Determination of the amount of water of crystallisation in hydrated sodium carbonate

Theory

Hydrated sodium carbonate has the formula $Na_2CO_3.xH_2O$, where x is the number of molecules of water of crystallisation present. In this experiment, x is determined by titration of a solution made using hydrated sodium carbonate with a standard solution of hydrochloric acid. The equation for the reaction is

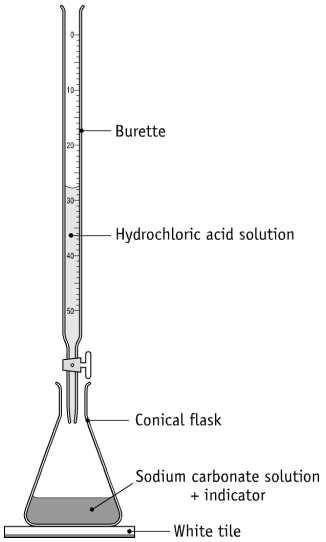
$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

Methyl orange indicator solution is used. At the end-point the indicator changes colour from yellow to peach/pink.

Procedure

NB: Wear your safety glasses.

Weigh accurately approximately 1.5 g of hydrated sodium carbonate into a beaker. Add about 50 cm^3 of deionised water and stir to dissolve the sample.



Transfer all of the solution into a 250 cm^3 volumetric flask. Rinse the beaker with deionised water and add the washings to the volumetric flask.

Make up the volumetric flask to the mark, using a dropper to add the final amounts of deionised water. Stopper the flask and invert several times.

Rinse the burette, pipette and conical flask respectively with deionised water.Rinse the burette with hydrochloric acid solution, and rinse the pipette with sodium carbonate solution.

Titrate the sodium carbonate solution against 0.1 M hydrochloric acid, using 25 cm^3 of sodium carbonate solution in the conical flask and methyl orange as indicator. Repeat the titrations until the readings agree to within 0.1 cm^3.

Calculate the concentration of the sodium carbonate solution. Determine the formula of hydrated sodium carbonate.

Specimen Results (washing soda)

Mass of hydrated sodium carbonate	= 1.57 g
Rough titre	= 13.0 cm^3
Second titre	= 12.5 cm^3
Third titre	= 12.6 cm^3
Average of accurate titres	= 12.55 cm^3
Volume of sodium carbonate solution used in each titration	= 25.0 cm^3
Concentration of hydrochloric acid solution	= 0.1 M

Specimen Calculations

$$V_A \times M_A \times n_B = V_B \times M_B \times n_A$$

$$12.55 \times 0.1 \times 1 = 25 \times M_B \times 2$$

$$M_B = 12.55 \times 0.1 \times 1 / (25 \times 2)\ M = 0.0251\ M$$

Concentration of sodium carbonate solution	= 0.0251 M
Moles of Na_2CO_3 present in 250 cm^3	= 0.0251 / 4 = 0.006275
Molar mass of Na_2CO_3	= 106 g mol^{-1}
Mass of Na_2CO_3 present in 250 cm^3	= 0.665 g
Mass of $Na_2CO_3.xH_2O$ present in 250 cm^3	= 1.57 g
Mass of water present in this amount of $Na_2CO_3.xH_2O$	= 0.905 g
Percentage of water present in $Na_2CO_3.xH_2O$	= 0.905 X 100 / 1.57 = 57.64%
Moles of water present in this amount of $Na_2CO_3.xH_2O$	= 0.905 / 18 = 0.05028
Moles of Na_2CO_3 present in this amount of $Na_2CO_3.xH_2O$	= 0.0006275 x 10 =0.006275
Value of x in $Na_2CO_3.xH_2O$	= 0.05028 / 0.006275 = 8.01 = 8
Formula of hydrated sodium carbonate	= $Na_2CO_3.8H_2O$

student questions

What was done to the volumetric flask and its contents immediately after the solution had been made up to the mark with deionised water? Why was it important to do this?

It was stoppered, and then inverted several times. To ensure a homogeneous solution.

In acid-base titrations it is preferable to use as little of the indicator as possible. What is the reason for this?

An indicator is a weak acid or a weak base. Use of an excessive amount of indicator will affect the titre value.

Give the name of a suitable piece of apparatus to measure accurately (i) the 25cm^3 portions of sodium carbonate solution, (ii) the volume of hydrochloric acid needed for a complete reaction.

(i) Pipette.
(ii) Burette.

n a similar experiment, 1.51 g of hydrated sodium carbonate was used. If the average titre reading was 10.6 cm^3, calculate the value of x in $Na_2CO_3.xH_2O$.

Volume of hydrochloric acid solution used = 10.6 cm^3
Moles of hydrochloric acid used = 10.6 x 0.1 / 1000 = 0.00106

Balanced equation:

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$
1 mole 2 moles 2 moles 1 mole 1 mole

Moles of Na_2CO_3 used	= 0.00106 / 2 = 0.00053
Molar mass of Na_2CO_3	= 106 g mol^{-1}
Mass of Na_2CO_3 present in 25 cm^3	= 0.00053 x 106 g = 0.05618 g
Mass of Na_2CO_3 present in 250 cm^3	= 0.5618 g
Mass of $Na_2CO_3.xH_2O$ present in 250 cm^3	= 1.51 g
Mass of water present in this amount of $Na_2CO_3.xH_2O$	= 0.9482 g
Percentage of water present in $Na_2CO_3.xH_2O$	= 62.79%
Moles of water present in this amount of $Na_2CO_3.xH_2O$	= 0.9482 / 18 = 0.05268
Moles of Na_2CO_3 present in this amount of $Na_2CO_3.xH_2O$	= 0.0053
Value of x in $Na_2CO_3.xH_2O$	= 0.05268 / 0.0053 = 9.94 = 10
Formula of hydrated sodium carbonate:	= $Na_2CO_3.10H_2O$

Describe the physical appearance of hydrated sodium carbonate.

White crystalline solid. However, if larger crystals are purchased, these tend to have a clear glassy appearance.

Explain water of crystallisation.

Water chemically bound in the compound, which gives rise to the crystalline form **or** water present in definite proportions in crystalline compounds.

Name another compound that has water of crystallisation present.

Hydrated copper sulfate.