

To determine the average value of ***x*** in the formula **$Na_2CO_3.xH_2O$** for a sample of washing soda, 3.46 g of the crystals were dissolved in deionised water and made up to exactly 250 cm^3 of solution. 25.0 cm^3 volumes of this solution were pipetted into a conical flask and titrated with a previously standardised hydrochloric acid solution using a suitable indicator.

The balanced equation for the titration reaction is:

$$2HCl + Na_2CO_3 \rightarrow 2NaCl + H_2O + CO_2$$

(*a*) Identify a primary standard that could have been used to standardise the hydrochloric acid solution for this analysis. (5)

(*b*) Describe how the 250 cm^3 solution of washing soda was prepared starting with 3.46 g of washing soda measured out accurately on a weighing boat. (12)

(*c*) (*i*) Name a suitable indicator for this titration.

(*ii*) Justify your choice of indicator.

(*iii*) Using this indicator what colour change was observed in the conical flask at the end point? (12)

(*d*) On average 21.5 cm^3 of 0.12 M hydrochloric acid solution were required to completely neutralise 25.0 cm^3 of the washing soda solution.

Find by calculation

(*i*) the average number of moles of **HCl** used up in a titration,

(*ii*) the number of moles of **Na_2CO_3** neutralised in each titration,

(*iii*) the number of moles of **Na_2CO_3** in 250 cm^3 of the washing soda solution,

(*iv*) the mass of **Na_2CO_3** in 250 cm^3 of the washing soda solution,

(*v*) the mass of water of crystallisation and hence the number of moles of water in 3.46 g of the crystals,

(*vi*) the ratio of moles of water of crystallisation to moles of **Na_2CO_3** in the crystals and hence the value of ***x*** to the nearest whole number. (21)

Question 5

1. Vinegar is a solution of ethanoic acid (acetic acid). Some bottles of vinegar are labelled "*White Wine Vinegar*".

(a) What compound in white wine is converted to ethanoic acid in vinegar?
What type of chemical process converts this compound to ethanoic acid? (8)

The concentration of ethanoic acid in vinegar was measured as follows:
A 50 cm^3 sample of vinegar was diluted to 500 cm^3 using deionised water. The diluted solution was titrated against 25 cm^3 portions of a standard 0.12 M sodium hydroxide solution, using a suitable indicator.

(b) Describe the procedure for accurately measuring the 50 cm^3 sample of vinegar and diluting it to 500 cm^3. (12)

(c) Name the piece of equipment that should be used to measure the ethanoic acid solution during the titration. State the procedure for washing and filling this piece of equipment in preparation for the titration. Name a suitable indicator for this titration. (15)

The titration reaction is

$$\mathbf{CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O}$$

After carrying out a number of accurate titrations of the diluted solution of ethanoic acid against the 25 cm^3 portions of the standard 0.12 M sodium hydroxide solution, the mean titration figure was found to be 20.5 cm^3.

(d) Calculate the concentration of ethanoic acid in the diluted vinegar solution in moles per litre and hence calculate the concentration of ethanoic acid in the original sample of vinegar.
Express this concentration in terms of % (w/v). (15)

Question 6

1. To determine the concentration of ethanoic acid in a sample of vinegar, 25.0 cm^3 of the vinegar were diluted to 250 cm^3 and then the diluted vinegar was titrated with a previously standardised solution which contained 1.20 g of sodium hydroxide in 500 cm^3 of solution. On average, 18.75 cm^3 of the diluted vinegar were required to neutralise 25.0 cm^3 of this sodium hydroxide solution.

The equation for the titration reaction is:

$$\mathbf{CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O}$$

(*a*) Describe in detail the procedures involved in measuring a 25.0 cm^3 sample of the vinegar and diluting it using deionised water to exactly 250 cm^3. (15)

(*b*) Name a suitable indicator for this titration.

What colour change is observed at the end point? (9)

(*c*) Calculate

(*i*) the number of moles of sodium hydroxide in each 25.0 cm^3 portion,

(*ii*) the number of moles of ethanoic acid per cm^3 of *diluted* vinegar. (12)

(*d*) Find the concentration of ethanoic acid in the *original* vinegar

(*i*) in terms of moles per litre,

(*ii*) as a percentage (w/v). (9)

(*e*) Starting with a primary standard solution made from anhydrous sodium carbonate, what two titrations are required to standardise a sodium hydroxide solution? (5)

Question 7

1. To determine the concentration of ethanoic acid, **CH_3COOH**, in a sample of vinegar, the vinegar was first diluted and then titrated against 25.0 cm^3 portions of a previously standardised 0.10 M solution of sodium hydroxide, **NaOH**. One rough and two accurate titrations were carried out.

The three titration figures recorded were 22.9, 22.6 and 22.7 cm^3, respectively.

(*a*) Why was the vinegar diluted? (5)

(*b*) Describe the correct procedures for measuring exactly 25.0 cm^3 of vinegar and diluting it to exactly 250 cm^3 using deionised water. (15)

(*c*) The equation for the titration reaction is:

$$\mathbf{CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O}$$

Name an indicator suitable for this titration. Justify your choice of indicator.
State the colour change at the end point. (12)

(*d*) Calculate the concentration of the diluted solution of ethanoic acid in

(*i*) moles per litre, (*ii*) grams per litre.

State the concentration of ethanoic acid in the original vinegar sample in grams per litre.

Express this concentration in terms of % (w/v). (15)

(*e*) Ethanoic acid is a carboxylic acid. Identify the carboxylic acid which occurs in nettles and stinging ants. (3)