Plan To Determine The Concentration Of A Limewater Solution

In order to determine the concentration of this limewater solution I must perform a titration (also known as volumetric analysis) between the alkali and acid given to me. In order to carry this out I must know the concentration of one of the solutions (in this case the acid, which has been given to me at 2.00 mol dm^{-3}) and the balanced equation between my two reactants; which is:

$$Ca(OH)_{2\,(aq)} + 2HCl_{(aq)} \rightarrow CaCl_{2\,(s)} + 2H_2O_{(l)}$$

For which the ionic equation would be (as with all neutralisation reactions):

$$OH^-_{(aq)} + H^+_{(aq)} \rightarrow H_2O_{(l)}$$

Dilution Calculations

As the concentration of my acid is 2.00 mol dm^{-3} I believe this will be too strong, so little will be used and my results will be more unreliable.
If I did the experiment with the 2 mol dm^{-3} HCl:

I will be using 25cm^3 of sodium hydroxide so there would be:

$\frac{1}{74.1}$ = 0.0135 moles in 1dm^3 of $Ca(OH)_2$ as there is 1g dm^{-3}
so the concentration is 0.0135 mol dm^{-3}

this means there will be $\frac{25}{1000} \times 0.0135 = 0.0003375$ moles in the 25cm^3 $Ca(OH)_2$ I will use
so the approximate amount of HCl needed to neutralise this will be 0.000746 moles

$Ca(OH)_2$: HCl
1 : 2
0.0003375 : 0.000675

if the concentration of HCl is 2 mol dm^{-3} then

$$\frac{0.000675}{2} = 0.0003375\ dm^3 = 0.3375\ cm^3$$

This is a very small volume so the measurement errors will be large:
(the error margin for a 50cm^3 burette is ± 0.1)

$$\frac{0.1}{0.3375} \times 100 = 29.6\ \%$$

As I plan to use a 50cm^3 burette, an ideal volume of HCl to be measured out would be between 20-30cm^3; so if I want to use about 25cm^3 of HCl then the concentration will need to be about:

$$\frac{0.000746}{25/1000} = 0.02984\ mol\ dm^{-3}$$

To make dilution process easier (and more accurate) I will dilute to a concentration of 0.02 mol dm^{-3} .I could use a single or two fold dilution.

Dilution Method

If a single fold dilution was used:

equipment:

- $50cm^3$ burette
- burette stand
- $250cm^3$ volumetric flask
- distilled water
- 2 mol dm^{-3} hydrochloric acid

Begin with 2.00 mol dm^{-3} HCl, take $2.5cm^3$ using a $50cm^3$ burette and put it into a $250cm^3$. Add $222.5cm^3$ of distilled water, using the $250cm^3$ mark on the volumetric flask.

$50cm^3$ burette:
(accurate to $\pm$ $0.1cm^3$) $\frac{0.1}{2.5} \times 100 = 4\ \%$

$250cm^3$ volumetric flask:
(accurate to $\pm$ 0.15) $\frac{0.15}{250} \times 100 = 0.06\%$

sum of measurement errors: $4 + 0.06 = 4.06$

Using a two fold dilution:

equipment:

- $25cm^3$ pipette
- pipette filler
- $100cm^3$ volumetric flask
- $250cm^3$ volumetric flask
- distilled water
- 2 mol dm^{-3} hydrochloric acid

Begin with the hydrochloric acid at 2.00 mol dm^{-3}. Using a $10cm^3$ pipette measure $10cm^3$ of the 2M HCl into a $100cm^3$ volumetric flask then add $90cm^3$ of distilled water, and shake to mix; this will give $100cm^3$ of $0.2cm^3$ HCl. Then take $25cm^3$ of the 0.2M acid that has just been made and – using a $25cm^3$ pipette and pipette filler – put it into a $250cm^3$ volumetric flask with $225cm^3$ of distilled water and shake; this will provide $250cm^3$ of 0.02 mol dm^{-3} hydrochloric acid to use in the main experiment.

$10cm^3$ pipette:
(accurate to $\pm$ 0.04 cm^3) $\frac{0.04}{10} \times 100 = 0.4\ \%$

$100cm^3$ volumetric flask:
(accurate to $\pm$ 0.20 cm^3) $\frac{0.2}{100} \times 100 = 0.2\ \%$

$25cm^3$ pipette: $\frac{0.06}{25} \times 100 = 0.24\ \%$

$250cm^3$ volumetric flask:
(accurate to $\pm$ 0.15) $\frac{0.15}{250} \times 100 = 0.06$

sum of measurement errors: $0.4 + 0.2 + 0.24 + 0.06 = 0.9\ \%$

The sum of the measurement errors for the two fold method are much smaller so I think this will be the simpler and more accurate method, so I will use the two fold dilution method (outlined above).

In order to know when the alkali has been neutralised I will need to use a suitable indicator. Two indicators that function within this pH range are phenol phthalein and bromothymol blue; I have decided that phenol phthalein will give me more accurate results as it produces a more definite end point (it changes from vibrant pink to clear in acid, whereas bromothymol blue is blue in alkaki and yellow in acid but has a halfway point of green so it would be more difficult to determine an exact point).

Titration Equipment List And Diagram

- 50cm^3 burette
- burette stand
- 25cm^3 pipette
- pipette filler
- funnel
- 250cm^3 conical flask
- white tile
- 0.02 mol dm^{-3} hydrochloric acid
- 1g dm^{-3} calcium hydroxide solution
- phenol phthaline

I am using volumetric equipment (pipette and burette) so that the measurement errors are lower and my end result is more accurate. The white tile is used so that the colour of the alkali and indicator mixture is more visible and I will be able to determine the end point more easily.

Titration Method

Set up the equipment as shown in the diagram: attach the burette to the 50cm^3 burette stand at a height that allows the burette to be read easily and leaves enough room for the conical flask to be placed underneath Using a plastic funnel, fill the burette up to the 0cm^3 mark with the 0.02 mol dm^{-3} hydrochloric acid made during the dilution process. Remove the funnel so excess drips of acid do not affect the initial volume. Use a 25cm^3 pipette and pipette filler to put 25cm^3 of the 1g dm^{-3} calcium hydroxide solution in a 250cm^3 conical flask. Add a few drops of phenol phthaline so that the pink colour is clearly visible. Place the conical flask on top of a white tile and underneath the nozzle of the burette. Allow acid to run into the conical flask until a colour change – from pink to colourless – occurs, swirling the flask as the acid runs out to ensure it is properly mixed. Once a rough result has been obtained, repeat process, but as approximate end point approaches slow down the flow of acid and swirl the conical flask more often. Do a minimum of 3 repeats, so that at least 3 of the results are within 0.01 of each other; this will ensure the average result is accurate.

(*Essential AS Chemistry for OCR* pg 23)

Results Table

Set out a results table like the one below:

	rough	accurate 1	accurate 2	accurate 3
final burette reading (cm^3)				
initial burette reading (cm^3)				
change in volume (cm^3)				

mean change in volume:

By putting the final burette reading above the initial one it is easier to subtract the two. The mean volume given will be the amount of hydrochloric acid needed to neutralise the limewater; it will then be possible to work out the exact concentration of the limewater.

For example:

if the mean volume of 0.02 mol dm^{-3} used was $30cm^3$

$$0.02 \times \frac{30}{1000} = 0.0006 \text{ moles of HCl}$$

$HCl : Ca(OH)_2$

2 : 1

0.0006 : 0.0003

so there were 0.0003 moles of $Ca(OH)_2$ in $25cm^3$

$$\frac{0.0003}{25/1000} = 0.012 \text{ mol dm}^{-3}$$

$$0.012 \times 74.1 = 0.88892g$$

so in this case the concentration of the calcium hydroxide solution would be 0.012 mol dm^{-3} or 0.88892g dm^{-3}

Measurement Error Calculations

$50cm^3$ burette
(accurate to $\pm 0.1cm^3$)
measured twice so 0.1 + 0.1 = 0.2

e.g: $\frac{0.2}{30} \times 100 = 0.67\%$

$25cm^3$ pipette
(accurate to $\pm 0.06cm^3$)

$\frac{0.06}{25} \times 100 = 0.24\ \%$

sum of measurement errors: 0.67 + 0.24 = 0.91

Hazards

Hydrochloric Acid –

As I am using this in a very low dilution then it will have irritant rather than corrosive properties, so this in itself greatly reduces the risk. Fumes may be harmful but usually only in stronger concentrations of acid, but to ensure safety I will perform the experiment in a well ventilated area. It is poisonous if ingested and can irritate skin and eyes. If swallowed, large quantities of water must be drunk but vomiting must not be induced, and wash hands after handling acid to reduce risk of ingestion. If it comes into contact with skin or eyes then wash thoroughly with water; so I will need to keep a supply of clean water close by. Also, to protect eyes and skin I will wear a lab coat and goggles. It is not considered to be a fire or explosion hazard nor is it very reactive.

(http://www.jtbaker.com/msds/englishhtml/h3883.htm)

Calcium Hydroxide –

Again the concentration I am using is very low but I will still follow most of the recommended safety practices. Avoid lost term exposure by inhalation by performing experiment in a well ventilated area. If ingested drink two glasses of water then induce vomiting. Has mild irritant properties, so long term contact with skin and eyes should be avoided; I will wear goggles and a lab coat to reduce the chance of any contact being made; but if some is spilt on my skin I will wash the area thoroughly with soap and water; if any gets into my eyes I will rinse with clean water immediately for at least 15 minutes lifting the lids occasionally. Not flammable or reactive.

(http://www.sciencestuff.com/msds/C1989.html)

I will immediately clean up any spillages using water and a paper towel, and to try and reduce the likelihood of spills I will immediately replace lids onto any bottles of solution once I have finished using them

I will also be handing a lot of glass equipment, so I must ensure the burette is firmly held in place by its stand, and I will not leave the burette or pipette anywhere may they roll off and smash. If a breakage does occur I will clear it up immediately using a dustpan and brush and put the shards inside some newspaper before I place them in the bin.

Bibliography

Ted Lister and Janet Renshaw (2004) *Essential AS Chemistry for OCR* Cheltenham Nelson Thornes Ltd pg 23

Science Stuff (2006) MSDS: Limewater (Calcium Hydroxide Sat.) http://www.sciencestuff.com/msds/C1989.html 24/02/2008

J.T Baker (2005) MSDS: Hydrocholic Acid (Less Than 10%) http://www.jtbaker.com/msds/englishhtml/h3883.htm 24/02/2008