

**OCR ADVANCED SUBSIDIARY GCE
IN CHEMISTRY (SALTERS) (3887)**

**OCR ADVANCED GCE
IN CHEMISTRY (SALTERS) (7887)**

Teacher Support: Exemplar Coursework Guidance

2852/02 and 2855/01

2nd EDITION 2004

This Teacher Support: Exemplar Coursework Guidance booklet is intended to accompany the OCR Advanced Subsidiary GCE and Advanced GCE in Chemistry (Salters) specifications for teaching from September 2003.

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1 General Introduction

This booklet is intended to assist teachers in preparing candidates for the AS coursework component (Unit 2852/02) and A2 coursework component (Unit 2855/01) of the OCR specification, Salters Advanced Chemistry.

This booklet should be read in conjunction with the OCR booklet 'Teacher Support: Coursework Guidance 2nd Edition', which is designed to assist teachers in setting suitable coursework tasks and in assessing candidates' work.

This booklet contains a section of exemplar material for AS coursework (Unit 2852/02), followed by a section of exemplar material for A2 coursework (Unit 2855/01). Each section contains 5 exemplar candidate coursework reports together with commentaries on each report that include suggested marks for each skill area.

2 AS Coursework – Experimental Skills

Commentaries are provided on five experimental skills reports. These have been chosen to cover a range of candidate performance and to illustrate some common features that occur in many reports. They illustrate the most common tasks chosen for the assessment of experimental skills and link to detailed mark schemes included within the OCR booklet, 'Teacher Support: Coursework Guidance'.

2.1 Assessment Tasks

The exemplar experimental reports cover the following topics:

Report Number	Assessment Task
0401	Comparing the enthalpy changes of combustion of different alcohols
0402	Finding out how much acid is in a solution
0403	Finding out how much acid is in a solution
0404	Determination of the solubility of calcium hydroxide
0405	Determination of the enthalpy change of a reaction

2.2 Suggested Marks

Each commentary suggests marks that are appropriate in the four assessed skill areas.

These are summarised in the following table.

Report Number	Suggested marks in each skill area			
	Planning	Implementing	Analysing	Evaluating
0401	9	11	9	6
0402	8	7	9	1
0403	10	7	6	7
0404	6	7	5	4
0405	11	not applicable	8	11

3.1 Candidate Experimental Skills Report 0401

Comparing the enthalpy changes of combustion of different alcohols

COMPARING THE ENTHALPY CHANGES OF COMBUSTION OF
DIFFERENT ALCOHOLS

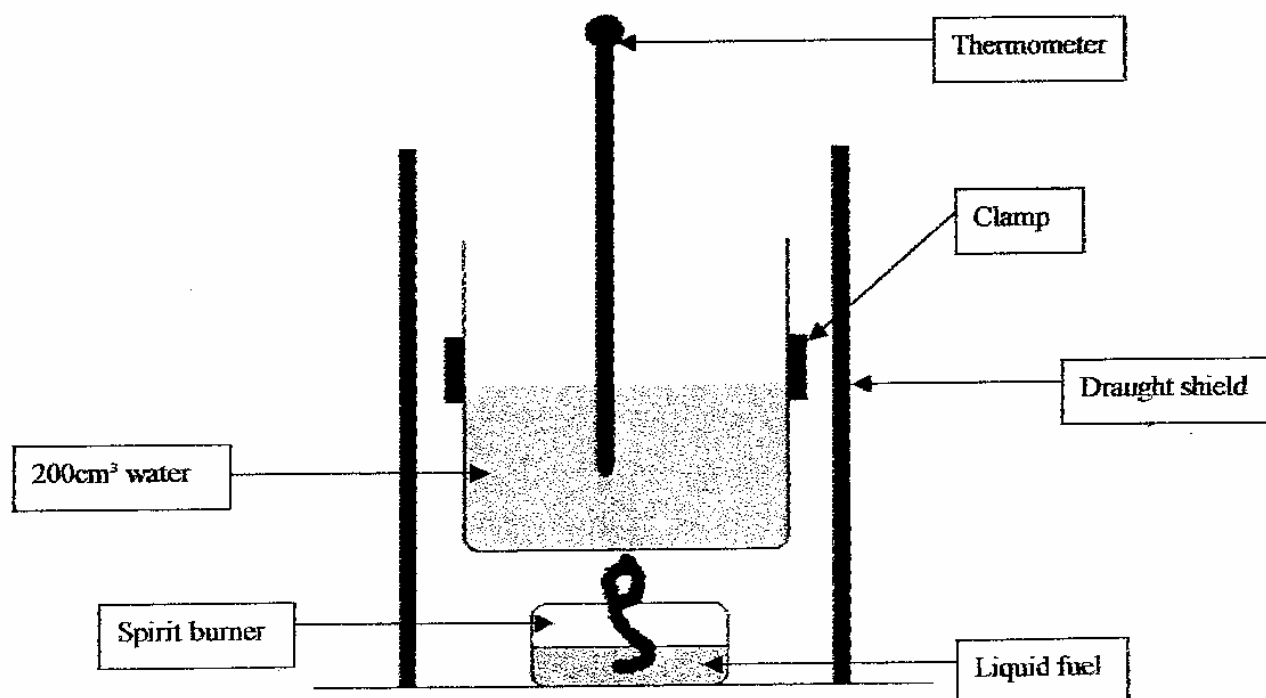
Student Report

Aim

The aim of my experiment will be to find the enthalpies of combustion for a set of alcohols, which will be the first four of the alcohols series, methanol, ethanol, butanol and propanol

Diagram

Below is the way I will set out my apparatus which I have listed overleaf.



Equipment

Below is a list of the equipment I shall use and the reasons why this particular piece of apparatus will be used.

- Spirit burner. This will be what the liquid fuel will be put into to be burnt
- 500ml copper calorimeter. This is where I will put the 200cm³ water will be. The copper will allow more of the energy to get to the water compared to other metals.
- Clamp stand. This will be used to hold the copper calorimeter above the flame, instead of using a metal tripod which would heat up and energy would be lost
- Electronic balance. This would weigh the spirit burner to two decimal places, which allows more accuracy when results are calculated.
- Heat proof mats. These will be used as draught excluders, and will make the experiment safer so that things do not set on fire
- Goggles. These will be worn to protect my eyes
- Measuring cylinder. This will be used to measure out 200cm³ of water to a good degree of accuracy
- Thermometer. This will be used to measure the waters temperature rise within one degree of accuracy
- Extinguisher. This will be placed onto the spirit burner when the required temperature is reached

Plan

First I will collect an empty spirit burner and then wash it out with water and will then dry it out. I will then put on my protective clothing and my goggles because of the dangers of fire and the dangers of the alcohols. I will then add methanol to the spirit burner until it is half full. I will then place the extinguisher onto the spirit burner and weigh it on the balance. I will record the weight in my table of results. I will then place the spirit burner onto a heatproof mat for safety in case of a spillage. I will then collect a 100cm³ measuring cylinder and wash it out. I will collect a copper calorimeter and wash this out. When this is done I will measure out two lots of 100cm³ of water and pour it into the copper calorimeter. I will place the copper calorimeter into a clamp, which will be 10cm above the heatproof mat. This will leave enough room between the top of the spirit burner and the bottom of the copper calorimeter for the flame to burn. I will the place four heatproof mats around the copper calorimeter and spirit burner so they surround the items, reducing the heat

loss. The heatproof mats will also be used for safety in case of spillages. I will then place the thermometer into the water and allow for it to reach the water's temperature. When it has done this I will record the water's temperature in my results table. I will then take the extinguisher off the spirit burner and will take care in lighting the wick. When it is lit I will use the thermometer to stir the water in the copper calorimeter. I will allow the water temperature to rise by exactly 15°C , while always stirring the water. When the water's temperature has risen by 15°C I will place the extinguisher onto the spirit burner being careful not to burn myself. This will put out the flame of the spirit burner. As soon as I have put the lid onto the burner I will record the overall temperature and put this result into my table of results. I will then pick up the spirit burner carefully and weigh it on the balance. I will leave the extinguisher on the spirit burner so there is no loss of alcohol due to evaporation. I will record the final weight of the spirit burner and record this result in my table of results.

With the results I have recorded I would be able to work out the temperature change and the change in the alcohol's mass.

I will repeat the experiment with each fuel twice as to gain more accurate results, and all of these results will be recorded in a table.

Things I must consider when I repeat the experiment would be to make sure I change the water in the copper calorimeter so the water is fresh and at room temperature. I must also make sure that when I put the calorimeter back into the clamp that it is still 10cm above the heatproof mat. I must remove the soot that I expect to be on the bottom of the copper calorimeter; if I do not do this then less heat will be able to get through to the water.

Safety precautions

When using dangerous substances and being around naked flames it is always important to take safety precautions while doing the experiment. I will take the following precautions;

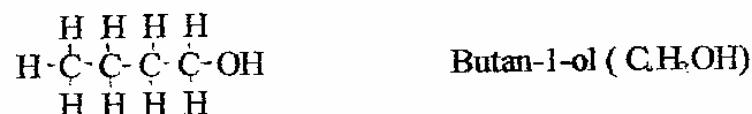
- Wear goggles and protective clothing
- If spilt turn off the source of ignition and clean up using a mineral absorbent
- If spilt on clothes remove the item of clothing and wash
- Be aware of where fire extinguishers are in case of fire
- Do not leave naked flames unattended
- Be aware of where the fire exits are

Prediction

I believe that butanol will have the highest enthalpy of combustion, and that methanol will have the lowest enthalpy of combustion.

Why?

Below are the four alcohols drawn out in their full structural formula;



The chemical formulas are shown in brackets next to the named alcohol. The general formula for the alcohol series is $\text{C}_n\text{H}_{2n+1}\text{OH}$. This means that as you move along the series the amount of carbon and hydrogen atoms increase. This also means that the relative atomic masses of the alcohols as you go along the series.

I believe that to break up the butanol bonds will need more energy to be put in than that of the methanol because there are more atoms and so more bonds. This would in fact mean that when the alcohol bonds are breaking that the methanol would have a higher enthalpy of combustion than butanol. The reason why the butanol will have a higher enthalpy of combustion overall is because it will release more energy when the new bonds are formed with the oxygen. This is because butanol has more carbon and hydrogen atoms for the oxygen to bond with compared to the amount of carbon and hydrogen atoms that methanol has. This means overall the butanol will have a higher enthalpy of combustion than methanol, as the graph shows overleaf.

Below are the table of results of the fuels that I burnt. In my plan I said I would use four fuels but I have used five because pentanol was made available and using it would improve my results.

Alcohol	Start Mass (g)	End Mass (g)	Mass Change (g)	Start Temp (°C)	End Temp (°C)	Temp Change (°C)
Methanol	233.07	232.11	0.96	20.0	35.4	15.4
	232.11	231.29	0.82	20.2	35.7	15.5
	245.32	244.41	0.91	18.5	34.4	15.9
Ethanol	210.00	209.27	0.73	19.9	35.7	15.8
	209.27	208.46	0.81	19.9	35.9	16.0
	182.11	181.05	1.06	18.3	34.2	15.9
Propanol	198.42	197.73	0.69	19.8	35.7	15.9
	197.73	197.12	0.61	20.0	36.1	16.1
	194.70	194.12	0.58	18.6	34.0	15.4
Butanol	190.27	189.76	0.51	20.2	36.6	16.4
	186.86	185.33	0.53	19.6	35.6	16.0
	189.39	188.89	0.50	20.3	36.4	15.9
Pentanol	246.89	246.41	0.48	22.1	37.6	15.5
	246.27	245.85	0.42	21.2	36.3	15.1
	177.03	176.57	0.46	18.5	34.5	16.0

Using the information I have gathered from the table above I can now work out the enthalpies of combustion for the five alcohols. I will do this by using the formula below,

$$\text{Energy} = \text{Mass} \times 4.18 \times \text{Temp. Change}$$

This is where the mass is the mass of the water used (200g) and the 4.18 is the specific heat capacity of water where one gram of water needs this much energy to raise the gram of water by one Celsius.

I have collected three results for each fuel and I will use the average temperature rise for each fuel to put into the formula to work out the enthalpy of combustion.

I will run through the calculations for one of the fuels and process the other four into a table with this result so they can be compared.

The fuel I will use as an example is Methanol. The average temperature rise of methanol is 15.6 °c. I will now use this piece of information and put it into the formula to find the enthalpy of combustion for methanol.

$$\text{Energy} = \text{Mass} \times 4.18 \times \text{Temp. Change}$$

$$E = 200 \times 4.18 \times 15.6$$

$$E = 13041.6 \text{ J}$$

So I can say that the methanol released 13'041.6J of energy on average when burnt.

The calculation used above was used for all of the values obtained below in the table of results collected.

Alcohol	Average Temp Change (°c)	Enthalpy Of Combustion (J)
Methanol	15.6	-13041.6
Ethanol	15.9	-13292.4
Propanol	15.8	-13208.8
Butanol	16.1	-13459.6
Pentanol	15.5	-12985.9

The results obtained above give little information into the trends of the enthalpy of combustion of the fuels. As you can see pentanol has the lowest enthalpy of combustion. The way that I will turn these results into a more conclusive set will be to bring the amount of fuel that was burnt to release this energy into the equation.

I will do this by seeing how much fuel was burnt to produce xJ of energy and then find out how much energy should therefore be released by one mole of fuel. I will demonstrate this for one fuel and then do the same for the other fuels and process the results into a table.

I will choose methanol once again to find out the enthalpy of combustion for one mole of fuel.

I know that on average that when 0.90g of methanol is burnt 13041.6J of energy are released. I will use this information to find out the energy released when one mole of methanol is burnt.

I know that methanol has 1 carbon, 1 oxygen and 4 hydrogen's present in one mole. So I can work out the molar mass of methanol as shown below,

$$\text{Molar mass} = 12 + 16 + 4(1)$$

$$\text{Molar mass} = 32\text{g}$$

I now know that one mole of methanol weighs 32g. when I burnt the methanol only 0.90g of fuel were burnt. I can now use my maths to work out the enthalpy of combustion for one mole of methanol.

$$0.90\text{g} = 13041.6\text{J} \quad 32\text{g} = ?\text{J}$$

$$\frac{32 \times 13041.6}{0.90} = -417302.4\text{J}$$

From this I can say that one mole of methanol releases 417.3KJ of energy. I will now do these calculations for all of the alcohols and put the results into a table below.

Alcohol	Average Mass Burnt (g)	Enthalpy of Combustion (J)	Molar Mass (g)	Enthalpy Of Combustion/Mole Of Fuel (KJ/mol)
Methanol	0.90	13041.6	32	- 417.3
Ethanol	0.87	13292.4	46	- 702.8
Propanol	0.63	13208.8	60	-1257.9
Butanol	0.51	13459.6	74	-1940.3
Pentanol	0.45	12985.9	88	- 2520.8

The results above clearly show that the enthalpies of combustion increase.

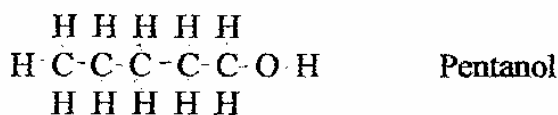
I believe the main reason behind this is because of the atoms present in the alcohols. The methanol has 1 carbon, 1 oxygen and 4 hydrogen atoms. Ethanol has 2 carbon, 1 oxygen and 6 hydrogen atoms. From this I can see that ethanol has 1 extra carbon atom and 2 extra hydrogen atoms. Between ethanol and propanol there is the same difference that propanol has 1 extra carbon and 2 extra hydrogen atoms compared to ethanol. This is the same as you go through the alcohols. This means that pentanol has more bonds than methanol. This is a vital thing to know because it means that pentanol needs more energy to break up its bonds compared to methanol. At this point methanol's enthalpy of

combustion is higher because it requires less energy to break up its fewer bonds. However it is true to say that when the methanol bonds reform into carbon and water that it gives out less energy than pentanol because it has fewer bonds to form and so it is here where we see that pentanol has a higher enthalpy of combustion than methanol.

This is the main reason why pentanol has a higher enthalpy of combustion than methanol. Because pentanol has more atoms present in one mole of substance it also has a higher molar mass. Methanol's molar mass is 32g but pentanol's is double over that at 88g. In my calculations I saw that the energy released by the fuels were all within the same region of about 130KJ. But in my calculations to find the enthalpy of combustion per mole of fuel I multiplied this value by the molar mass and so this is why the enthalpy of combustion for pentanol is a lot more than that of methanol's.

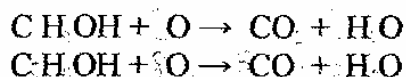
It is also true to say that the energy released by the fuels may be the same but pentanol did not have to burn as much fuel as methanol to do this. And so this was also a factor in the calculations to find the enthalpy of combustion for one mole of fuel. This is because the mass of fuel burnt was used to divide the values above and the smaller the decimal value the larger the above number becomes.

If I look at the structures of the alcohols once more, I will draw out the full structural formula of methanol and pentanol below,



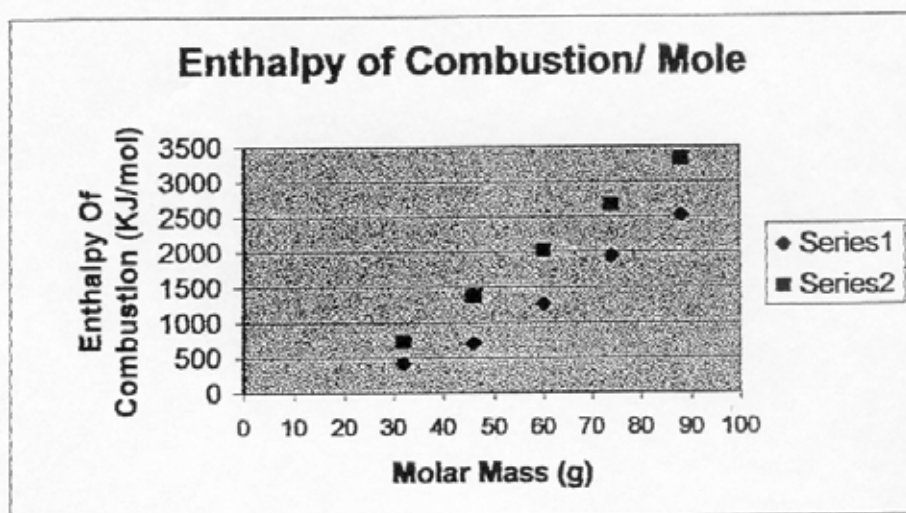
I will analyse the amount of hydrogen bonds that methanol and pentanol have because these are the most common in alcohols. I can see that methanol has 4 hydrogen bonds, which would require breaking, but pentanol has 12 hydrogen bonds, which would require breaking. Already from this I can see that pentanol would require three times as much energy as methanol to break all of its bonds.

I know that when alcohols are burnt they produce carbon dioxide and water, and so below are the chemical equations for the enthalpy of methanol and pentanol.



From the chemical equations I can see that one mole of propanol will produce a lot more carbon dioxide and water than methanol because it has more bonds which can be formed. Once again methanol has 4 hydrogen bonds in the water formed and pentanol has 12 hydrogen bonds formed in the water which means more energy is released by pentanol when it is burnt.

From the results I have collected and calculated I have produced the graph shown below and it shows that as the molar mass of the alcohol increases, the enthalpy of combustion increases. It shows a steady increase. From this graph I would be able to estimate the enthalpies of combustion for other alcohols.



Series one is the results that I gathered by my experiments and series two is the expected results, which I obtained from my data sheet. Although the results I have collected do not match the values of the expected results, there is still the same clear pattern emerging that as the molar mass increases the enthalpy of combustion is also increasing.

Evaluation

My results do not show any anomalous results. However the graph I drew shows that all of my enthalpy values are below the expected values. The pattern is still the same, a rise in enthalpy as the number of carbons increase. The reasons for this are many but the main reason is due to heat loss.

The main two types of heat loss are convection and unburnt fuel. In the case for the convection of heat I was able to reduce heat loss by placing draught mats around the fuel burner and the copper calorimeter. This stopped only one way for the heat escaping, other ways that the heat may escape is conduction of heat through the mats and the convection of the heat into the surrounding air entering through the gaps, and through the top. This was the main reason that my results differed so much from the expected results. I could reduce the heat loss by placing more draught mats around the experiment, and maybe adding a lid to reduce convection out of the top of the copper calorimeter.

The other main error I have mentioned was the unburnt fuel. When the fuel had been burnt there was a sooty deposit on the bottom of the copper calorimeter. I found that this deposit was carbon, which is present in alcohols. The carbon would have left the burner but would remain unburnt, and so when weighing the burner the unburnt carbon would not be taken into account, and so the amount of fuel burnt would be too high a value.

There are other smaller errors which are still significant in the overall calculating of the enthalpy of each fuel, one of these being the height of the copper calorimeter. In the case of my experiment I placed the copper calorimeter about 13cm above the table. I believe I can measure this height with an accuracy of ± 0.5 cm, which would give a percentage error of 3.9%, which is a large error.

When I measured out the water I used a measuring cylinder, which I believe has an accuracy of ± 1 cm³. This would give a percentage error of 0.5%. I believe that I could have reduced this error by weighing out the 200g of water. To prove this I will calculate the percentage error of weighing out the water. I believe that the balance can be accurately read to ± 0.1 g, calculating this into a percentage error I get 0.05%, which is 10 times more accurate than using a measuring cylinder.

When weighing out the spirit burner there would be the same percentage error as weighing out the water. This once again gives a percentage error of 0.05% when the spirit burners mass is weighed out.

I would also have an error in reading the thermometer. I believe I can read the thermometer to an accuracy of $\pm 0.5^{\circ}\text{C}$. This would give a percentage error of 3.2%, which like the height error is a very large error.

Other errors include stirring the water with the thermometer constantly for when each fuel was burnt. Did I place the extinguisher onto the burner at the correct times for each experiment? I believe that I did both of these, yet there may still be errors which may accumulate to the overall errors in doing this experiment.

Although the two large errors in heat loss make up for the main reason in the differences in expected and collected results, the smaller errors would build up and add another large error overall to my experiment.

I believe that my results were useful in identifying which alcohol has the highest enthalpy of combustion. I believe that they were as accurate as I could possibly do them. I believe that when seeing what errors could have been, and were made that a lot were unavoidable and were due to human error. This means that even if I redid the experiment with the improvements I have commented on, I would still have a difference in the collected results due to the human error factor. I believe that with the improvements I have stated would still however improve my overall results and would improve my readings.

Overall I believe that my experiment succeeded in finding out which alcohol out of the five provided produces the highest enthalpy of combustion.

3.2 Commentary on Experimental Skills Report 0401

Comparing the enthalpy changes of combustion of different alcohols

Planning

The general strategy in the plan is sound and meets the descriptors up to level 8. Most of the choices within the plan expected at this level are included although the use of similar temperature changes with different alcohols is not explicit. Two relevant sources are quoted and the risk assessment contains most expected points. The plan is therefore a good, if not perfect, match with the descriptors at level 8.

In comparing the plan to the descriptors at level 11, it is apparent that some of the expected fine detail such as ensuring a correct final temperature reading and use of similar temperature changes are missing and the attempt to explain why procedures will ensure precise and reliable data is weak. There are two rather than three source references and the risk assessment lacks fine detail.

The account only partially meets the descriptors at level 11 and a mark of 9 is therefore appropriate for this section.

Implementing

An appropriate amount of data is recorded in an expected format with suitable units in a clearly labelled table. The volume of water is also referred to within the text.

The descriptor requirements of the recording strand of implementing are therefore met up to, and including, level 11.

Analysing

The heat absorbed by water during the experiments and the enthalpy changes of combustion are correctly calculated and most steps of the calculations are explained.

The increasing enthalpy values of the enthalpy change of combustion is linked to an extra CH_2 group in alcohols, but the similarity in difference of the enthalpy change between successive alcohols is not identified. Some inappropriate terms such as 'hydrogen bonds' are used and the account lacks clarity in places.

Overall, the descriptors at level 8 are met but the descriptors at level 11 are only partially met. A mark of 9 or 10 is therefore appropriate, with a mark of 9 being most suitable here.

Evaluating

Some of the limitations of the experimental procedures are identified including heat loss to the air and incomplete combustion. This aspect meets the descriptors at level 5, but is limited in range and lacks clarity and is not sufficient to meet the descriptors at level 8.

The uncertainties associated with measurements of mass, volume and temperature are quoted. The percentage uncertainties are also stated, but the calculations are not shown. The differences in uncertainties between measurements of the mass of water and burner are not appreciated and the inclusion of a similar treatment for the height of can above burner reveals a lack of understanding about the evaluation of data.

Overall, the evaluation meets the descriptors at level 5 but does not meet those at level 8. A mark of 6 or 7 is therefore appropriate with a mark of 6 being most suitable here.

3.3 Candidate Experimental Skills Report 0402

Finding out how much acid there is in a solution

Student Report

Plan

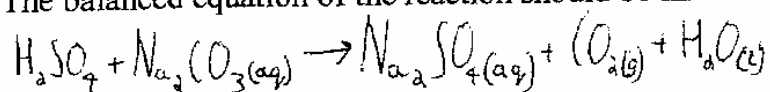
The task is to find out the accurate concentration of an acid solution given to me. To do this I will titrate a weak alkali into a strong acid then use methyl orange to indicate when the acid is neutralized. I will be using methyl orange as it is a clear indicator and reacts well with weak acids and alkalis.

I intend to use a 0.1 mol/dm^3 solution of sodium carbonate as the acid is predicted to be somewhere between 0.05 and 0.15 mol/dm^3 in concentration.

Apparatus to be used:

Burette
Clamp Stand
Beaker
Conical flask
Pipette
Pipette filler
Volumetric flask
Glass rod
Digital balance
Weighing bottle

The balanced equation of the reaction should be like this:



From the equation I can see that it is a 1:1 ratio therefore the mols of each substance in the final solution will be equal.

I will be using approximately 250 cm^3 of the acid and approximately 250 cm^3 of the standard sodium carbonate solution in total.

Ideally I will be needing a concentration of 0.1 mol/dm^3 of sodium carbonate solution, to achieve this I need 2.65 g of anhydrous sodium carbonate. I reached this amount by working out first the Relative Molecular Mass (RMM) of sodium carbonate, I then worked out how much I would need to produce a sample of 0.1 mol/dm^3 solution in 1000 cm^3 of solution I then divided this by four to account for the fact I was using 250 cm^3 of the solution (this is all shown in maths point 1).

From the results of the titre I can work out the concentration of the acid, I already know that the amount of mols in the beaker of my standard solution will be the same as the mols in the beaker of the acid. For example if I ended up with a titre of 20 cm^3 I could work out that there was 0.002 mol of my standard solution in the beaker therefore there would be 0.002 mol of the acid in the 25 cm^3 sample, from this I could

then work out that the concentration of the acid would be 0.8 mol/dm^3
(see maths point 2)

Method

Initially I will weigh out as close to 2.65g of anhydrous sodium carbonate in a weighing bottle. I will then empty this out into a beaker. I will weigh the bottle before and after transferring the sodium carbonate as to account for any material that may be left behind in the weighing bottle. Distilled water is then added to the beaker and stirred with a glass rod until the anhydrous sodium carbonate is completely dissolved. The solution is then carefully poured into the volumetric flask using the glass rod to help with accuracy in pouring, the glass rod and beaker are then rinsed with distilled water to ensure that no sodium carbonate is left behind the rinse water is added to the solution. More distilled water is added to the solution using a dropping pipette until the base of the meniscus is touching top of the white line (the line is actually a circle around the neck of the flask but to ensure accuracy it must be seen as a line). The flask then needs to be inverted several times to ensure that the solution is mixed evenly. The volumetric flask should now contain a solution of hydrated sodium carbonate of a concentration of 0.1 mol/dm^3 .

The burette is then set up using a clamp stand and a beaker containing 25 cm^3 of the standard solution underneath which should be filled using a pipette and pipette filler. The burette should then be filled with the acid using a pipette and pipette filler. 2/3 drops of methyl orange is added to the sodium carbonate, then the titre can begin to be dropped into the mixture slowly until the methyl orange changes to a pink colour. The end point needs to be recorded accurately. The experiment should be repeated until there is at least two concordant results.

Safety precautions

- Beware of any spillage, they should be cleaned up immediately to prevent any accidents on a slippery floor.
- Similarly any broken glassware should be cleaned up to prevent injury.
- The Hazcards state that goggles should be worn due to the acid being corrosive and the carbonate being an irritant.
- Be sure that a pipette filler is used and not the more traditional and dangerous method of sucking the air out using one's mouth.

Reliability

Certain checks are undertaken to ensure fair and reliable results:

- A White tile is placed under the beaker containing the acid and the methyl orange, this will highlight any colour changes and ensure a more accurate reading of the endpoint.
- The line used to measure the meniscus is actually a white ring around the circumference of the pipette, volumetric flask or burette this allows for the measurements to be more accurate as the glassware has to be level for the ring to appear to be a line.
- All items should be rinsed beforehand to prevent contamination which could affect the final results.
- A glass rod must be used on top of the beaker when pouring to allow for a more accurate stream of liquid, this achieved using surface tension.
- A weighing bottle is used to minimize the amount of anhydrous sodium carbonate left being when it is weighed.
- The beaker at the bottom should be oscillated so that the acid added is able to react with the methyl orange with greater ease.
- The end point should be reached using small drops to allow for maximum precision.

References

- Salters Advanced Chemistry, Chemical Ideas, Titration activity M 2.4
- Hazcards

Results

Titration

Initial Reading (cm ³)	Final Reading (cm ³)	Titre (cm ³)
0.00	20.05	20.05
2.00	24.40	22.40
24.40	45.05	20.65
4.60	25.10	20.50

2.67g of anhydrous sodium carbonate used in the standard solution.

Analysis

The average titre from my concordant results came to 20.58cm^3 of the acid.

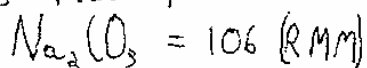
I added this to the 25cm^3 of the standard solution. In order to work out the mols of acid in the sample I need to first work out the exact concentration of my standard solution.

I dissolved 2.67g of the anhydrous sodium carbonate into 250cm^3 of distilled water. This means that there was a concentration of 0.10075 mol/dm^3 in my standard solution.

In 25cm^3 of the standard solution there was 0.00252 mol of sodium carbonate, so in the 20.58cm^3 of acid there was also 0.00252 mol of acid, thanks to the 1:1 ratio. From this we can work out that the concentration of the acid was, 0.122 mol/dm^3 (see maths point 3).

Maths Points

Maths Point 1



$$\text{for one mol} = 106\text{g}$$

$$0.1 \text{ mol} = 10.6\text{g}$$

$$\frac{10.6\text{g}}{4} = 2.65\text{g}$$

Maths Point 2

20 cm³ litre contains 0.002 mol

therefore

25 cm³ acid contains 0.002 mol

so the concentration is 0.08 mol/dm³

$$\begin{aligned} 1000 \text{ cm}^3 &= 0.1 \text{ mol} \\ \div 50) \quad 20 \text{ cm}^3 &= 0.002 \text{ mol} \end{aligned}$$

$$\begin{aligned} 25 \text{ cm}^3 &= 0.002 \text{ mol} \\ \times 40) 1000 \text{ cm}^3 &= 0.08 \text{ mol} \\ (1 \text{ dm}^3 &= 1000 \text{ cm}^3) \end{aligned}$$

Maths Point 3

2.67g of solid in 250 cm³ (x4)

10.68g of solid in 1000 cm³ ($\div 10.6$)

$$* 1.0075 \text{ mol} \div 40 = 0.00252 \text{ mol}$$

$$48.59 \times 0.00252 = 0.122 \text{ mol/dm}^3$$

$$(1000 \div 40 = 25)$$

$$(1000 \div 20.58 = 48.59)$$

$$* 1.0075 \text{ mol in } 1000 \text{ cm}^3 = 1.0075 \text{ mol/dm}^3$$

Evaluation

Ultimately I feel that the titration performed was very accurate, and the results were reliable. I put this down to:

- All figures were taken to a minimum of two decimal places
- All calculations were checked multiple times
- Titrations were taken until two concordant results were taken and then these were averaged
- All equipment was rinsed and any loss of substance or inaccuracies in amounts was accounted for in the calculations.
- All safety aspects were undertaken.
- All of the reliability points were covered.

Because of the human element in the titration there has to be a percentage error to be worked out, it is worked out below:

The percentage error for the scales

3.4 Commentary on Experimental Skills Report 0402

Finding out how much acid there is in a solution

Planning

The overall strategy in the plan is generally sound. Most of the choices within the plan expected at this level are included, although the use of a beaker rather than a conical flask in which to carry out titrations is not good practice and the use of a pipette to fill up a burette reveals a lack of understanding about the use of these types of glassware. Two relevant sources are quoted although the specific Hazcards are not indicated. The risk assessment covers hazards associated with acid and carbonate but incorrectly uses the term corrosive for the dilute acid used. The plan is just about a good, but not perfect, match with the descriptors at level 8.

In comparing the plan to the descriptors at level 11, it is apparent that some of the expected fine detail such as the difference in procedure between a trial and accurate titration and washing glassware with water or specified solutions are missing. The poor choices of beaker rather than conical flask and use of a pipette to fill a burette should also be considered here. The explanation of choice of indicator is unclear but there are several sound points made to explain why the procedures are likely to achieve precise and reliable data. The references and risk assessment are not of the quality expected at level 11 and the account lacks clarity in places..

Overall, the account meets the descriptors at level 8 but does not meet sufficient additional descriptors at level 11 to advance beyond this point. A mark of 8 is therefore appropriate for this section.

Implementing

In the recording strand of implementing, titrations are not repeated until titres are achieved within 0.1cm^3 of each other, which means that one of the descriptors at level 11 is not met.

However, appropriate readings used to find the mass of sodium carbonate used have not been included in this section which means that one of the descriptors at level 8 has not been met.

A maximum mark of 7 is therefore available for this skill area.

Analysing

An appropriate average titre has been calculated for use in calculations but the calculation is not clearly shown. The concentration of the sodium carbonate solution and the concentration of the acid solution are correctly calculated but some steps are not well explained and the choice of significant figures is not always suitable. A molar reacting ratio between acid and carbonate of 1 to 1 is quoted but is not supported by an equation in this section of the report.

Overall, this section is a sufficiently good match to satisfy the descriptors at level 8 but only partially meets the descriptors at level 11. A mark of 9 is therefore appropriate.

Evaluating

This brief section includes some comments on aspects of the experimental procedure which ensure that the data collected is precise and reliable but there are no comments on the uncertainties associated with the measurements recorded.

The descriptors at level 2 are not sufficiently met so that a mark of 1 is appropriate for this section.

3.5 Candidate Experimental Skills Report 0403

Finding out how much acid there is in a solution

EXPERIMENTAL SKILLS REPORT 0403

FINDING OUT HOW MUCH ACID THERE IS IN A SOLUTION

Candidate Report

PLAN

I am going to be given a sample of sulphuric acid solution. The solution is thought to have a concentration of between 0.05 and 0.15 mol dm⁻³. I have to find an accurate concentration of the solution.

To conduct my experiment I will use:

A funnel, volumetric flask, burette, graduated pipette, 250 cm³ beaker, test tubes, conical flask, weighing bottle, boss and clamp, white tile, retort stand, piece of white paper, top pan balance, 2.65 g of anhydrous sodium carbonate dissolved in 250 cm³ of distilled water, methyl orange, sulphuric acid of unknown concentration.

I used an information sheet to work out which indicator would be best to use. I chose methyl orange as I am using a strong acid and a weak alkali.

Safety precautions:

Eye protection must be worn at all times when using chemicals such as anhydrous sodium carbonate and sulphuric acid as they are harmful to eyes. Wear protective gloves. Sulphuric acid is corrosive. Do not consume food or drink in labs. Hold pipette

close to end to which you are attaching the pipette filler so as not to snap the pipette. When conducting an experiment you must stand up at all times, tie back long hair and wear protective clothing. Clean up any spills immediately and dispose of waste safely. Place any broken glass in a container marked 'broken glass'; if not possible, wrap it in newspaper and dispose of safely.

This is how I am going to carry out the experiment:



To start, I will work out the mole ratio of Na_2CO_3 and H_2SO_4 . They react together in a 1:1 ratio so I know that amount of acid that I have to run in is proportional to the amount of sodium carbonate I have in the beaker.

I will make up the sodium carbonate solution to a concentration of 0.1molar. This amount is between 0.05 and 0.15 which is thought to be the concentration of the acid. I will work out how many grams of each element there is in the compound of sodium carbonate.

2 × Na	=	45.99
1 × C	=	12.00
3 × O	=	<u>48.00</u>
		105.99

I want to make a 250 cm³ of 0.1 mol solution

To make 1 mol solution dissolve 105.99g of anhydrous sodium carbonate in 1dm³ of distilled water

To make a 0.1mol solution dissolve 10.599g of anhydrous sodium carbonate in 1dm³ water

To make 250cm³ of 0.1mol solution dissolve 10.599/4g anhydrous sodium carbonate in 250cm³ water

So $10.599/4 = 2.65\text{g}$ of Na_2CO_3 in 250cm³ of distilled water

I will weigh the anhydrous sodium carbonate in a weighing bottle on a top pan balance. Then I will dissolve the sodium carbonate in a beaker, rinsing the weighing bottle with distilled water so as not to lose any sodium carbonate. Once it is all dissolved, I will use a funnel to transfer it to a volumetric flask, rinsing with distilled water again. I will then top up the flask with distilled water, stopping before the calibration line to transfer the last drops by pipette for accuracy. I will view the line against a piece of white paper to ensure that I can see the line and the meniscus clearly, to avoid over filling. The next step is to invert the flask to make sure the solution is well mixed.

I will fill the burette with acid. If the burette is wet I will rinse it with the acid solution to avoid dilution of the acid solution, using a funnel, running a little through to ensure that the jet is full. By placing a piece of white paper behind it, I will be able to record an accurate reading on the burette. Using the graduated pipette, 25cm³ of sodium carbonate solution will be transferred to the conical flask, along with three drops of methyl orange. I will wash down the sides of the flask with distilled water for any drops. I will then run in the acid from the burette slowly keeping a hand on the tap and swirling the flask at the same time. When the acid comes into contact with the sodium carbonate there will be a pink area in an orange solution.

The acid will need to be added drop by drop as the colour becomes more intense. When the pink colour remains for 30 seconds the reaction is complete. A white tile was placed under the conical flask to make the end point easier to identify.

I will take the reading of the level in the burette as before and record it. This is my rough titration.

I will need to dispose of the solution in the conical flask, rinse it with distilled water and repeat the titration process above until I have at least three readings within 0.1cm^3 of each other i.e. concordant results.

References:

Salters Activity EL 2.1

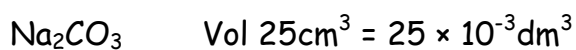
Haz Card for sulphuric acid

RESULTS

Initial burette reading/cm ³	Final burette reading/cm ³	Amount of acid run in/cm ³
0.95	22.20	21.25
0.90	21.90	21.00
0.60	21.50	20.90
0.30	21.15	20.85
0.35	21.21	20.85

ANALYSIS

Interpreting and calculating the results:



$$\text{Concentration} = \frac{\text{moles}}{\text{Volume}}$$

$$\text{Moles} = \text{concentration} \times \text{volume}$$

$$= 0.1\text{mol dm}^{-3} \times 25 \times 10^{-3}\text{dm}^3$$

$$= \text{ x moles in flask}$$

reacts 1:1 with acid

so concentration = $\frac{x}{\text{average titre}}$

I am only going to take the average of the three closest results

$$\text{Average} = \frac{20.9 + 20.85 + 20.85}{3} = 20.8\text{cm}^3$$

$$\text{concentration} = \frac{0.1\text{mol dm}^{-3} \times 25 \times 10^{-3}\text{dm}^3}{20.8 \times 10^{-3}\text{dm}^3} = 0.120192307$$

$$\text{concentration} = 0.1\text{mol dm}^{-3}$$

EVALUATION

Where the errors could happen:

Volumetric flask. When a 250cm^3 volumetric flask is filled correctly, i.e. the bottom of the meniscus rests on the calibration line, the error is 0.2cm^3 or 0.08%

Burette. One drop from a burette has a volume of approximately 0.05cm^3 . All burette readings should include two decimal places in which the second is either 0 or 5. An error of one drop in a volume of 25.00cm^3 gives a percentage error of 0.2% for each reading. After calculating the average titre you should correct the value to one decimal place.

Pipette. When a 25cm^3 pipette is used correctly, i.e. it is allowed to drain and retain the last drop, the error is 0.06cm^3 or 0.24%

Percentage error for glassware = $0.005\% + 0.08\% + 0.2\% + 0.24\% = 0.525\%$

Errors for all the glassware

Error for top pan balance	= 0.0367%
Error for graduated pipette	= 0.24%
Error for conical flask	= 0.08%
Error for burette	= <u>0.235%</u>
Total error for titre1	0.5913

This systematic error is probably not very significant as it will be very small

The main sources of error in my experiment was when I had decided when the end point was.

I think that my results are precise and accurate as most of them are within 0.05 of each other and I was aiming for 0.1 so this gives less error. There is a very small and virtually insignificant percentage error for the glassware.

I believe that the concentration of the sulphuric acid I was given is near to 0.1 as there is a possibility of a percentage error.

Weighing by difference increased the accuracy of and reliability of my results as the percentage error is less than if I had not weighed by difference. I washed the glassware with appropriate solutions as it washes away any traces of substances as these may affect my results. Washing down the side of the flask during the titration ensured that all the acid I had run in was reacted. Using a white tile and colour guide helped me identify the end point of the reaction. The white piece of paper made the meniscus easier to see and read.

3.6 Commentary on Experimental Skills Report 0403

Finding out how much acid there is in a solution

Planning

The overall plan to make up a solution of sodium carbonate and to titrate it with the acid solution is sound. Most of the expected fine detail is included, although there is no distinction made between the procedure for a trial titration and for an accurate titration. The choice of sodium carbonate concentration is well explained and some aspects of procedure that ensure that the data is precise and reliable are identified. Only two rather than three sources are quoted and the risk assessment states incorrectly that the acid used is corrosive.

Overall, the plan is a good match with the descriptors at level 8 but does not sufficiently match all of the descriptors at level 11. A mark of 10 is therefore appropriate for this skill area.

Implementing

The titration results are recorded in a suitable table with correct units. Unfortunately, the actual balance readings from which the mass of sodium carbonate is calculated are not included. This section does not, therefore, match the descriptors at level 8 and a maximum mark of 7 is available for this skill area.

Analysing

There is a small error in the calculation of the average titre. The concentration of sodium carbonate solution is assumed, rather than calculated but the concentration of the acid solution is correctly calculated. The explanation of the steps in the calculations are not always clear.

Overall, this section provides a match with the descriptors at level 5 but does not sufficiently match the descriptors at level 8. A mark of 6 is therefore appropriate for this skill area.

Evaluating

The percentage uncertainty associated with the use of a volumetric flask, burette, pipette and balance are quoted but the actual calculations are not shown. The value for the burette is based on a volume of 25 cm^3 rather than the actual burette readings recorded. The calculation of an uncertainty in the use of a conical flask is not appropriate. The limitations associated with noting the precise end point are identified and several valid comments are included about aspects of procedure that are important in ensuring that the data collected is precise and reliable.

Overall, this section is a good match with the descriptors at level 5, but does not sufficiently meet the descriptors at level 8 where it is expected that the uncertainties associated with specific examples of most types of measurements will be calculated. A mark of 7 is therefore most appropriate for this skill area.

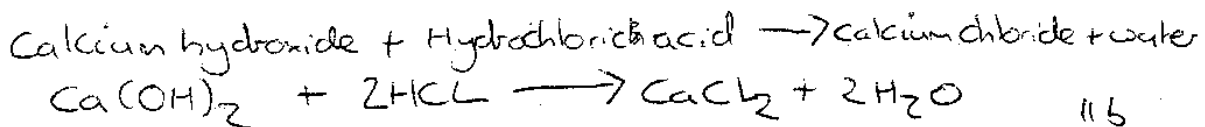
3.7 Candidate Experimental Skills Report 0404

Determination of the solubility of calcium hydroxide

DETERMINATION OF THE SOLUBILITY OF CALCIUM HYDROXIDE

Student Report

An equation for calcium hydroxide reacting with hydrochloric acid is:



The substance that will need to be diluted will be the hydrochloric acid to take it from 0.3 mol dm^{-3} to approximately $0.015 \text{ mol dm}^{-3}$. by doing so, the acid will be the same concentration as the calcium hydroxide thus making an equal and fair test

To perform the dilution I will have to calculate the volume of acid needed to be diluted with water to be a concentration of $0.015 \text{ mol dm}^{-3}$.

Formula for volume =



So volume will be moles divided by concentration

I know the concentration which is the target concentration and the number of moles by the starting amount of hydrochloric acid which is 0.3 moles

$$\therefore \text{volume} = \frac{0.3}{0.015} = 20 \text{ cm}^3$$

but this is in a starting volume of acid of 100 cm^3 so you must divide this ~~as~~ 100 cm^3 by the answer to get the target volume

$$\therefore \text{volume} = \frac{100}{20} = 5 \text{ cm}^3$$

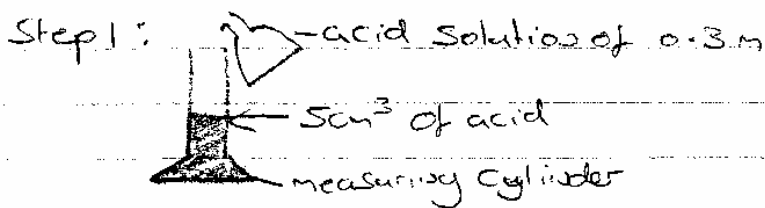
so you must use 5 cm^3 of acid diluted with water to give the target concentration

(1)

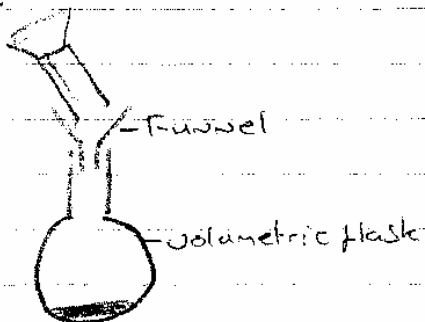
To dilute the solutions you must:

- Take 5cm^3 of Hydrochloric acid from the container by filling it into a 20cm^3 measuring cylinder
- Transfer this to a 100cm^3 volumetric flask by pouring the contents of the cylinder, through a funnel into the flask
- Wash all the remaining acid from the cylinder, into the volumetric flask by using distilled water
- Fill up the rest of the volumetric flask with distilled water up to the 100cm^3 mark on the bottle.
- put on the lid and shake well to ensure even mixing
- This now should be the 0.015mol dm^{-3} of concentrated hydrochloric acid (diluted)

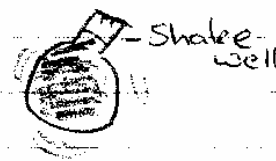
Diagram to show the process:



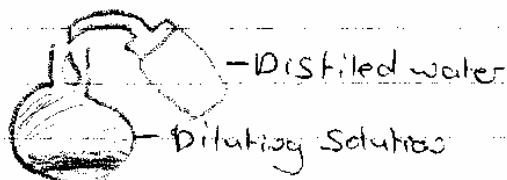
Step 2:



Step 4:



Step 3:



(2)

To do the titration you must:

- clamp a burette to a clamp stand and making sure the tap is at a horizontal angle, fill up the burette with distilled water and flush through into a beaker, do the same with the hydrochloric acid solution you distilled and pour it through. **Caution!** to avoid spillage use a funnel and place the equipment as to the floor
- now fill up the burette up to a sensible amount of acid and write down the reading of the bottom of the acid line to 0.05 cm^3
- pipette 10 cm^3 of lime water, ~~and then~~ using a volumetric pipette and empty into a conical flask
- add 2-3 drops of either methyl orange or phenolphthalein into the flask
- start titrating by ~~by~~ adding small amounts of acid into the flask (around 0.5 cm^3 at a time) until there is a slight colour change, swirl to mix the contents
- when you get to the point of slight colour change, add in 3 drops then 2 then 1 drop until there is a permanent clearness in phenolphthalein or a orange/redish pink colour for methyl orange
- Take the reading of the acid level to the same accuracy as the start reading
- Repeat to get ^{consistent} more results to compare
- add up all the titres. (finish volume - start volume) and divide by that amount of constants to get an average titre
- **CAREFUL** Hydrochloric acid is an irritant and ^{corrosive} ~~hazardous~~. use gloves and goggles, and lab coats when you use it and wipe up any spills immediately

(3)

when in my plan I was calculating the volume it is in 100cm^3 of solution. So would differ if you had it in a 200cm^3 of solution where you would just change the answer to 20 and ~~also~~ divide 200 by 20 to give 10cm^3 of acid in a 200cm^3 flask. Note also any time you are filling or relinquishing fluids, not all the fluid will be taken, but this is accounted for in the percentage error calculation later on.

Sources I have used for this plan are:

- Data books
- Shared area printout
- Chemical ideas
- module booklet

CAUTION

Both Hydrochloric acid and calcium hydroxide are hazardous, irritants and acid is corrosive

Take care by wearing gloves, goggles and lab coats. Wipe up any ~~spills~~ spills with a wet cloth and dry up immediately. Work slowly when carrying the equipment and don't carry the bottles in one hand

(4)

results

	Rough	Test 1	Test 2	Test 3	Test 4	Test 5
Final vol	35.60	42.01	35.51	35.01	40.51	35.60
start vol	0.05	6.55	04.00	0.48	5.02	0.04
Titre	35.60	35.46	31.51	35.49	35.49	35.56

Average titre = 35.50 cm^3

Analysing results

The concentration of acid =

$$\text{Volume} = 250 \text{ cm}^3$$

$$\text{moles} = 0.3 \text{ mol}$$

$$\text{Concentration} = \frac{0.3}{x \text{ (vol of acid)}}$$

$$\text{Volume} = 250 \text{ cm}^3 \text{ of acid solution}$$
$$25 \text{ cm}^3 \text{ of acid}$$

$$= \frac{250}{25} = 10$$

$$\text{Concentration} = \frac{0.3}{10} = 0.03 \text{ mol dm}^{-3}$$

The concentration of calcium hydroxide solution =

$$\text{moles} = 3x$$

$$\text{Volume} = x$$

Volume (x) is the average of consistent titres. My consistent titres were test 1, 3, 4 = 1. 35.46

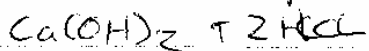
$$3: 35.49$$

$$4: 35.49$$

$$\text{Average} = 35.48$$

This is the volume of calcium hydroxide reacting with 25 cm^3 of 0.03 mol dm^{-3} of hydrochloric acid

The number of moles in the solutions are:



Ratio 1:2

(5)

So the number of moles of calcium hydroxide is half that of hydrochloric acid. So this means that there is $\frac{1}{2}$ the amount of hydrochloric acid moles which equals 0.15

\therefore the equation for the concentration is

$$\frac{0.15}{35.48} = 0.0042 \text{ mol dm}^{-3}$$

evaluation

In my titration, there was only 1 anomalous result, this was 'test 2' in which it gave me the result of 31.51 cm^3 whereas the rest of the titres gave me around 35.48 or there about.

My titration was alright, but not all the measurements or readings were total was not accurate, so the percentage error for the measurements are as follows

$$\begin{aligned} \text{Burette titration} &= \text{Final reading} = 35.51 \\ &\text{Start reading} = 4.00 \\ \text{Titre} &= 31.51 \text{ cm}^3 \end{aligned}$$

$$\text{Percentage error} = \frac{0.05}{31.51} \times 100 = \pm 0.16\% \text{ error for the anomalous result}$$

Because there were two readings to get this result, the % age error is doubled to = 0.32 % error

another error was the volumetric pipette so: E8b

$$\text{Percentage error} = 0.05 \times 100 = 5\% \text{ error}$$

The importance of these errors are that not all the correct amount of solution (s) were added to get an accurate result.

⑥

The sources of error that could occur from this results are the fact that not all the equipment was for example the volumetric pipette you couldn't get all of the solution out of the end or the same with the burette. These could affect the results because if the solution had all gone through, then the results would be accurate and the titres would be constant or equal to each other.

The overall accuracy of this titration was not all ways accurate because when you judge the base of the meniscus, of the solution, not everyone can read the same or exactly on the line with only a 0.00001 of a cm out, this happens in both the pipette and the burette. The more important of the two is the burette because this is the difference between getting an accurate or an anomalous result because it depends on everyone eye line to differ the amount of acid to react with the lime water.

The procedures could have been more accurate depending on what apparatus were used. For example, if we had used an inaccurate amount amount of acid, then it would affect the experiment because the readings would be inaccurate and would give a false reading (titre). To ensure they were as accurate as possible, you should use a specialised pipette that can only go up to 25cm^3 to ensure both readings were accurate.

It will ensure the procedures are accurate because it is set to only fill up to 25cm^3 of acid or lime water and will fill up to a region of 0.001-0.01 and will be more accurate than trying to measure with your eyes because everyone will judge differently, but with this tool, everyone will possibly measure the same amount of substance.

(7)

3.8 Commentary on Experimental Skills Report 0404

Determination of the solubility of calcium hydroxide

Planning

The general plan to dilute the acid solution and to titrate the diluted solution with lime water is sound. There are significant problems, however, with some of the detail within the plan. The use of a measuring cylinder and the factor by which the acid is diluted are not suitable. In addition, the risk assessment does not distinguish between corrosive and irritant and the quoted references lack detail.

Overall, this section just satisfies the descriptors at level 5 but only partially meets the descriptors at level 8. A mark of 6 is therefore appropriate.

Implementing

In the recording strand of implementing, the titration results are clearly recorded in a table but units are only given for the average titre and not for start and end burette readings or for individual titres.

This section can be just be considered a match for the descriptors at level 5 but the descriptors at level 8 are not sufficiently met since they require that units be supplied with most data. A maximum mark of 7 is therefore possible for this skill area.

Analysing

There is some doubt about the validity of the calculated average titre since it is different from the value given in the results table and does not make use of the titre from titration number 5. The concentration of the diluted acid is correctly calculated but the rest of the calculations and explanations are incorrect and confused.

The descriptors at level 5 are met but there is very little additional achievement so that a mark of 5 is appropriate for this section.

Evaluating

The comments made on the limitations of experimental procedure are superficial and some illustrate a lack of understanding about the use of burette and pipette. Key features such as recognition of the end point, shaking up the diluted solution before use and repeating titrations to get concordant results are not included. The uncertainty associated with measurements using a burette are correctly calculated but a similar calculation for the use of a pipette is wrong and there is no attempt to calculate the uncertainty associated with the use of a volumetric flask.

Overall, this section does not provide a good enough match with the descriptors at level 5 in terms of comments on limitations of practical procedures or on aspects of procedures that are important in ensuring that the data collected is precise and reliable. A mark of 4 is therefore appropriate for this skill area.

3.9 Candidate Experimental Skills Report 0405

Determination of the enthalpy change of reaction

EXPERIMENTAL SKILLS REPORT 0405

DETERMINATION OF THE ENTHALPY CHANGE OF REACTION

Candidate Report

Plan

The first part of my plan is to find the temperature change when calcium carbonate reacts with hydrochloric acid.

I will be using about 2.5g of calcium carbonate and I need to work out how much 2.0mol dm^{-3} hydrochloric acid will be needed to react with it.

$$\text{Mr CaCO}_3 = 40 + 12 + (3 \times 16) = 100$$

$$2.5 \text{ g CaCO}_3 = \frac{2.5}{100} = 0.025 \text{ moles}$$



1 mole CaCO_3 reacts with 2 moles HCl

0.025 mole CaCO_3 reacts with 0.05mole HCl

A 2.0mol dm^{-3} hydrochloric acid contains 2 moles in 1000cm^3

It contains 0.05 moles in $\frac{1000}{2} \times 0.05 = 25\text{cm}^3$

2

So if I use 50cm^3 of the hydrochloric acid I will have double the volume I need and I can be sure that all the calcium carbonate will be used up

I will put a weighing bottle on a top pan balance and weigh it. I will add solid calcium carbonate to the weighing bottle until I have added about 2.5g and I will record the mass. After I have tipped out the solid I will weigh the weighing bottle again so that I know exactly how much solid I have used.

I will use a 100cm^3 measuring cylinder to measure out 50cm^3 of 2.0mol dm^{-3} hydrochloric acid into an expanded polystyrene cup.

I will stir the acid with a thermometer and record the initial temperature. I will add the calcium carbonate from the weighing bottle to the acid in the cup. I will stir the solution in the cup with the thermometer and record the final temperature that is reached. I will pour the contents of the cup down the sink and rinse it with distilled water so that it is ready for the next step.

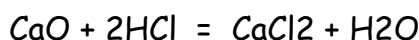
I now need to find the temperature change when calcium oxide reacts with hydrochloric acid.

I will use the same number of moles of calcium oxide as the number of moles of calcium carbonate.

$$M_r \text{ CaO} = 40 + 16 = 56$$

1 mole of CaO has a mass of 56 g

0.025mole CaO has a mass of $56 \times 0.025 = 1.4\text{g}$



0.025g CaO reacts with 0.05 mole HCl

0.05mole of HCl is contained in 25cm^3 of 2.0mol dm^{-3} hydrochloric acid

(see calculation in previous step)

Therefore I will use 50cm^3 of the acid again to make sure that all the calcium oxide reacts

I will repeat the method described above but this time I will use 1.4g of calcium oxide instead of 2.5 g of calcium carbonate

The reasons that the data I collect is likely to be precise and accurate are:

I am using an excess of acid to make sure that all the calcium carbonate and the calcium oxide are fully reacted.

I am using an expanded polystyrene cup to carry out the experiment in as this will minimise the loss of heat to the surroundings.

I am using a weighing bottle so I can tell exactly how much solid has been used because I will weigh it before and after I have tipped out the solid.

I am using the same number of moles of calcium carbonate and calcium oxide so I can use the same method and equipment.

I will stir the contents of the cup to make sure that the heat is evenly distributed.

I will take care to record the maximum temperature change for the final temperature reading.

Risk Assessment:

Calcium oxide is corrosive and dangerous with water so I will need to wear safety glasses, make sure that I don't get it on my skin, and to take great care when I add it to the acid solution

Hydrochloric acid is an irritant so I will need to wear safety glasses

Calcium carbonate is a low hazard so I don't need to take any special precautions for it.

References consulted:

1. Practical Number 8, page 20 Chemistry in Context Laboratory Manual and Study Guide. Graham Hill and John Holman
2. Salters Chemical Ideas page 60
3. Haz Cards for calcium oxide and hydrochloric acid

Analysis

Mass of calcium carbonate + weighing bottle	15.51g
Mass of empty weighing bottle	13.01g
Mass of calcium carbonate used	2.50g
Initial temperature of the acid	18.0°C
Temperature of the solution when the reaction is complete	20.5°C
Temperature change of the reaction	2.5°C
Mass of calcium oxide + weighing bottle	14.00g
Mass of empty weighing bottle	12.60g
Mass of calcium oxide used	1.40g
Initial temperature of the acid	18.0°C
Temperature of the solution when the reaction is complete	31.5°C
Temperature change during the reaction	13.5°C

To find the enthalpy change for the reaction between calcium carbonate and hydrochloric acid:

I will assume that the density of the solution in the cup is 1.0gcm^{-3} and its specific heat capacity is $4.2\text{g}^{-1}\text{K}^{-1}$

Volume of solution is 50cm^3 and so we can assume that the mass of the solution is 50g

Enthalpy change when the calcium carbonate reacted with the hydrochloric acid

$$= - (50 \times 4.2 \times 2.5) = - 525\text{J}$$

This is for 2.5g CaCO_3 which is 0.025mole

$$\text{Enthalpy change for 1mole calcium carbonate} = - \frac{525}{0.025} = - 21000\text{Jmol}^{-1}$$

$$= - \frac{21000}{1000} = -21.0\text{kJmol}^{-1}$$

To find the enthalpy change for the reaction between calcium oxide and hydrochloric acid:

I will assume that the density of the solution in the cup is 1.0gcm^{-3} and its specific heat capacity is $4.2\text{g}^{-1}\text{K}^{-1}$

Volume of solution is 50cm^3 and so we can assume that the mass of the solution is 50g

Enthalpy change when the calcium oxide reacted with the hydrochloric acid

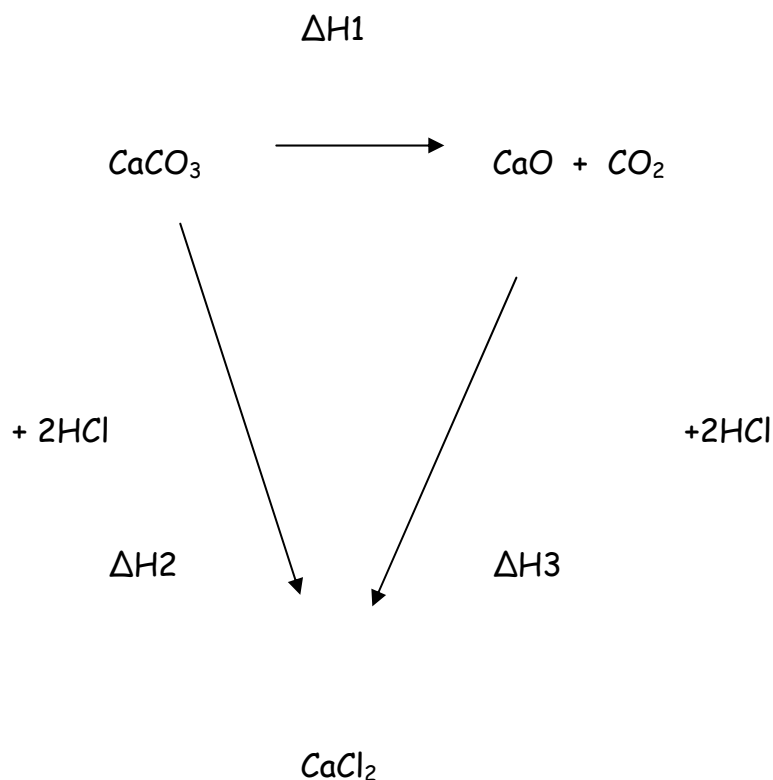
$$= - (50 \times 4.2 \times 13.5) = -2835\text{J}$$

This is for 1.4g CaO which is 0.025mole

$$\text{Enthalpy change for 1mole calcium oxide} = - \frac{2835}{0.025} = -113400\text{Jmol}^{-1}$$

$$= - \frac{113400}{1000} = -113.4\text{kJmol}^{-1}$$

To calculate the enthalpy change for the decomposition of calcium carbonate into calcium oxide and carbon dioxide I will use the Hess's Law cycle below:



$$\Delta H_1 = \Delta H_2 + \Delta H_3$$

$$\Delta H_1 = -21.0 + (-113.4) = -134.4 \text{kJmol}^{-1}$$

Therefore the enthalpy change of combustion for the decomposition of calcium carbonate = -134kJmol^{-1}

Evaluation

First I will calculate the uncertainties associated with the measurements that I have taken. I will choose the lowest value where I have a choice to illustrate the 'worst case scenario'.

Using the balance:

The uncertainty associated with the balance reading is 0.05g

$$\text{The \% uncertainty in a balance reading of } 12.60\text{g} = \frac{0.05}{12.6} \times 100 = 0.4\%$$

We read the balance twice so the combined uncertainty associated with the mass difference = $2 \times 0.05 = 0.1\text{g}$

Therefore the percentage uncertainty associated with the mass difference

$$\begin{aligned} &= \frac{0.1}{12.6} \times 100 \\ &= 0.79 \\ &= 7.9\% \end{aligned}$$

Using the measuring cylinder:

The uncertainty associated with the measuring cylinder reading is 0.5cm^3

$$\text{The \% uncertainty in a measuring cylinder reading of } 50\text{cm}^3 = \frac{0.5}{50} \times 100 = 1.0\%$$

Using the thermometer:

The uncertainty associated with the thermometer reading is 0.5°C

The % uncertainty in a thermometer reading of 18.0°C = $\frac{0.5}{18.0} \times 100 = 2.8\%$

But we read the thermometer twice so the combined uncertainty for the temperature change will be $2 \times 0.5 = 1.0^{\circ}\text{C}$

So the uncertainty associated with the temperature change = $\frac{1}{2.5} \times 100 = 40\%$

I have listed some of the limitations of the practical procedures in the following table:

Aspect of procedure	What is the limitation	How might this effect the overall result
Losing heat to the surroundings	Some of the heat produced does not help raise the temperature of the solution	The temperature rise will be less than it should be and so the calculated enthalpy change will be smaller
Not stirring the solution in the cup	The temperature may not be equally spread out in the cup so the temperature recorded may not be accurate	The final temperature recorded may be lower or higher than it should be meaning that the enthalpy change calculated from the temperature change will be smaller or higher
Recording the final temperature too quickly	The recorded temperature may be less than it should be	The calculated enthalpy change would be smaller than it should be
Spilling solid while transferring it to the cup	Not all the weighed amount of solid is able to take part in the reaction	Less heat is given out, the temperature rise is lower than it should be and the calculated enthalpy is lower than it should be

Overall, the most significant impact on my results is going to be problems associated with recording the correct temperature when the temperature change is small. Part of the problem can be minimised by constant stirring of the contents of the cup so that the heat is evenly spread. However, there is uncertainty associated with measurement in the smallest temperature change of up to 40% which is something I can do nothing about. It should be born in mind, however, that because this is the smallest temperature change, only a small enthalpy change will be calculated from it. Therefore, the overall error in the final calculated result for the enthalpy change of decomposition of calcium carbonate will be much less than the uncertainty associated with this specific temperature change.

The largest component of the calculation of the enthalpy change of decomposition of calcium carbonate is the enthalpy change from the reaction of calcium oxide with the acid. There is an uncertainty in measuring the small mass difference of 7% which may make a significant contribution to the error in the overall result.

Loss of heat to the surroundings is minimised by using an expanded polystyrene container. There will, however, be some heat loss out of the top of the cup and so the recorded temperature change is likely to be smaller than it should be. This will mean that the overall enthalpy change will be smaller than it should be.

3.10 Commentary on Experimental Skills Report 0405

Determination of the enthalpy change of reaction

Planning

This is an excellent plan. The general strategy is sound and it includes all the expected fine detail. The explanation of the choice of amounts of material is particularly good and there is a clear account of why the procedures are likely to ensure that the data collected is precise and reliable. The risk assessment and quoted references are sound.

Overall, this section is a match with all of the descriptors up to and including level 11 and a mark of 11 is therefore appropriate for this skill area.

Analysing

The enthalpy changes for the reactions between calcium carbonate and calcium oxide are correctly calculated and the calculations clearly explained. An appropriate Hess's Law cycle to calculate the enthalpy change for the decomposition of calcium carbonate is devised but a basic error is made in using it.

This section matches the descriptors at level 8 but does not match the additional descriptors at level 11. A mark of 8 is therefore appropriate for this skill area.

Evaluating

This is another excellent section. The percentage uncertainties associated with all types of measurements are correctly calculated. The key limitations in practical procedures are identified and described in a very effective table. There is also a sound assessment of the relative significance of the limitations and uncertainties that have been noted.

Overall, this section is a good match with all of the descriptors up to including level 11 and a mark of 11 is therefore appropriate for this skill area.