

A GUIDE TO WRITING PRACTICAL REPORTS

The main purpose of scientific report writing is to communicate the results of your experiment so that other people can reproduce your results if necessary. The process of writing a scientific report gives you valuable practice in clearly explaining the theoretical concepts and interpreting and manipulating data. Since these skills are also vital for performing well in the written examination, mastering the art of writing practical reports is essential!

This document gives a general description of the sections of a scientific report; however, you should check with your teacher about their specific requirements as there may be differences in approach, style and presentation.

WRITING STYLE

A scientific report should be written in a straight forward and precise manner so that it is easy for other people to read and understand.

- You should write in complete, grammatically correct sentences.
- Avoid elaborate vocabulary.
- Use chemical terms and conventions correctly, including chemical equation and units of measurement.
- Be concise. If you can use one word instead of a phrase with two or more words, then choose the one word (get around = avoid).
- Avoid long sentences. If most of your sentences are long (4 or more 'clauses' or parts) you will confuse the reader.
- Write in the third person ('it' rather than I or we).
- Write in past tense.
- Avoid definitive words (proves, definitely, will cause).

Useful words to use are: Possibly, inference, presumably, probably, apparently, not likely, seemingly, appear, suggest, seem, maybe.

- Write objectively: present facts and figures only, do not include your beliefs or feelings. Avoid colloquialisms such as 'the results dramatically showed...'

| Avoid | Instead use |
|-----------------------------|-------------|
| I observed the angle to be | |
| I suggest | |
| I found | |
| In this report I will show | |
| The loss in mass was due to | |
| The results prove that | |

GENERAL FORMAT OF PRACTICAL REPORTS

While different schools will vary in the sections required in a practical report, generally all reports follow a similar format as follows.

Experimental details:

- Practical title
 - Your name
 - Laboratory partners
 - Date
-

Introduction

Some teachers may like you to include relevant background information. For example:

Colorimetry is an analytical chemistry technique used to determine the concentration of coloured solutions. A white light source is passed through a colour filter or alternative wavelength selection device. The coloured light then passes through a cuvette containing a chemical compound in solution. The intensity of the light leaving the sample will be less than the light entering the cuvette. The loss of light or absorption is proportional to the concentration of the compound. To quantitatively analyse a sample, the absorbance of standard solutions containing the substance being analysed are measured. This data is converted into a calibration curve so that the concentration of the unknown sample can be determined.

Aim:

Writing an aim involves concisely describing the purpose of the experiment. There may be one aim or several. For instrumentation-based practicals it is customary to mention the apparatus to be used.

The aim for a chemistry practical which uses a colorimeter to determine the concentration of iron in spinach might be written as:

To use a colorimeter to measure the absorbance of five standard solutions containing iron and use the data to construct a calibration curve. Transfer the iron from spinach into solution and measure its absorbance under identical conditions. Use the calibration curve to determine the iron content of the spinach and compare this to the manufacturer's value.

Equipment:

Provide a list of the equipment that was used. Be specific. Clearly indicate the size of the glassware needed (50 mL beaker) and the concentrations of any solutions used. A list of equipment is usually included on the practical sheet and you may not be required to rewrite it. If this is the case, reference the practical sheet in this section and make sure you include it with your report. Any changes to the equipment used must be annotated on the practical sheet.

Method:

Provide progressive, step by step instructions of how to conduct the experiment from beginning to end so that it can be easily and accurately duplicated by others. Be explicit and accurate and quantify the steps as much as possible.

This section should start with a list of safety precautions. Safety information may be found on the practical sheet or your teacher may provide you with MSDS (Material Safety Data Sheets) information. You may be required to find this information yourself and in this case you will probably need to do an internet search.

Normally, the method is given out as part of the practical notes and very rarely would you be required to rewrite it. Some teachers will be happy with a reference to the method. If any changes have been made, ensure that they are clearly annotated on the sheet.

Example: Refer to attached sheet titled "Determination of HCl concentration in brick cleaner".

If you have taken a photograph of your experimental set up, you would include it here. Make sure it is given a descriptive heading.

Results:

Any data collected or observations made during the experiment should be accurately recorded in this section. Your teacher may require you to include the rough copy of your results from the experiment in order to verify your work. The results section is divided into sub sections as described below.

Observations (qualitative results):

Observations include things like colour changes, the appearance of a gas, sounds that were made (popping, hissing) and also anything that could influence the outcome of the experiment. Do not analyse or comment on the relevance of the observations. This will be done in the discussion section.

Examples

- Some of the precipitate stuck to the bottom of the flask and could not be removed.
- Even after thorough mixing, some of the fertiliser did not dissolve.
- The red solution became darker as time passed.

Numerical Data

Numerical data should be presented in tables, figures or graphs.

Tables

- Require a descriptive title.
- Each column of data should be clearly labelled. Units should be included with the title of the column NOT in the body of the table where the numerical data is recorded. The associated uncertainty should also be stated.
- The number of significant digits should reflect the precision of the measurements.
- There should be no variation in the precision of raw data. For example, the same number of decimal places should be used if the measuring device is consistent.

Example:

Table 1: Change in temperature of water when heated.

| Time (sec) ± 1 sec | Temperature ($^{\circ}\text{C}$) $\pm 0.5^{\circ}\text{C}$ | Temperature ($^{\circ}\text{C}$) $\pm 0.5^{\circ}\text{C}$ |
|---------------------------|---|---|
| | Trial 1 | Trial 2 |
| 0 | 21.0 | 21.5 |
| 30 | 23.5 | 22.5 |
| 60 | 26.5 | 26.0 |
| 90 | 30.0 | 30.5 |

Subsequent calculations are usually clearer if data is arranged in columns instead of rows (as above). The table below is harder to interpret for most people.

| Time (sec) ± 1 sec | | 0 | 30 | 60 | 90 |
|---|---------|------|------|------|------|
| Temperature ($^{\circ}\text{C}$) $\pm 0.5^{\circ}\text{C}$ | Trial 1 | 21.0 | 23.5 | 26.5 | 30.0 |
| Temperature ($^{\circ}\text{C}$) $\pm 0.5^{\circ}\text{C}$ | Trial 2 | 21.5 | 22.5 | 26.0 | 30.5 |

Figures

Figures can include graphs, scatterplots, drawings or even photographs. Essentially, figures are pictures of things.

Example:



Figure 1: Drawing of NaCl crystals.

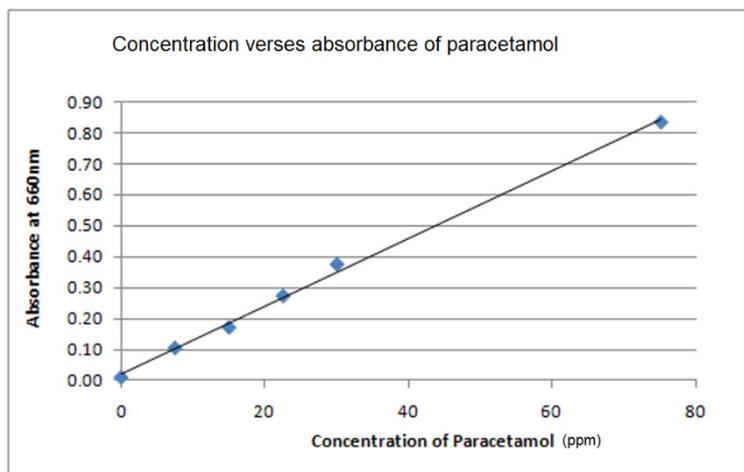
Graphs:

The type of graph required depends on the type of data collected. In chemistry, the most common type of graph will be one that shows a relationship between two variables. This type of data is best represented using a line graph.

Line graphs require:

- A descriptive title.
- Labelled axes with units.
- A line of best fit.
- The independent variable (the variable you are in control of changing) goes on the x axis.
- The dependant variable (the thing that you are recording) goes on the y axis.

Example:



Calculations:

Calculations will only apply to particular experiments. All steps should be shown in a logical order and be clearly set out.

Remember to:

- Show all calculations including averages, additions and subtractions.
- Use the correct number of significant figures.
- Use SI units.
- If a calculation is repeated a number of times, the full working out can be shown once as an example and the others can be recorded in a table.
- Error and uncertainty calculations should also be included here.

Your teacher may require you to propagate uncertainties through a calculation by using the absolute and/or percent uncertainties from measurements to determine the overall uncertainty in calculated results. Usually only a simple treatment is required.

For example, functions such as addition and subtraction, absolute uncertainties can be added. For multiplication, division and powers, percentage uncertainties can be added. You will need to discuss how to address errors with your teacher as it may be different to the method used in this document.

- Include a calculation of overall error if your result can be compared to a known value.
 - Relevant, balanced equations with states can be included here.
-

Discussion:

The discussion section is used to identify the significance and meaning of the results that were collected and to identify any flaws or errors that occurred.

The discussion should cover the following questions and is usually written in an essay style (i.e. not as a question and answer section). The general topics found in a discussion are:

Discussion of results

- What do the results show? How do they relate to known theory?
- Do the results answer the aim?
- Are the results consistent with those reported by other groups?
- For quantitative experiments, compare your value to the expected value.

Errors and uncertainties

- If the results were not as expected, what are some possible explanations?
- What errors occurred and how did they affect the results?
- Comment on the overall error or % uncertainty in your quantitative results if possible.

Evaluation

- How could the experiment be improved?
- Were there any variables that should have been controlled but were not?
- Should more data have been collected in order to draw clearer conclusions?
- Could any of the errors and uncertainties be reduced or eliminated?
- Could the data have been measured more accurately?

Focus questions

Sometimes there will be questions included on the practical sheet for you to answer. These questions should be answered in the discussion.

SOME POINTS REGARDING ERRORS, MISTAKES AND UNCERTAINTIES

Errors, mistakes and uncertainties are not the same as each other. Make sure you understand the difference between them.

Mistakes: are usually caused by careless work or a temporary fault in equipment. Mistakes can be avoided so, if they occur, the experiment should be redone. A 'mistake' in an experiment is not considered an acceptable reason for inaccurate results.

Errors: are unavoidable and cause inaccuracies in the recorded data. Errors are classified as either systematic or random.

- Systematic errors are the same for each measurement (the measurement is always larger or always smaller than it should be). They result from permanent faults or inaccuracies in equipment and therefore they cannot be eliminated by repeating the experiment.
- Random errors cause fluctuations in measurements (sometimes the measurement is larger than it should be and sometimes it is smaller). Often they are caused by difficulties in reading off measuring equipment. Averaging results can minimise these types of errors.
- Uncertainties: are present in all measurements and their magnitude is determined by the accuracy of the measuring apparatus (e.g. the uncertainty in a volumetric flask may be 50.00 mL \pm 0.2 mL). Since uncertainties can cause a measurement to be greater or less than the true value, they are a source of random error.

Conclusion:

This section contains a brief but specific statement stating how the results prove or disprove the aim. Statements such as "the aim of the experiment was achieved" are NOT acceptable as they provide no information about what the results indicated about the aim. No new information should be included in the conclusion. An indication of the accuracy of the results can be given.

Example:

The iron content of spinach was determined via calorimetry using a calibration curve. The iron content was found to be 15.3%w/w which was less than the amount stated by the manufacturer. A likely explanation for this difference is unavoidable loss of the sample at various stages of the experiment.

Iron content of Food

Name: _____

| | H | M | L | NS | Score |
|------------------------|--|---|---|-----------|--------------|
| Aim | An accurate aim has been included. | | | | /1 |
| Method | The experimental sheet has been accurately referred to and is included in the report. Safety considerations have been listed if necessary | The method and safety has been referred to but there are some errors or omissions | | | /2 |
| Data Collection | Transmission results for the standard solutions and food sample are clearly presented in a table. Qualitative results are included. | Results are present in a table but lack accuracy. Qualitative results may be missing. | Results are not in a table and lack accuracy. Qualitative results are missing. | | /3 |
| Data Processing | The calibration graph is completed on graph paper with an appropriate scale, title, labeled axis, units and line of best fit. Calculations are accurate, clearly set out and units are included. | The calibration graph and calculations are generally well done with some errors or omissions. | The graph is poorly presented and lacking accuracy. Significant errors have been made in the calculations | | /6 |
| Theory | Colorimetry has been explained with accuracy and detail. | The basic concept of colorimetry has been explained but there are some omissions or errors. | Colorimetry has been poorly explained or there are major errors | | /3 |
| Evaluation | The results are discussed accurately and meaningfully. This includes discussion on the accuracy of the experiment. Errors are fully explained (including their effect on the result of the experiment) and realistic improvements have been suggested. | The results are discussed accurately and meaningfully with some small errors or omissions. A reasonable attempt has been made to discuss the reliability of the results, errors and improvements. | The evaluation is lacking depth and accuracy. An attempt has been made to discuss the results of the experiment but there are significant errors or omissions | | /6 |
| Conclusion | A clear and concise conclusion has been made which clearly states the outcome of the experiment. | A conclusion has been included but is too general or is poorly written | An imprecise or erroneous conclusion has been made | | /2 |

EXTENDED PRACTICAL RESPONSE

The following report is an example of the type of report that can be produced if time is not limited. Each section is completed in precise detail. It is unlikely that you will be able to reproduce a report of this depth and length in a limited time period (e.g. if given a period to write a SAC report).

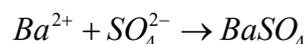
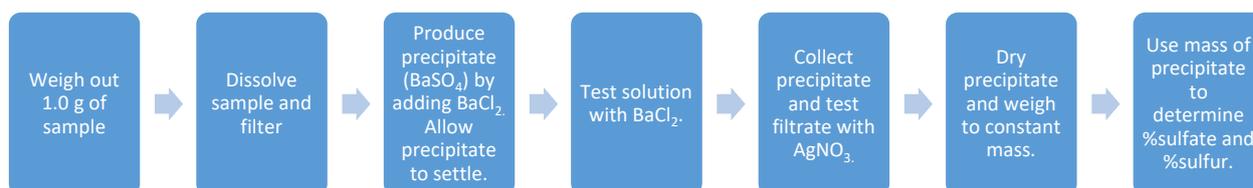
Use this example to guide you in:

- Presenting result clearly.
- Presenting calculations clearly including propagation of errors if necessary.
- The requirements of each section of the report.
- Discussing the accuracy and reliability of results.
- Discussing errors **in detail**.
- Discussing practical and relevant improvements.

GRAVIMETRIC DETERMINATION OF SULFATE IN FERTILISER

Summary: The sulfate ions from the fertiliser are precipitated as $BaSO_4$. The mass of the precipitate is then used to determine the percentage sulfate and sulfur.

Simplified Flow Chart



EXTENDED EXPERIMENTAL REPORT

GRAVIMETRIC DETERMINATION OF SULFATE IN FERTILISER

Experimental details:

Name: Student A

Laboratory partner: Student B

4th February 2017

Introduction

Gravimetric analysis involves analysing a sample using masses. The analyte is dissolved and reacted with a precipitating reagent. This precipitate is collected via filtration, washed and weighed to constant mass. The mass of the precipitate is used in conjunction with the original mass of the sample to find the percent composition of the substance being analysed.

This experiment involves analysing the percent sulfur and sulfate in a commercial brand of fertiliser. The sulfate in the fertiliser will be dissolved into solution and then precipitated out as barium sulfate by using barium chloride as a precipitating reagent.

The amount of sulfur and sulfate in fertilisers is of considerable concern because they are indirectly responsible for two serious problems associated with the handling and treatment of water. That is, the odour and sewer corrosion problems that result from the reduction of sulfate to hydrogen sulphide under anaerobic conditions.

Aim

- To use gravimetric analysis to determine the % sulfur and % sulfate in Quickgrow fertiliser.
 - To compare the experimental values to those quoted by the manufacturer.
-

Equipment and Method

See attached sheet "Experiment 7 – Gravimetric determination of sulfate in fertiliser".

Safety

- Wear safety goggles and lab coat.
 - Soluble barium compounds are toxic.
 - Silver nitrate stains skin and clothes.
 - Hydrochloric acid is corrosive.
-

Results

Quantitative Results

Precipitation reaction: $Ba_{(aq)}^{2+} + SO_{4(aq)}^{2-} \rightarrow BaSO_{4(s)}$

Table 1: Masses recorded during the gravimetric analysis of Quickgrow fertiliser.

| Mass of Fertiliser Sample (g) ± 0.005 g | Mass of Filter Paper (g) ± 0.005 g |
|--|---------------------------------------|
| 1.000 | 2.080 |

Table 2: Masses recording during the drying of $BaSO_4$.

| Mass of Filter Paper + $BaSO_4$ (g) ± 0.005 g | |
|--|-------|
| 1 st drying | 2.095 |
| 2 nd drying | 2.441 |
| 3 rd drying | 2.441 |

Table 3: Manufacturers quoted values

| Quoted amounts of sulfur and sulfate in Quickgrow fertiliser | |
|--|-----------|
| % Sulfate | % Sulfur |
| 17.0 | Not given |



ANALYSIS:

| | |
|---|--------|
| TOTAL NITROGEN (N) as ammonium | 12.3% |
| Phosphorus (P) as water soluble | 1.4% |
| Phosphorus (P) as citrate soluble | 0.3% |
| Phosphorus (P) as citrate insoluble | 0.1% |
| TOTAL PHOSPHORUS (P) | 1.8% |
| TOTAL POTASSIUM (K) as potassium chloride | 5.2% |
| Calcium (Ca) as superphosphate | 4.2% |
| Sulphur (S) as sulphates | 17.0% |
| Iron (Fe) as ferrous sulphate | 1.1% |
| Copper (Cu) as copper sulphate | 0.005% |
| Zinc (Zn) as zinc sulphate | 0.005% |
| Boron (B) as borax | 0.01% |
| Manganese (Mn) as manganese sulphate | 0.01% |

Figure 1: Photograph of Quickgrow fertiliser package

Table 4: Class results for the % sulfate and % sulfur in Quickgrow fertiliser

| % w/w sulfate and sulfur in Quickgrow fertiliser | | |
|--|-------------|---------------|
| | % sulfate | % sulfur |
| Group 1 | 15.8 ± 3.2% | 5.26 % ± 3.2% |
| Group 2 | 14.5 ± 3.3% | 4.83 % ± 3.3% |
| Group 3 | 19.4 ± 3.0% | 6.46 % ± 3.0% |
| Group 4 | 16.1 ± 3.2% | 5.36 % ± 3.2% |
| Our result | 14.9 ± 3.3% | 4.96 % ± 3.3% |

Qualitative Results

- It was difficult to grind all of the fertiliser into a fine powder. The resulting powder had some small lumps in it.
- When barium chloride was added to the fertilizer solution, a white precipitate formed.
- When the solution in Step 5 was tested with barium chloride, it went slightly cloudy. After the addition of an extra 3 mL of barium chloride, this test produced no further precipitate.
- When the filtrate was tested with silver nitrate, no precipitate formed.

Calculations

Mass of precipitate

$$\begin{aligned}m(\text{BaSO}_4) &= m(\text{filter paper} + \text{BaSO}_4) - m(\text{filter paper}) \\ &= 2.441 \pm 0.005 - 2.080 \pm 0.005 \\ &= 0.361 \pm 0.010\text{g}\end{aligned}$$

Error is additive

$$\begin{aligned}\% \text{ error in } m(\text{BaSO}_4) &= \frac{0.010}{0.361} \times 100 \\ &= \pm 2.8\%\end{aligned}$$

Mass of sulfate in Quickgrow fertiliser

$$\begin{aligned}n(\text{BaSO}_4) &= \frac{0.361 \pm 2.8\%}{233.4} \\ &= 1.55 \times 10^{-3} \text{ mol} \pm 2.8\% \\ n(\text{SO}_4^{2-}) &= n(\text{BaSO}_4) \\ &= 1.55 \times 10^{-3} \text{ mol} \pm 2.8\% \\ m(\text{SO}_4^{2-}) &= 1.55 \times 10^{-3} \pm 2.8\% \times 96.1 \\ &= 0.149 \text{ g} \pm 2.8\%\end{aligned}$$

Percent sulfate in Quickgrow fertiliser

$$\begin{aligned}\% \text{ error in } m(\text{sample}) &= \frac{0.005}{1.000} \times 100 \\ &= \pm 0.5 \%\end{aligned}$$

Uncertainty in scales

$$\% \text{SO}_4^{2-} = \frac{\text{mass of sulfate}}{\text{mass of sample}} \times 100$$

$$= \frac{0.149 \pm 2.8\%}{1.000 \pm 0.5\%} \times 100$$

$$= 14.9 \% \text{w/w} \pm 3.3\%$$

Error is additive

Mass of sulfur in Quickgrow fertiliser

$$\begin{aligned}n(\text{S}) &= n(\text{BaSO}_4) \\ &= 1.55 \times 10^{-3} \text{ mol} \pm 2.8\%\end{aligned}$$

$$\begin{aligned}m(\text{S}) &= 1.55 \times 10^{-3} \pm 2.8\% \times 32.1 \\ &= 4.96 \times 10^{-2} \text{ g} \pm 2.8\%\end{aligned}$$

Percent sulfur in Quickgrow fertiliser

$$\begin{aligned}\% \text{S} &= \frac{\text{mass of sulfur}}{\text{mass of sample}} \times 100 \\ &= \frac{4.96 \times 10^{-2} \pm 2.8\%}{1.000 \pm 0.5\%} \times 100 \\ &= 4.96 \% \text{w/w} \pm 3.3\%\end{aligned}$$

Error is additive

Overall experimental error

$$\begin{aligned}\% \text{ error} &= \frac{\text{quoted \% sulfate} - \text{experimental \% sulfate}}{\text{quoted \% sulfate}} \times 100 \\ &= \frac{17.0 - 14.9}{17.0} \times 100 \\ &= 12.4\%\end{aligned}$$

Discussion

The sulfate content of Quickgrow fertiliser was determined gravimetrically to be 14.9% w/w $\pm 3.3\%$ which was less than manufacturers quoted value of 17.0% w/w. This result was relatively consistent with other groups within the class except for group 3. Group 3's results were considerably different to the rest of the class indicating that a significant human error occurred during that particular experiment. Given that the majority of groups had results similar to the one from this experiment, it is unlikely that a major mistake occurred. The percent sulfur was found to be 4.96%w/w $\pm 3.3\%$. The manufacturer did not quote the amount of sulfur so there was no way to determine the accuracy of these results. However the results of this experiment were also consistent with most other groups suggesting that correct experimental procedures were followed.

The overall error of the experiment was 12.4% which is larger than the error due to uncertainties in the scales which was 3.3%. This indicates that there are systematic or random errors that contributed to the overall error in the experiment. Errors that would result in a smaller percent sulfate are:

1. Not all of the sulfate from the sample dissolved into solution (systematic error).

When the water was added to the finely ground fertiliser, some granular pieces remained in the solution. These were then removed via filtration. It is possible that these remaining solids contained undissolved sulfates. If this was the case, then the resulting solution would have less sulfate than it should, meaning a smaller mass of precipitate would be collected. This would result in the calculated percent sulfur/sulfate being smaller than it should be and is one of the most likely causes of error in this experiment.

2. Not all of the sulfate ions were converted into the barium sulfate precipitate (systematic error).

If some of the sulfate ions remained unreacted in the solution, then the final mass of the barium sulfate precipitate would be lower than it should be. This would result in the calculated percent of sulfur/sulfate being smaller than it should be. In this experiment, this error was avoided by testing the solution with extra barium chloride until no more precipitate formed. The solution was also boiled to ensure a complete reaction. Therefore, this error should not have significantly affected the result.

3. Precipitate residue left in the gooch crucible (systematic error).

Once the precipitate had been collected in the gooch crucible, the filter paper and precipitate were removed and weighed. It is possible that a small amount of the precipitate was left behind in the crucible. This would result in calculated mass of precipitate and percent sulfate being smaller than it should be. Since there was no observable precipitate left in the crucible, it is unlikely that this error had a large effect on the results.

There are also errors that could result in a higher percentage of sulfate in the fertiliser. It is unlikely that these types of errors occurred to any significant extent in this experiment since the percent sulfate was lower than the expected value.

1. Co-precipitation (systematic error)

Barium chloride was added to precipitate out the sulfate ion as barium sulfate. However, it is possible that the barium ions also formed a precipitate with other ions in the fertiliser. For example if any phosphates or carbonates are present, then the barium could precipitate these ions out as well. The barium chloride is also a source of chloride ions. These ions could combine with lead or copper (I) to form a precipitate. Any extra precipitates which form during the experiment will add to the final mass of barium sulfate. This would result in a higher calculated percentage of sulfate in the fertiliser.

2. Insufficient washing of the precipitate (mistake).

If the precipitate was not washed properly, it is possible that other ions from the solution would adhere to it and cause the mass of the precipitate to be higher than it should be. This would make the calculated value of percent sulfate/sulfur higher as well. If this occurred in this experiment, it would be considered as a mistake as the filtrate can and was tested for chloride ions using silver nitrate hence avoiding this source of inaccuracy. Hence this error should not have occurred in this experiment unless there were other ions present that could not be tested with silver nitrate.

3. Precipitate not dried properly (mistake).

Incomplete drying of the precipitate would cause the mass of the precipitate to be higher than it should be. This would make the calculated value of percent sulfate/sulfur higher as well. This would technically be a mistake since the precipitate can be weighed to constant mass, hence avoiding this source of inaccuracy. The correct experimental procedure was followed in this experiment so no water should have been present in the final mass of the precipitate.

The experiment determined the sulfate/sulfur content of Quickgrow fertiliser in the same order of magnitude as the manufacturer but with an overall error of 12.4%. To reduce this error and improve the accuracy of the experiment, the following improvements could be made.

- When water is added to the ground fertiliser, heat the mixture to encourage as much of the sulfate to dissolve as possible.
- When the precipitating reagent is added (barium chloride), cool the beaker in an ice bath to encourage the precipitate to form.
- After filtering the precipitate, test the filtrate for other ions other than just chloride ions.
- Analyse the contents of the fertiliser to see if there is the possibility of co-precipitation when barium chloride is used as the precipitating reagent. If so, consider using a different precipitating reagent that will reduce or eliminate co-precipitation.
- Collect and dry the precipitate in the Gooch crucible. This avoids leaving some of the precipitate in the crucible when the filter paper and precipitate is removed.

All measurable quantities in the experiment were obtained using the most accurate equipment available and all the variables were controlled as carefully as possible so there are no further improvements that could be made. The results from multiple groups were compared so sufficient data was collected to indicate that the experiment was conducted with no significant human error.

Conclusion

Using gravimetric analysis, the percent sulfur and sulfate in Quickgrow fertiliser were found to be 4.96%w/w \pm 3.3% and 14.9%w/w \pm 3.3% respectively. The percent sulfate calculated was less than that quoted by the manufacturer and this was most likely due to the difficulty in dissolving the sample.

EXPERIMENTAL REPORT – IMPROVEMENTS ANNOTATED

GRAVIMETRIC DETERMINATION OF SULFATE IN FERTILISER

Experimental details:

Name: Student A
Laboratory partner: Student B
4th February 2017

Introduction

In this experiment, the percent sulfur and sulfate in a commercial brand of fertiliser was analysed via gravimetric analysis which involves the analysis of masses. The iron from spinach will be isolated from the sample and its mass compared to the original mass of the sample.

Too general. There is no mention of forming a precipitate, what the formula of the precipitate will be or how it will be accurately measured.

Aim

- To determine the % sulfur and % sulfate in a brand of fertiliser.

The type of analysis should be mentioned and so should the exact brand if known. Since commercial products usually list the % composition of ingredients, part of the aim should be to compare the results to the published results.

Equipment and Method

See attached sheet “Experiment 7 – Gravimetric determination of sulfate in fertiliser”.

Safety:

- Wear goggles and lab coat.
- HCl is corrosive.
- Avoid spillages.

Try to list precautions that are specific to the experiment. E.g. Barium compounds are toxic, silver nitrate stains skin. MSDS information may also be required.

Results

Quantitative Results

Table 1: Masses

| Mass of Fertiliser Sample (g) | Mass of Filter Paper (g) |
|-------------------------------|--------------------------|
| 1.000 | 2.08 |

Uncertainties are missing. Data is not presented with the same precision. If the same scale was used for both measurements, both pieces of data should have three decimal places.

Table 2: Masses recorded during drying

| Mass of Filter Paper + BaSO ₄ (g) ±0.005 g | |
|--|-------|
| 1 st drying | 2.095 |
| 2 nd drying | 2.441 |
| 3 rd drying | 2.441 |

Table 3: Class results

| % w/w sulfate and sulfur in Quickgrow fertiliser | | |
|--|-------------|---------------|
| | % sulfate | % sulfur |
| Group 1 | 15.8 ± 3.2% | 5.26 % ± 3.2% |
| Group 2 | 14.5 ± 3.3% | 4.83 % ± 3.3% |
| Group 3 | 19.4 ± 3.0% | 6.46 % ± 3.0% |
| Group 4 | 16.1 ± 3.2% | 5.36 % ± 3.2% |
| Our result | 14.9 ± 3.3% | 4.96 % ± 3.3% |

Personal language. Could be "This experiment"

Calculations

Mass of precipitate

$$\begin{aligned}m(\text{BaSO}_4) &= m(\text{filter paper} + \text{BaSO}_4) - m(\text{filter paper}) \\ &= 2.441 - 2.080 \\ &= 0.361 \pm 0.01 \text{ g}\end{aligned}$$

$$\begin{aligned}\% \text{ error in } m(\text{BaSO}_4) &= \frac{0.01}{0.361} \times 100 \\ &= \pm 2.8 \%\end{aligned}$$

It would be better to show how this value was calculated. That is, from adding the $\pm 0.005 \text{ g}$ error associated with the two masses.

Mass of sulfate in Quickgrow fertiliser

$$\begin{aligned}n(\text{BaSO}_4) &= \frac{0.361}{233.4} \\ &= 1.55 \times 10^{-3} \text{ mol} \pm 2.8\% \\ n(\text{SO}_4^{2-}) &= n(\text{BaSO}_4) \\ &= 1.55 \times 10^{-3} \text{ mol} \pm 2.8\% \\ m(\text{SO}_4^{2-}) &= 1.55 \times 10^{-3} \times 96.1 \\ &= 0.149 \text{ g} \pm 2.8\%\end{aligned}$$

Percent sulfate in Quickgrow fertiliser

$$\begin{aligned}\% \text{ error in } m(\text{sample}) &= \frac{0.005}{1.00} \times 100 \\ &= \pm 0.5 \%\end{aligned}$$
$$\begin{aligned}\% \text{SO}_4^{2-} &= \frac{\text{mass of sulfate}}{\text{mass of sample}} \times 100 \\ &= \frac{0.149}{1.000} \times 100 \\ &= 14.9 \text{ \%w/w} \pm 3.3\%\end{aligned}$$

Mass of sulfur in Quickgrow fertiliser

$$\begin{aligned}n(\text{S}) &= n(\text{BaSO}_4) \\ &= 1.55 \times 10^{-3} \text{ mol} \pm 2.8\% \\ m(\text{S}) &= 1.55 \times 10^{-3} \times 32.1 \\ &= 4.96 \times 10^{-2} \text{ g} \pm 2.8\%\end{aligned}$$

Percent sulfur in Quickgrow fertiliser

$$\begin{aligned}\% S &= \frac{\text{mass of sulfur}}{\text{mass of sample}} \times 100 \\ &= \frac{4.96 \times 10^{-2}}{1.000} \times 100 \\ &= 4.96 \% \text{w/w} \pm 3.3\%\end{aligned}$$

Overall experimental error

$$\begin{aligned}\% \text{ error} &= \frac{\text{quoted \% sulfate} - \text{experimental \% sulfate}}{\text{quoted \% sulfate}} \times 100 \\ &= \frac{17.0 - 14.9}{17.0} \times 100 \\ &= 12.4\%\end{aligned}$$

Discussion

The sulfate content of the fertiliser was determined to be 14.9% w/w \pm 3.3% which was less than manufacturers quoted value of 17.0% w/w. The percent sulfur was found to be 4.96%w/w \pm 3.3%. The experimental results were consistent with those from most other groups.

This comment indicates that not all groups were consistent. Try to give a reason for this. How significant is it that one group's results did not match all of the others? What is the likely reason for this?

The overall error of the experiment was 12.4%. There are a number of errors that would result in a smaller mass of precipitate and hence a smaller percent sulfate/sulfur. These include some of the fertiliser remaining undissolved, incomplete reaction when the precipitate is formed and precipitate being left behind in the crucible when the paper and precipitate were removed for weighing. Since the calculated percent sulfate was lower than that quoted by the manufacturer, it is likely that some of these errors occurred in the experiment.

Are there observations from the experiment which support these claims (e.g. precipitate stuck to glassware). How significant are these errors (was there something in the method that was designed to avoid them from occurring)? What type of errors are they (systematic, random, mistakes?).

With what? Try to be specific. Look at what else is in the fertiliser that could form a precipitate.

There are also errors that could increase the mass of the precipitate and hence increase the calculated percent sulfate/sulfur. For example, there could have been co-precipitation by other ions and the precipitate may not have been washed or dried properly. There were procedures put in place to avoid these errors so they should not have had a significant effect on the mass of precipitate collected.

Like what? Try to be specific.

Which stages?

There are a number of improvements which could be made to the experiment. Heating and cooling could be used at various stages to ensure each process goes to completion. Instead of pre-weighing just the filter paper, the crucible could be pre-weighed too. In the drying step, the crucible, paper and precipitate could be weighed and this would avoid transfer errors. Overall, however, the experiment seemed to go well and the percentage sulfate/sulfur was determined.

Arrgh! A meaningless comment. What evidence is there that it 'went well'? Give an indication of how accurate the result was!

These two sentences could be better phrased:
"... the crucible could be pre-weighed too. Then, in the drying step...."

Conclusion

The percent sulfur in the fertiliser was 4.96%w/w \pm 3.3% and the percent sulfate was 14.9%w/w \pm 3.3%.

Comment on the accuracy of the experiment and how the results compared to the manufacturer's claims.

OBSERVATION SKILLS

Making and recognising the significance of observations during experiments is an essential skill. You will rely on your observations to make meaningful comments about the success or failure of your experiment. They will also allow you to identify sources of error.

| Observation | Implication |
|--|-------------|
| The indicator changed slowly from yellow to pink | |
| The HCl acid solution was slightly opaque. | |
| The breeze in the room was causing fluctuating readings on the scales. | |
| The sample was difficult to dissolve. | |
| Unexpected bubbles were observed during the reaction. | |
| The temperature of the beaker increased then the reactants were mixed. | |
| A fruity smell was apparent during the reaction | |
| Two groups making the same concentration of copper sulfate solution end up with solutions that differ in the intensity of the 'blue' colour. | |
| The Mg ribbon is dull and black | |
| There was precipitate stuck to the crucible. | |

RANDOM ERRORS, SYSTEMATIC ERRORS AND MISTAKES

Random errors: the measured value could be larger or smaller than the true value.

Systematic error: the effect of the error is always the same.

Mistake: the procedure has not been carried out properly and should be done again.

| | Random error, systematic error or mistake? |
|---|--|
| You measure the mass of a 17.45 g watch glass three times using the same balance and get slightly different values: 17.46 g, 17.42 g, 17.44 g | |
| A scale is improperly tared and weighs +0.5g higher than it should. | |
| A student estimates the volume in a volumetric flask | |
| A student determines the end point of a titration from the colour change of an indicator which changes from yellow to orange to pink. | |
| A burette is rinsed with water before use | |
| The mass on a scale fluctuates due to air movement in the classroom. | |
| The mass of a precipitate is not dried properly before it is weighed. | |
| The end point of a titration always occurs after the equivalence point. | |
| A thermometer has an uncertainty of $\pm 0.05^{\circ}\text{C}$ | |
| Co-precipitation occurs during a gravimetric analysis | |
| Multiple substances (rather than the target substance) absorb light during a spectroscopic experiment. | |
| A student leaves their fingerprints on the cuvette during a colorimetry analysis. | |
| The sodium hydroxide used to make a standard solution is contaminated. | |

DETERMINING THE IMPACT OF ERRORS ON CALCULATIONS

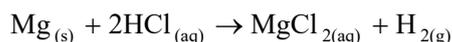
When an error occurs in an experiment, it will cause the calculated value to be larger or smaller than it should be. The effect of the error can be determined by using logic or by analysing the effect of the change on the calculations. Remember, when errors occur, you will not be aware of them.

Example: 10.0 g of magnesium reacted was reacted with hydrochloric acid until the metal had completely disappeared. If the scales were reading over by 1.00 g, how would the calculated mole of acid that reacted differ from the amount that actually reacted?

1. Use logic.

When you weigh out 10.0 g of magnesium, there will actually only be 9.00 g present since the scales are reading over by 1.00 g. This means there will be less magnesium reacting than you think there is. When you do your calculations, you do them assuming there is 10.0 g of magnesium. Your calculated value for the mole of magnesium will be larger than it should be which will make the calculated mole of acid reacting more than the actual amount.

2. Analyse the calculations.



$$\begin{aligned}n(\text{Mg}) &= \frac{10 \uparrow}{24.3} \\ &= 0.412 \uparrow \text{ mol}\end{aligned}$$

The mass is larger than it should be, so $n(\text{Mg})$ is larger than it should be.

$$\begin{aligned}n(\text{HCl}) &= 2 \times n(\text{Mg}) \\ &= 2 \times 0.412 \uparrow \\ &= 0.823 \uparrow \text{ mol}\end{aligned}$$

$n(\text{Mg})$ is higher than it should be, so $n(\text{HCl})$ is higher than it should be.

FORMING A HYPOTHESIS

Some experimental work will require you to form a hypothesis rather than stating an aim.

An aim identifies the purpose of the investigation. It is a straightforward expression of what the researcher is trying to find out from conducting an investigation. The aim typically involves the word "investigate" or "investigation".

A hypothesis is a precise, testable statement of what the researchers predict will be the outcome of the study. This usually involves proposing a possible relationship between two variables: the independent variable (what the researcher changes) and the dependant variable (what the research measures). Often a hypothesis is formulated in a statement;

"if y is done, then z will occur because.....".

Answering the "because" in this hypothesis is an important part of the criteria being evaluated. The known theory must be used to substantiate your hypothesis. The theory may be part of an introduction or abstract.

| | Aim or Hypothesis? |
|--|--------------------|
| To determine the concentration of HCl in brickcleaner. | |
| If the temperature is increased a reaction will occur at a faster rate. | |
| When the volume of a gas is increased, the pressure will decrease if the temperature is held constant. | |
| To investigate the effect of caffeine on academic performance. | |
| Academic performance is not affected by drinking caffeine. | |

Example:

Writing a hypothesis for a Reaction Rate Experiment

Propose a hypothesis that tests the link between the concentration of HCl and its rate of reaction with CaCO_3 .

1. Identify the variables

| | |
|-----------------------|--|
| Independent variable: | |
| Dependent variable: | |
| Controlled variables: | |

2. Propose a hypothesis based on your understanding of chemistry.

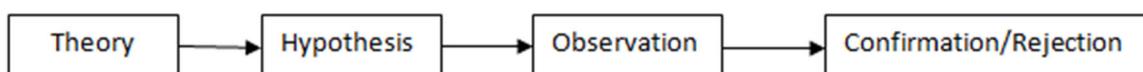
3. Supply supporting theory.

HOW TO PROPOSE A TESTABLE HYPOTHESIS

Tips for writing a hypothesis.

- Try to write the hypothesis as an if-then statement. IF an action is taken, then a certain outcome is expected.
- Identify the independent and dependent variable in the hypothesis. The independent variable is the one that is being changed in a controlled manner. The dependent variable is the one that changes because of this.
- Write the hypothesis in such a way that it can be proven or disproven. For example, a person has skin cancer, it can't be proven they got it from being out in the sun. However, it can be demonstrated that there is a relationship between exposure to ultraviolet light and increased risk of skin cancer.
- Make sure the hypothesis can be tested with reproducible results. If your face breaks out, it can't be proven that it was caused by the french fries you had for dinner last night. However, the effect of eating french fries on skin conditions can be measured. It's a matter of gathering enough data to be able to reproduce results and draw a conclusion.

ACCEPTING OR REJECTING A HYPOTHESIS



Begin with thinking up a *theory* about the topic of interest. Then narrow that down into more specific *hypotheses* that can be tested. Next collect *observations* to address the hypotheses. This ultimately leads to testing the hypotheses with specific data – a *confirmation* (or not) of the original theories.

THE IMPORTANCE OF UNDERSTANDING PRACTICAL WORK

Competent practical writing skills are not only required for success in SACs, but also for success in certain exam situations. For the last three years in a row, the final exam has included at least one question which focusses on experimental procedure. Therefore, it is imperative that a good understanding of experimental procedure is part of your exam preparation.

| Year of Exam | Marks based on experimental procedure | % of total marks |
|--------------|---------------------------------------|------------------|
| 2016 | 7 | 5.8 |
| 2015 | 6 | 5.0 |
| 2014 | 6 | 5.0 |

Past exam questions have focussed on critically reviewing the design and results of the given experiment.

Students are typically asked to:

- Identify and explain improvements to the method.
- Identify the strengths of the given method.
- Discuss the expected outcomes and justify them with the relevant chemical theory.
- Identify safety measures.
- Identify errors or omissions and predict their effect on the final result. Predictions also need to be justified.
- Comment on the validity of the results.

The best place to practise discussing these types of issues is in your practical reports!

SAFETY ISSUES

It is common to be asked for a relevant safety precaution for the experiment described in the question. To successfully answer this question your answer should be **specific and relevant to the experiment described in the question**.

Answers such as:

- Wear a lab coat
- Wear goggles
- Wear mask

are generally not specific enough!

- If a chemical is corrosive then full body protection must be worn, a lab coat is not adequate.
- If a reaction is explosive, full protective head gear would be required.
- If a chemical is volatile and poisonous, full breathing apparatus is required.

EVALUATING EXPERIMENTAL PROCEDURE

Things to look out for:

- Were the relevant variables controlled?
- Were there variables that couldn't be controlled?
- Was the method successful in testing the aim?
- Does the given conclusion match the results?
- What errors occurred? Could they have been avoided? How?
- What was the effect of the errors?
- Were enough trials completed?
- Were the results accurate and precise?
- What further testing should be done?

Comment from chief examiner 2015:

“...more practice is needed in the analysis of experimental techniques, recorded data and associated calculations.

Students' ability to discuss the appropriateness of practical procedures and associated calculations is related to their practical experience throughout VCE Chemistry. Responses to this question suggested that further discussion of procedures and associated calculations when considering experimental work is needed.”

Excerpt from: VCE Chemistry examination report 2015

SOLUTIONS

| Avoid | Instead use |
|-----------------------------|---------------------------------------|
| I observed the angle to be | The angle was |
| I suggest | It is suggested that |
| I found | It was found that |
| In this report I will show | This report shows |
| The loss in mass was due to | The loss in mass may have been due to |
| The results prove that | The results indicate that |

| Observation | Implication |
|--|--|
| The indicator changed slowly from yellow to pink | It will be hard to accurately pinpoint the endpoint. |
| The HCl acid solution was slightly opaque. | The HCl solution was contaminated hence the calculated mole of solution may be inaccurate. |
| The breeze in the room was causing fluctuating readings on the scales. | Random error will be present in the recorded masses. |
| The sample was difficult to dissolve. | Not all of the sample went into the solution which may affect the calculations. |
| Unexpected bubbles were observed during the reaction. | A side reaction may be occurring. |
| The temperature of the beaker increased then the reactants were mixed. | The reaction is exothermic. |
| A fruity smell was apparent during the reaction | The product of the reaction is volatile. |
| Two groups making the same concentration of copper sulfate solution end up with solutions that differ in the intensity of the 'blue' colour. | The concentrations are different. One group has made a mistake in preparing the solution. |
| The Mg ribbon is dull and black | There is an oxide layer on the Mg ribbon. |
| There was precipitate stuck to the crucible. | The mass of the precipitate will be less than it should be. |

| | Random error, systematic error or mistake? |
|---|---|
| You measure the mass of a 17.45 g watch glass three times using the same balance and get slightly different values: 17.46 g, 17.42 g, 17.44 g | Random |
| A scale is improperly tared and weighs +0.5g higher than it should. | Systematic |
| A student estimates the volume in a volumetric flask | Random |
| A student determines the end point of a titration from the colour change of an indicator which changes from yellow to orange to pink. | Random |
| A burette is rinsed with water before use | Mistake |
| The mass on a scale fluctuates due to air movement in the classroom. | Random |
| The mass of a precipitate is not dried properly before it is weighed. | Mistake |
| The end point of a titration always occurs after the equivalence point. | Systematic |
| A thermometer has an uncertainty of $\pm 0.05^{\circ}\text{C}$ | Random |
| Co-precipitation occurs during a gravimetric analysis | Systematic |
| Multiple substances (rather than the target substance) absorb light during a spectroscopic experiment. | Systematic |
| A student leaves their fingerprints on the cuvette during a colorimetry analysis. | Mistake |
| The sodium hydroxide used to make a standard solution is contaminated. | Systematic or Mistake Mistake if student is aware of contamination. Systematic if not |

| | Aim or Hypothesis? |
|--|--------------------|
| To determine the concentration of HCl in brickcleaner. | A |
| If the temperature is increased a reaction will occur at a faster rate. | H |
| When the volume of a gas is increased, the pressure will decrease if the temperature is held constant. | H |
| To investigate the effect of caffeine on academic performance. | A |
| Academic performance is not affected by drinking caffeine. | H |

Writing a hypothesis for a Reaction Rate Experiment

1. Identify the variables.

| | |
|-----------------------|---|
| Independent variable: | The concentration of HCl |
| Dependent variable: | The reaction rate |
| Controlled variables: | Mass of CaCO_3 Particle size of CaCO_3 Volume of HC Temperature of HCl |

2. Propose a hypothesis based on your understanding of chemistry.

Hypothesis: Increasing the concentration of HCl will increase the rate it reacts with CaCO_3 .

3. Supply supporting theory.

To increase the reaction rate of a chemical reaction, successful collisions between reactant particles need to occur more frequently. Increasing the concentration of HCl increases the number of HCl particles within a certain volume. This means that more HCl particles will be colliding with CaCO_3 at any one time which increases the frequency of successful collisions. Hence the reaction rate will increase.