Chemistry Skills

Experiments

Experiment Structure and Design

All the experiments we will do in chemistry and indeed all the experiments you will do for the other science are known as controlled experiments. Controlled experiments are used to test a hypothesis, a proposal that can be tested experimentally. They require one variable to be manipulated (independent variable) whilst another is measured (dependent variable). All other variables must be controlled or kept constant. A variable is anything that can affect the results of an experiment.

All experimental reports have the same basic structure although not all sections are always used. Each section occurs in the order below:

Purpose
Hypothesis – Only if required
Variables
Apparatus
Procedure
Results – Tables, graphs and observation
Sample Calculation – Only if required
Interpretation and Evaluation
Conclusion

Purpose
The purpose is a clear and short, often one sentence statement, identifying the purpose of the investigation and the report. Labs usually fall into one of the following categories:

- Observation of a phenomena (*example*: The purpose of this experiment is to observe the shape of the moon tonight.)
- Testing a model or hypothesis (*example*: The purpose of this experiment is to test the diminished intensity of light as it spreads unhindered in all directions.)
- Finding an empirical relationship (*example*: The purpose of this experiment is to find the mathematical relationship between work and distance.)
- Acquiring a skill (*example*: The purpose of this experiment is to acquire the skill of measuring pH in order to collect precise H^+ concentration data.)
- Forming a hypothesis (*example*: The purpose of this experiment is to form a model for the intensity of radioactivity as time passes.)
- Using an equation to measure an unknown (*example*: The purpose of this experiment is to use the definition of density, *D* = *mass/volume*, to find the density of iron.)

Hypothesis
The hypothesis is an educated guess concerning the outcome of the experiment, or what you think will happen. It is not a blind shot in the dark, it should be based on research you have done or work you have learnt in class.

Variables
The variables section should contain to the independent and dependent variables in your experiment and also the variables that are being controlled. It attempts to justify why your experiment is fair.

Apparatus

Include a list of all equipment and chemicals used including the resolution of measuring instruments and concentrations of chemicals. It may also prove useful to include a labeled drawing of equipment and its arrangement. This might be a rough sketch, but it must be neat and the essential pieces of equipment should be shown and labeled.

Procedure

The procedure lists the steps used to do the experiment. The steps should be numbered sequentially. I.e., label Step 1, then Step 2, etc. Each step starts on a new line. Details should be sufficient so the reader could repeat the experiment and verify your results. Referring the reader to an apparatus diagram can often significantly reduce the need for textual descriptions.

Results

Results contains the evidence that supports your claims in the conclusion and makes them believable. Without the evidence, a reader has little reason to take your report seriously. The background information and procedural steps present how the evidence was gathered and provide justification why the results are good evidence supporting your findings.

Tables

Almost all experiments involve making measurements, recording numbers and collecting data. Data should be organized in a table with columns and rows. Use the following guidelines.

- Column and row labels should identify the properties being measured. Include the units used for the measurements at the top of the column or start of a row, rather than next to every number.
- The data must be neat.
- The first colum should contain your independent variable, next to this should be your controls where appropriate, then your dependent variable and finally any calculations done with this dependent variable.

Graphs

The following are requirements for all graphs. The graph must be neat–use graph paper or a graph printed by a suitable graphing program. Don't use a business graphing program (such as *Excel*) unless you can force it to construct a graph with the following characteristics:

- The indepenent variable must be on the horizontal x-axis whilst the dependent variable must be on the vertical y-axis.
- Generally patterns in scientific data are shown by dot graphs, not bar graphs or pie charts.
- Include a title for each graph. The title should tell what the graph shows.
- Each axis must have a uniform scale that produces a graph that occupies at least half the sheet of paper. Numbers correspond to grid lines, not spaces between the lines. The increase of the scale numbers must be constant and without breaks.
- Both axes must be labeled with the properties and units [such as **Time (seconds)** or **Mass (g)**].
- The graph must be precise and accurate for given data so that reasonable conclusions can be obtained.
- Do not connect the dots, but instead draw the best straight line or smooth curve that represents the data. Remember all data contains experimental errors, The purpose of the graph is to show the pattern that would have been shown had there been no errors rather than the errors.
- Include a caption for each graph which describes in words the relationship between variables shown on the graph.

Sample Calculation

It is not necessary to show each and every calculation you do, only one of each type of calculation. Include a neat and clear example of each kind of calculation. Start with definitions, show substitutions, and simplifications leading to an answer.

example: To find the area (A), the formula used was
$A = \pi (r)^2$ where (r) = radius. For the first circle,
$A = \pi (4\ cm)^2$
$A = 50\ cm^2$.

Interpretation and Evaluation

The interpretation and evaluation goes into a bit more depth regarding the experiment. It should contain an evaluation of the experiment, sources of error and improvements that can be made to the experiment for next time. It can also answer specific questions dealing with the experiment and how we can use the data and apply it to solve other problem or explain what we already know.

Conclusion

This section should contain a statement of each of the generalizations that you are able to draw on the basis of your analysis of data, and if not obvious, an explanation of how you came to each conclusion. Such conclusions should pertain to the aim stated in the report. (While conclusions often match the intended purpose, occasionally results indicate an anticipated finding was actually wrong!) Also included in your conclusion any equations or proportions which have been developed from the experiment.

Errors

In all experiments that you will perform, there will be errors. No matter how careful you are, or how good the equipment you are using, these errors cannot be avoided, however they can be minimised. It is important to note that errors are not mistakes. Mistakes are caused by carelessness and can be easily avoided, errors cannot. It is therefore important to identify these sources of error within our experiments and realise how they may affect our results.

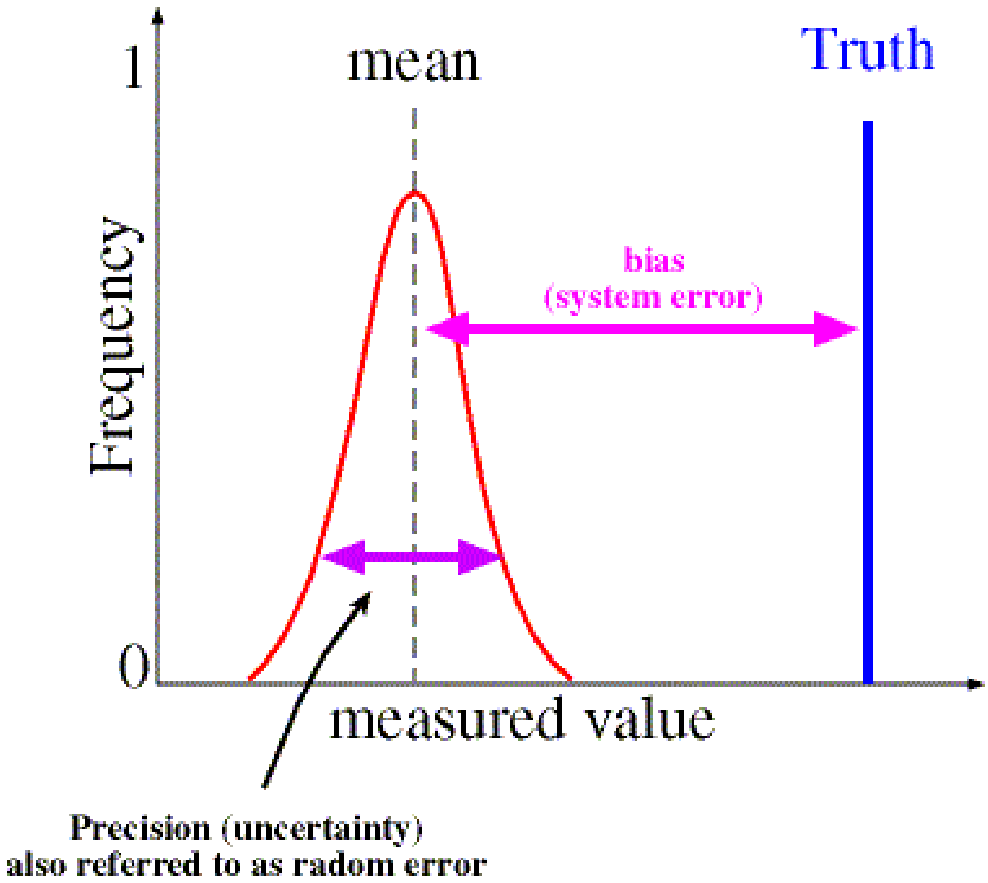
Random and Systematic Errors

There are two types or errors that you will encounter

Random Errors - Usually result from the experimenter's inability to take the same measurement in exactly the same way to get exact the same number. An example may be the measurement of volumes of liquid, you may have half a drop to much or not enough. Random errors can be minimised by repeating experiments several times and taking the average of your results.

Systematic Errors - Reproducible inaccuracies that are consistently in the same direction with the same magnitude. Systematic errors are often due to a problem that persists throughout the entire experiment, more often than not it is a problem with the calibration of a piece of equipment. An example of this is a tape measure that may have stretched over the years through repeated usage. Systematic errors can be minimised by repeating the experiment with different equipment to note any differences.

The relationship between random errors, systematic errors and the true value can be shown in the graph below

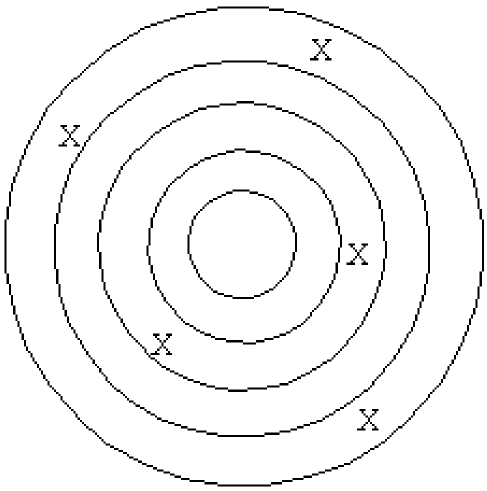


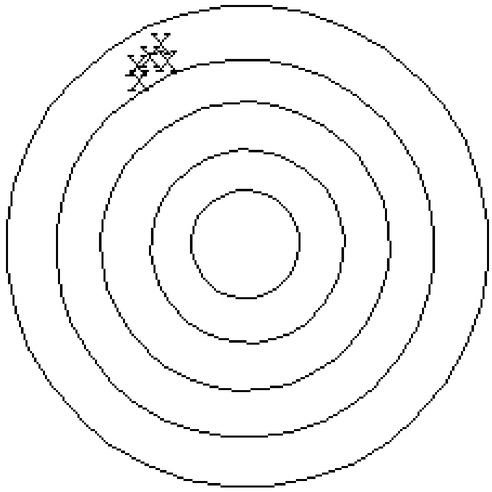
<u>Accuracy and Precision</u>

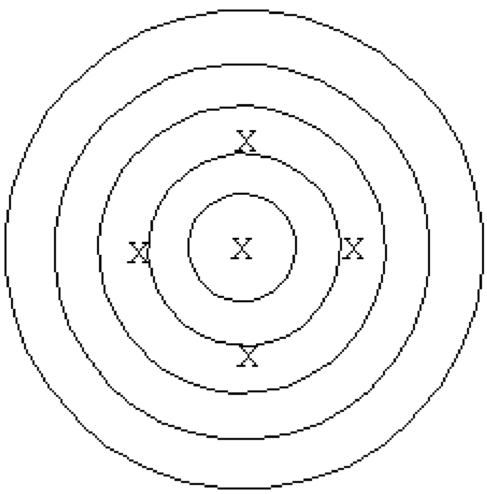
Accuracy - The closeness of the experimental values to the true value. In experiments the accuracy of the result is normally affected by systematic errors.

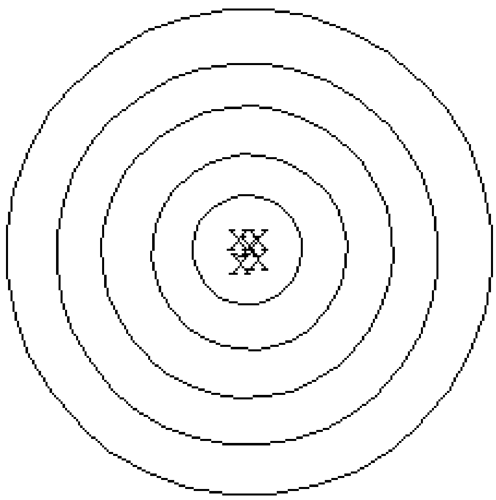
Precision - How close the results are in respect to each other or the reproducibility of the results. . In experiments the precision of the result is normally affected by random errors.

The diagrams below should give you a better idea of the links between accuracy and precision. In these pictures the centre of the target represents the expected true value.

Neither Precise Nor Accurate	
	This is a random like pattern, neither precise nor accurate. The darts are not clustered together and are not near the bull's eye.

Precise, Not Accurate	
	This is a precise pattern, but not accurate. The darts are clustered together but did not hit the intended mark.

Accurate, Not Precise	
	This is an accurate pattern, but not precise. The darts are not clustered, but their 'average' position is the centre of the bull's eye.

Precise and Accurate	
	This pattern is both precise and accurate. The darts are tightly clustered and their average position is the centre of the bull's eye.

Significant Figures

The use of significant figures in experiments and calculations is an important skill to learn this year, as it is used extensively next year both in your course work and in the exam.

Rules for deciding the number of significant figures in a measured quantity:

(1) All nonzero digits are significant:

1.234 g has 4 significant figures,
1.2 g has 2 significant figures.

(2) Zeroes between nonzero digits are significant:

1002 kg has 4 significant figures,
3.07 mL has 3 significant figures.

(3) Leading zeros to the left of the first nonzero digits are not significant; such zeroes merely indicate the position of the decimal point:

0.001 ^{o}C has only 1 significant figure,
0.012 g has 2 significant figures.

(4) Trailing zeroes that are also to the right of a decimal point in a number are significant:

0.0230 mL has 3 significant figures,
0.20 g has 2 significant figures.

(5) When a number ends in zeroes that are not to the right of a decimal point, the zeroes are not necessarily significant:

190 miles may be 2 or 3 significant figures,
50,600 calories may be 3, 4, or 5 significant figures.

The potential ambiguity in the last rule can be avoided by the use of standard exponential, or "scientific," notation. For example, depending on whether the number of significant figures is 3, 4, or 5, we would write 50,600 calories as:

5.06×10^4 calories (3 significant figures)
5.060×10^4 calories (4 significant figures), or
5.0600×10^4 calories (5 significant figures).

Rules for mathematical operations

In carrying out calculations, the general rule is that the accuracy of a calculated result is limited by the least accurate measurement involved in the calculation.

(1) In addition and subtraction, the result is rounded off to the last common digit occurring furthest to the right in all components. Another way to state this rules is that in addition and subtraction, the result is rounded off so that it has the same number of decimal places as the measurement having the fewest decimal places. For example,

100 (assume 3 significant figures) + 23.643 (5 significant figures) = 123.643,

which should be rounded to 124 (3 significant figures).

(2) In multiplication and division, the result should be rounded off so as to have the same number of significant figures as in the component with the least number of significant figures. For example,

3.0 (2 significant figures) × 12.60 (4 significant figures) = 37.8000

which should be rounded off to 38 (2 significant figures).

Sample problems on significant figures

1. 37.76 + 3.907 + 226.4 =

2. 319.15 - 32.614 =

3. 104.630 + 27.08362 + 0.61 =

4. 125 - 0.23 + 4.109 =

5. 2.02 × 2.5 =

6. 600.0 / 5.2302 =

7. 0.0032 × 273 =

8. $(5.5)^3$ =

9. 0.556 × (40 - 32.5) =

10. 45 × 3.00 =

11. $3.00 \times 10^5 - 1.5 \times 10^2$ = (Give the exact numerical result, then express it the correct number of significant figures).

12. What is the average of 0.1707, 0.1713, 0.1720, 0.1704, and 0.1715?